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THE COMPARATIVE ECOLOGY OF HIGHRATE PLASTIC, CONVENTIONAL MINERAL AND MIXED PLASTIC/MINERAL MEDIA IN THE TREATMENT OF DOMESTIC SEWAGE IN PERCOLATING FILTERS

by

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ABSTRACT

The highest rate of oxidation occurs in the top section of percolating filters, where the limiting factor is usually the amount of oxygen provided by natural ventilation. An investigation was carried out to ascertain whether the loading to a conventional single pass filter could be increased by replacing the surface layer of mineral medium with a 750mm layer of random plastic medium, which has greater surface area and voidage. This would allow greater film accumulation and subsequent removal of organic matter, at the same time avoiding ponding and anaerobic conditions normally associated with excessively loaded single pass mineral filters.

A pilot plant was designed and three identical filters constructed, one containing 2 m^3 of blast furnace slag and another 2 m^3 of random plastic medium and the third 0.8 m^3 of plastic medium upon 1.2 m^3 of slag. The comparative treatment efficiencies of the various packings were studied at three different loadings, for three months during maturation at 5.72 $m^3m^{-3}d^{-1}$ (0.85 kg BOD $m^{-3}d^{-1}$) and then for 12 months at 1.68 $m^3m^{-3}d^{-1}$ (0.28 kg BOD $m^{-3}d^{-1}$) and a further 12 months at 3.37 $m^3m^{-3}d^{-1}$(0.63 kg BOD $m^{-3}d^{-1}$). The ecology was studied both qualitatively and quantitatively throughout the depth of the filters, during the two longer loading periods. The film accumulation, temperature and retention time were all recorded and directly compared with the biological and chemical results.

Medium replacement was shown to be a viable system for uprating

filters, providing the operator with a more versatile filter, less susceptible to ponding, with less variable retention times and capable of treating greater organic loadings than conventional filters in excess of 0.2 kg BOD $m^{-3}d^{-1}$. The cost of the system is dependent upon specific requirements and availability of medium.

In the mixed filter the slag portion regulated the loss of animals from the plastic layer, retaining greater numbers of micro- and macro-grazers in the lower mineral portion, resulting in an increase in film control, and lower film accumulation at both the interface and slag portion of the mixed filter.

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CONTENTS

VOLUME I

VOLUME II : APPENDICES

1.1 INTRODUCTION

The volume of water used in the United Kingdom is currently rising at the rate of just over two percent per annum (Department of the Environment, 1976). At present, some 23 million cubic metres of water are used daily, this being equivalent to about 400 litres per person per day. Two-thirds of this supply is obtained either from water impounded in the upper reaches of rivers or from underground sources; the remainder is abstracted from lowland rivers (Open University, 1975). Sewage effluent is already a significant proportion of many lowland rivers used for public supply, and the difficulty of meeting future demands from upland or underground sources makes the increased use of this source of water inevitable. Therefore sewage treatment processes must produce final effluents of a sufficiently high quality, not only to provide the raw water for public supply, but also to satisfy increasing amenity and recreational demands.

Present methods of sewage treatment depend largely on the aerobic activity of micro-organisms. The bio-degradable substances in the sewage are extracted and used metabolically by micro-organisms growing in contact with the sewage, leaving the treated effluent suitable for discharge to a natural watercourse. This process involves a constant wastage of the micro-organisms involved, the surplus being removed by physical settlement, prior to discharge. The necessary contact between organisms, sewage and air is achieved by either the activated sludge process or the biofiltration method. In the activated sludge process, the micro-organisms and sewage are mixed in a tank and the mixture aerated by compressed air or by vigorous agitation, while in the biofiltration method the sewage is passed over an inert medium on which the micro-organisms become established. The aeration is achieved by natural ventilation through the interstices of the medium.

The design and function of biological (percolating) filters has been described by numerous workers (Bruce, 1969; Warren, 1971; Pike, 1978). In its simplest form the filter consists of a bed of graded hard material, 'filter medium', about 2m deep. The interstices or voids also allow air and applied sewage to reach all parts of the bed. The filter has a ventilating system to ensure free access of air to the bed and a distributor to regulate the volume and frequency of application of the sewage (influent) over the surface.

The medium provides the necessary base for attachment of non-mobile micro-organisms, principally bacteria and fungi, which form a film. Mobile organisms both micro- and macro-scopic live in the shelter of the interstices, feeding on and controlling the accumulated film. The action of this grazing fauna prevents heavy film growths blocking the interstices (Hawkes, 1963), which would cause ponding and anaerobic conditions within the filter bed. The accumulation of the film follows a seasonal pattern, becoming thicker during the winter months. The action of the grazing fauna loosens and breaks down the film, resulting in a large removal of film each spring which is known as sloughing. The nutrients in the sewage promote the growth of the micro-organisms comprising the film, and therefore as the sewage percolates downwards over the film-covered medium, biological oxidation and conversion takes place.

Although biofiltration was historically the first process used, it still has certain advantages over the activated sludge process. Filters require virtually no skilled maintenance or close control. In energy terms, percolating filters are more economical than the activated sludge process, and are more versatile in responding to changes in the flow and character of the sewage (Hawkes, 1963). Filters are more tolerant, compared with the activated sludge process, of continual or shock discharges of certain organic pollutants (Cook and Herning, 1978), including toxic industrial wastes containing heavy metal ions, phenols, cyanides, sulphides and formaldehyde. Filters are widely used for both total and partial treatment of a wide variety of industrial liquid wastes (Bruce, 1969; Callely *et al*., 1977; Pike, 1978). Their major disadvantage is capital cost, and they are normally uneconomic in serving populations in excess of 50,000. This is due to a)high construction costs and b) the larger area of land they occupy, which is often at a premium in urban areas (Jeger, 1970). For this reason the activated sludge process predominates at very large sewage treatment works, and although the proportions of the population of England and Wales served by these two bio-oxidation processes are about the same, many more of the 5,000 or so sewage treatment works use percolating filters than use the activated sludge process (Institute of Water Pollution Control, 1972). Bruce (1969) concluded that there was no indication that the use of percolating filters was likely to be outmoded, and this remains true even with the introduction of new processes such as the biodisc and deep-shaft processes (Anon, 1979).

In the United Kingdom, experience has shown that in order to produce a Royal Commission standard effluent with a biological oxygen demand (BOD) of 20 mgl^{-1} and a suspended solids concentration of 30 mgl^{-1} (a '20:30' or 'Royal Commission' effluent), after settlement with a high degree of nitrification, filters treating domestic sewage should receive an organic loading of between 0.07 - 0.10 kg BOD m^{-3} d^{-1} and a hydraulic loading between 0.12 - 0.60 $m^3m^{-3}d^{-1}$. Generally increases in organic loading, in excess of 0.10 kg BOD $m^{-3}d^{-1}$, will result in heavier film growths which may result in ponding.

In an attempt to produce more efficient percolating filters which would operate at much higher loadings a number of modifications of the basic process have been adopted. By using larger mineral filter medium, greater loads can be applied to filters without the risk of ponding. Such high rate filtration will produce a 20;30 effluent with an increased hydraulic loading of up to 1.8 $m^3m^{-3}d^{-1}$, but with little or no nitrification (Institution of Public Health Engineers, 1978). If a less stabilised effluent is required, e.g. roughing treatment for strong industrial wastes, then loadings of up to 12 $m^3m^{-3}d^{-1}$ with organic loads up to 1.8 kg BOD $m^{-3}d^{-1}$ will give 60 - 70% BOD removals. Treatment at such rates is facilitated by using modular or random plastic medium (90% voids) in tall towers, in place of the usual stone medium (40% voids), thus reducing the risk of ponding. In both low rate and high rate filtration the influent passes through a single filter once only.

In double filtration (DF), two sets of similar filters are used in series, with sedimentation after each stage. Different media are used in the two sets of filters, a roughing filter with large medium followed by a conventional filter with smaller medium. Royal Commission standard effluents are achieved, except the extent of nitrification has been reported as being poor (Bruce, Merkens and Haynes, 1975). Alternating double filtration (ADF) also uses two sets of filters and settling tanks in series. The principle is that a ponded filter can be brought back into use by applying the partially stabilized effluent from another filter. The film in ADF alternatively grows and disintegrates, the total amount in the two filters being less than in a single filter, so that higher rates of loading can be safely employed. Two identical filters are operated in series, and when the first filter shows signs of ponding the direction of flow through the filters is reversed, and the accumulated film is rapidly depleted (Callely et al., 1977). A 20:30 effluent can be produced at loadings up to 1.5 $m^3m^{-3}d^{-1}$ and 0.24 kg BOD $m^{-3}d^{-1}$.

Another method for increasing filter capacity is recirculation. This is based on the principle of treating settled waste in admixture with settled filter effluent in ratios of 1:0.5-10 depending on the strength of the waste. The concentration of organic matter in the feed to the filter is thus reduced at the expense of larger hydraulic loadings, increasing the possible load to 0.15 - 0.20 kg BOD $m^{-3}d^{-1}$ but still producing a Royal Commission effluent (Pike, 1978). Nitrifying filters are often used to provide further stabilization and nitrification for an activated sludge plant effluent. These operate as high rate filters at loadings of 9 $m^3m^{-3}d^{-1}$ and between 0.05 - 0.47 kg BOD $m^{-3}d^{-1}$ to produce a nitrified 20-30 effluent (Escritt, 1978).

The aim of the present investigation was to ascertain whether the loading to a conventional single-pass mineral filter could be increased by replacing the surface layer of mineral medium with a 750 mm deep layer of random plastic filter medium. Random plastic medium is normally used in high rate filters, and has a greater capacity than a mineral medium of the same grade to remove high weights of BOD per unit volume. It is well known that the highest rate of oxidation occurs in this top section of filters, where the limiting factor is usually the amount of oxygen which can be provided by natural ventilation. The increase in surface area and voidage provided by the plastic medium in the top section of the filter should theoretically allow greater film accumulation and removal of organic matter, at the same time avoiding ponding and anaerobic conditions usually associated with single-pass low rate filters when excessively loaded. A pilot plant was constructed and a filter containing the mixed media was compared with identical filters, one containing blast furnace slag and another containing random plastic medium. The comparative treatment efficiencies of the various packings were studied at three different loadings, 1.68 $m^3m^{-3}d^{-1}$ (0.28 kg BOD $m^{-3}d^{-1}$) for 12 months, 3.37 $m^3m^{-3}d^{-1}$ (0.63 kg BOD $m^{-3}d^{-1}$) for 12 months and 5.72 $m^3m^{-3}d^{-1}$ (0.85 kg BOD $m^{-3}d^{-1}$) for 3 months. The comparative ecology of the three filters was only studied during the major loading periods of 1.68 $m^3m^{-3}d^{-1}$ for 12 months and 3.37 $m^3m^{-3}d^{-1}$ for 11 months.

This gave an opportunity not only for the mixed filter to be studied comparatively with the other filters, but for the random plastic and slag filters to be studied during both low and high rate operating conditions, which had not previously been undertaken. A comparative assessment of the possible financial benefits of the mixed media system was also made.

Under the operating conditions normally used in the United Kingdom, the fauna do play an essential role in the purification process (Hawkes, 1963). Therefore it was hoped that the investigation would provide a better understanding of the processes, especially the biological ones, involved in sewage treatment, in order that present treatment works may be operated more effectively than at present. If such increases in efficiency can be achieved by simple modifications and better operational management, then the capacity of sewage treatment works need not be expanded so much, in order to treat effectively the ever-increasing loads, with a consequent saving in expenditure.

2.1 INTRODUCTION

The function of the medium in a percolating filter is to provide an extensive surface to support the biological film and the associated animals necessary for the purification of settled sewage and trade wastes. At the same time it must allow sufficient ventilation for the process and ensure maximum contact between the active film and the waste liquid.

In order to choose the best filter medium, an extensive examination of the literature was undertaken. Once the media had been selected it was critically examined both physically and chemically before and after use in the pilot filters.

2.2 CHOICE OF MEDIA

One mineral and one random plastic medium were selected for use in the pilot filters. The basic criteria for selection were that the medium had to conform to British Standard 1438: 1971, and be widely used in order that the information gathered would have a broad applicability.

The important features of mineral medium were summarised in the original British Standard in 1948. It stated that a mineral filter medium should be selected for high surface area consistent with adequate voidage, and for satisfactory grading (within specified size limits), durability, roughness of texture, satisfactory shape characteristics and low cost.

Thompson (1925) had shown that the material had to be mechanically and chemically stable, while Levine et al., (1936), comparing a number of different filter media, found that the performance was directly related to the surface area of the medium. After the publication of the 1948 British Standard, it was the practice for engineers to choose a filter medium which was predominantly cubic in shape; this view was based on the supposition that filter medium containing a high proportion of flattish pieces would have an undesirably low voidage, and in many text books this still remains the view (Escritt, 1978). The more irregular a material is for a given nominal size, the greater the surface area. For example, although more costly, blast furnace slag or clinker is to be preferred to gravel or pebbles. For material of a given shape and uniform grade, the voidage is independent of size. However, the important factor is the actual dimensions of the void spaces (the interstices), since these will determine whether or not a given medium will clog during operation or will allow adequate ventilation. Excessive accumulation of film also reduces the effective surface area. The rejection of flaky media (i.e. particles with one excessively thin dimension) by BS 1438:1948 was proved to be unjustified by Schroepfer (1951), who, by examining the effect of particle shape on voidage and surface area, found that the more cubical material possessed a lower voidage than the flaky material and concluded that an increase in angularity of particles, of which flaky particles are an extreme example, resulted in an increase in voidage and surface area. Reduction of between 5 to 7% in the voidage due to the compaction of the medium was reported by Moncrieff (1953). In a review of the relationship of particle shape and voidage, Bruce (1968) supported the earlier findings of Schroepfer that flaky media possess a higher voidage and surface area than regular media of the same sieve size, but that the average volume of flaky particles was however smaller and this resulted in a reduction in the size of the voids, although the use of flaky material of a large grading would compensate for this. These findings led to a relaxation of the 'index of flakiness' and the withdrawal of the 'index of elongation' in the revised British Standard on Percolating Filter Medium in 1971.

Numerous comparative investigations into the ideal characteristics of filter media followed the publication of the British Standard in 1948, and in particular those carried out at Minworth (Hawkes and Jenkins, 1955, 1958) and at Stevenage (Wilkinson, 1958; Truesdale _et_ _al_., 1962). These investigations showed that the smaller media consistently produced better quality effluents, and that medium with a rough surface gave marginally better performance than the smooth surface materials such as gravel. Truesdale _et_ _al_. (1962) found that although small grade rough textured medium was extremely efficient in treating large organic loads of settled sewage during the summer (0.18 kg BOD $m^{-3}d^{-1}$), it suffered from excessive film accumulation during the colder winter months. This resulted in ponding and eventually clogged the filter. Experience has shown that in order to achieve maximum efficiency throughout the year, a 50mm mineral medium with a rough surface provides the best compromise between large surface area and the provision of large voidage, and that this will produce a high quality effluent in a conventionally operated British plant.

Plastic filter medium was introduced as early as 1958, originally produced in polystyrene and later in polyvinyl chloride. Initially the plastic media were only manufactured in assemblages of formed plastic sheets or tubes known as modular medium. The advantages of modular media were the high voidage (94 to 98%), unrestricted flow of sewage and good ventilation. Excessive build-up of film was discouraged by the smooth texture and vertical placement of the media, the film regularly sloughing due to its own weight (Pearson, 1965; Eden _et al_., 1966). It was quickly realised that modular plastic media were of limited value in the complete treatment of domestic effluents, partly because the introduction of the ADF and DF systems using large mineral media was much cheaper. They were, however, extremely effective as roughing filters removing large weights of BOD per unit volume of media at relatively low levels of efficiency in terms of BOD concentration, ie. between 50 to 80% (Ministry of Technology, 1968).

The short contact time between the influent sewage and the film, and the free fall of the sewage (i.e. when the influent passed directly through the medium without coming into contact with the film) prevented the modular media from producing well purified final effluents, and restricted their use as roughing filters treating sewages of extremely high organic strengths. In order to increase the contact time but retain the high surface area per unit volume of the modular medium, various new random plastic media were designed. These were shaped in such a way that the free fall of the sewage experienced in the modular designs was prevented. Its random nature increased contact time with the film while maintaining the high voidage and so reducing the problem of film accumulation and lack of ventilation experienced with mineral media (Ramsden, 1972). Plastic media have not, however, replaced mineral media in percolating filters, neither are they seen as a replacement for the activated sludge or advanced wastewater treatment processes. They are used essentially for the primary biological treatment of sewage and industrial wastes prior to their treatment by established methods (Anon, 1979; Hemming, 1979). The various types of plastic media available are reviewed by Porter and Smith (1979) who also compare the performance of various modular and random plastic media.

Learner (1975), in a survey of percolating filters, found that granite, clinker and blast furnace slag were the commonest media in use (Table 2.1a). Hawkes (1963) considered that the pitted structure of slag and clinker to be ecologically superior to other kinds of medium. But the choice of filter medium does not only depend upon its suitability but also on availability and especially cost. As Learner points out, the majority of clinker beds were constructed prior to 1956, and since then clinker has become more expensive and increasingly difficult to obtain. Another interesting aspect of the survey was that the majority of the filters sampled in Scotland used granite as a filter medium; although this may not be the most suitable medium it was the

TABLE 2.1: Kinds of medium (a) and grades of medium (b) used in the percolating filters sampled by Learner (1975), and their percentage occurrence.

Kind of Medium	%	Kind of Medium	%
Granite	26	Limestone	4
Clinker	24	Coke	4
Blast-furnace slag	23	Clinker and gravel	3
Rounded gravel	6	Slag and coke	1
Limestone and clinker	6	Saggar chippings	1

(a)

Grades of medium (mm)	0-13	13-25	25-38	38-51	51-64	64-76	> 76
%	2	21	39	29	6	3	0

(b)

most readily available in the area. From the information available it was decided that blast furnace slag would be the most appropriate mineral medium for use in the present investigation.

The capacity of the pilot filters was $2.1m^3$ each and so the use of a large medium would be unrepresentative. Learner (1975) lists the commonest range of medium in use as being 13 to 51mm (Table 2.1b) which is based on particle size analysis. Bruce (1969) states in his review of percolating filters that the commonest grades of medium in use in the United Kingdom are the nominal sizes of 38 to 51mm. As previously stated, 50mm mineral media provided a good compromise between surface area and voidage and have been shown to produce good quality effluents under low rate conditions (Hawkes and Jenkins, 1955; 1958). It was decided therefore to use blast furnace slag of 50mm nominal grading in the pilot filters.

Although there are a number of random plastic filter media commercially available, one in particular, Flocor RC*, is widely used. This has the additional advantage that an extensive literature concerning its use is available. Flocor RC has been shown to be effective in treating both industrial and domestic effluents at high and low organic loadings (Wheatley and Williams, 1976; Hemmings and Wheatley, 1979). Flocor RC has the advantage of being the same nominal size as the blast furnace slag chosen for the investigation.

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*Manufactured by ICI Limited, Hyde, Cheshire, England.

2.3 PHYSICAL AND CHEMICAL CHARACTERISTICS OF MEDIUM

The slag medium was graded by the supplier and certified as having a nominal size of 50mm. However, during transit much of the blast furnace slag was broken up and this produced a lot of fine material and dust. The slag was subsequently washed thoroughly to remove as much dust as possible, and when dry, regraded by hand discarding any pieces not within the 28 to 63mm range. The plastic medium arrived on site in $1m^3$ containers direct from the manufacturer and therefore did not require washing or regrading; any damaged or crushed modules were discarded.

Both media were packed into the pilot filters by hand and without any deliberate compaction in an attempt to reproduce the standard type of fill normally used in full scale filters.

Samples of the medium were taken randomly from the pilot filters as they were being packed. Approximately 100 kg of the slag and 500 modules of the plastic medium were taken for subsequent laboratory analysis.

2.3.1 PHYSICAL NATURE OF THE MEDIUM

2.3.1.1 General Characteristics and Shape

Flocor RC is a random plastic medium fabricated from Polyvinylchloride which is inert and has a high resistance to biological, chemical and photochemical degradation. The modules have a smooth surface and are tubular in shape with corrugations running around the circumference, Plate 2.1. The slag medium, Plate 2.2, is irregular and angular in shape and honeycombed with pores of various sizes. It is mechanically stable and relatively inert.

2.3.1.2 Particle Size and Grading

500 modules of unused plastic medium were examined. The length of each module was measured to the nearest 0.1mm using vernier calipers and then weighed to the nearest milligramme using an analytical balance. The diameter and thickness of the plastic remained constant for all 500 pieces. The results are summarised in Table 2.2.

Table 2.2: Physical parameters of a module of Flocor RC medium

	length (mm)	weight (mm)	diameter (mm)
Mean	38.75	4.89	3.40
Standard deviation	1.28	0.59	0.00
Confidence limits*	0.12	0.06	0.00
Range	15.10	2.66	0.00
Minimum	33.70	3.80	3.40
Maximum	48.80	6.46	3.40
Number of modules examined	500	500	100

*(95 per cent)

PLATE 2.1: Modules of Flocor RC

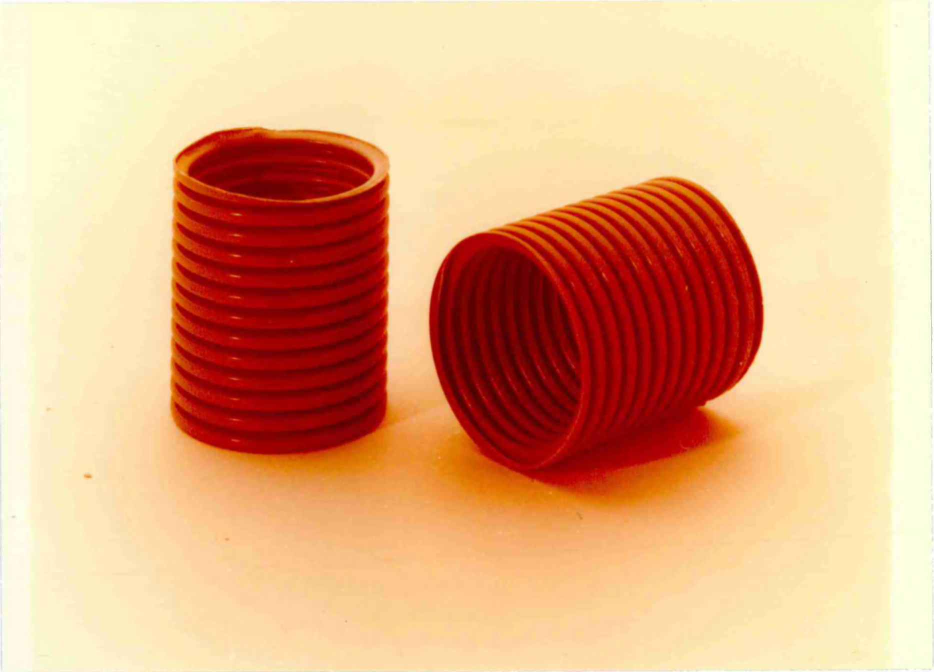


PLATE 2.2: 50mm Blast Furnace Slag

Due to the difficulty in measurement, only 80 pieces of slag medium were examined. Each piece was weighed to the nearest 0.01g, the volume of each was subsequently determined by displacement of water using a special vessel and expressed in cubic centimetres. The results are summarised below in Table 2.3. Full results are given in Appendix I.

Table 2.3: Physical parameters of a piece of slag medium

	Volume (cm^3)	Weight (g)	Surface Area (m^2)
Mean	56.93	103.97	0.018
Standard Deviation	17.64	33.17	0.005
Confidence limits*	4.49	10.27	0.002
Range	33.00	141.09	0.024
Minimum	73.00	53.60	0.007
Maximum	106.00	194.69	0.031
Number of modules examined	80	80	40

* (95 per cent)

The plastic medium was all of one nominal grade. The slag medium was graded to a nominal size of 50mm. This was checked by carrying out sieve analysis on a 40 kg sample of the medium using the method laid down in BS.410. Using a balance accurate to 0.1g, the medium was graded by determining the percentage by weight passing each sieve and the nominal size of the medium was calculated by comparing the results to the tables in BS.1438:1971 (Table 2.4). The results of the sieve analysis are given in Table 2.5. The analysis confirmed that the nominal size of the medium was 50mm; the particle size range was 28 to 63mm with 70% in the 37.5 to 50mm range.

Table 2.4: Grading limits for media

BS 410 square hole perforated plate test sieves	Nominal sizes mm					
	63	50	40	28	20	14
	% by weight passing					
mm 75	100	-	-	-	-	-
63	85-100	100	-	-	-	-
50	0-35	85-100	100	-	-	-
37.5	0-5	0-30	85-100	100	-	-
28	-	0-5	0-40	85-100	100	-
20	-	-	0-5	0-40	85-100	100
14	-	-	-	0-7	0-40	85-100
10	-	-	-	-	0-7	0-40
6.3	-	-	-	-	-	0-7

From BS.1438: 1971

Table 2.5: Sieve analysis of the slag medium

Sieve Size (mm)	Weight Retained (kg)	Retained (%)	Passing (%)
75.0	0.00		
63.0	0.00		
50.0	12.23	29.53	70.47
37.5	22.95	55.40	15.07
28.0	6.24	15.07	0.00
20.0	0.00		
Total	41.42	100.0	

2.3.1.3 Surface Area

The surface area of the plastic medium was determined directly by measurement. As the modules were fabricated, the diameter remained constant resulting in a clear length to surface area relationship.

A number of methods were tried in order to obtain an accurate determination of the surface area of the slag medium. Finally, it was decided to use the 'paint dipping technique' originally developed by Schroepfer (1951), but using the method and paint recommended by Truesdale *et al*., (1962). With bulk volumes of medium, problems were encountered in obtaining an even distribution of paint over all the medium, even after several dippings. A number of alternative paints and varnishes were tried including coloured boat varnishes, metal primers and various emulsions. The problem of uneven coating and also of paint collecting and thickening at the base of the medium remained unsolved. Using red lead paint BS.2523 (Type B) which is thick enough to give good coverage and heavy to ensure a good increase in weight after application, the medium was coated individually using a 10mm thick paint brush. This method ensured an even coat and that all the pores were covered, and by painting the pieces of medium individually, it was possible to examine any existing relationships between weight, volume and surface area. In order to determine the weight increase per unit surface area, twelve test blocks were constructed using crushed slag, each with a surface area of $0.00375m^2$ and these were painted in the same way. The surface area was then calculated by comparing the increase in weight of the media with the mean increase in weight obtained with the test blocks of directly measurable surface area. Truesdale et al. (1962) noted that filter media had different absorptive capacities. It was seen in this experiment that the absorption of the paint by the same type of medium varied from piece to piece. Table 2.6 illustrates how the weight of paint retained by the test blocks varied considerably on the first painting and how this variability became less with each subsequent coat of paint. It was decided to paint the medium three times, allowing each coat to dry before weighing and applying the next coat, before finally calculating the surface area (Table 2.7). Full results are given in Appendix I.

Table 2.6: Weight of paint retained by test blocks

BLOCK	Weight of first coat g	Weight of second coat g	Weight of third coat g
1	0.70	0.62	0.60
2	0.73	0.54	0.47
3	0.54	0.42	0.43
4	0.55	0.45	0.45
5	0.73	0.56	0.47
6	0.69	0.50	0.46
7	0.87	0.56	0.48
8	0.51	0.39	0.45
9	0.82	0.59	0.52
10	0.85	0.60	0.59
11	0.85	0.63	0.59
12	0.99	0.72	0.60
Mean	0.736	0.548	0.509
S.D.	0.149	0.095	0.067

$25mm^2$ cubes Total surface area = $0.00375m^2$

Table 2.7: Bulk parameters of the experimental medium

MEDIUM	Surface area m^2 m^3	Voidage	Number of units per m^3
Flocor RC	330.9	91.3	2×10^4
50mm Blast Furnace Slag	Estimated:143.0* Calculated:150.8	51.5	8.5×10^3

*From Table 2.8

There are a number of different ways in which the surface area of a filter medium may be calculated from easily measureable parameters (Pearson, 1977). In order to test the results obtained from painting the slag medium the surface area was determined directly from tables prepared by the Water Research Centre, Table 2.8, using the results of the particle size analysis. These tables have been prepared for the three most common mineral media using an improved paint dipping procedure (Pike, 1978). The calculated specific surface area is also given in Table 2.7.

Physical data for the media (Appendix I) were analysed by computer to determine if any relationships existed between the various measured physical parameters.

As already stated, a relationship was established between the length of the Flocor modules and specific surface area. A very highly significant correlation also existed between the length and weight of the plastic modules. Figure 2.1 shows that the sample of medium tested contained two separate populations of modules. Frequency histograms were plotted for the two variables, and Figure 2.2 shows that although the length of the modules has a normal distribution, the weight of the modules has two distinct distributions, Figure 2.3. No differences could be detected in either the thickness of the plastic used or in the overall diameter of the modules. Therefore difference between the two populations was most probably caused by either two different weights of plastic being used during manufacture, or minute differences in fabrication caused by the two separate production machines

Table 2.8: Values for specific surface areas of three different types of filter media in relation to nominal size and grading.

Range for graded material represents maximum oversize or undersize material permitted by B.S. 1438 specification.

		Specific surface area (m^2/m^3)*					
		Type of medium					
Nominal maximum size of medium		Granite		Blast furnace slag		Crushed gravel	
(mm)	(in)	Single-size	Range for graded material	Single-size	Range for graded material	Single-size	Range for graded material
25	1	194	185-237	208	200-246	176	169-208
37.5	1½	135	129-149	146	140-163	125	120-140
50	2	97	94-111	104	101-118	89	86-101
63	2½	75.5	73-85	81	79-90	69	67-77

From Pike[1], 1978.

Figure 2.1: Computed relationship between weight and length of modules of Flocor RC.

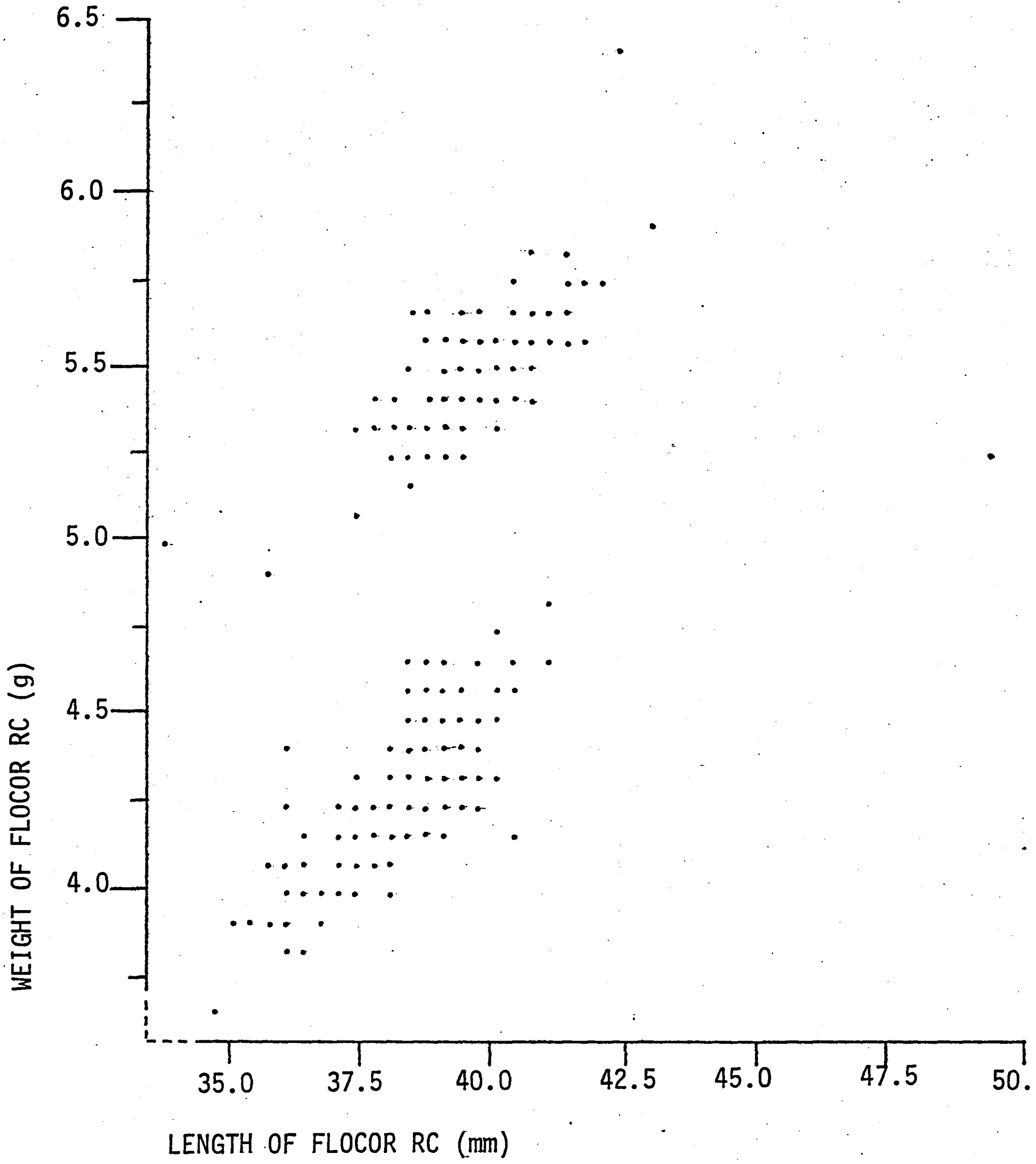


Figure 2.2: Frequency histogram showing the length distribution of modules of Flocor RC (sample = 500 modules)

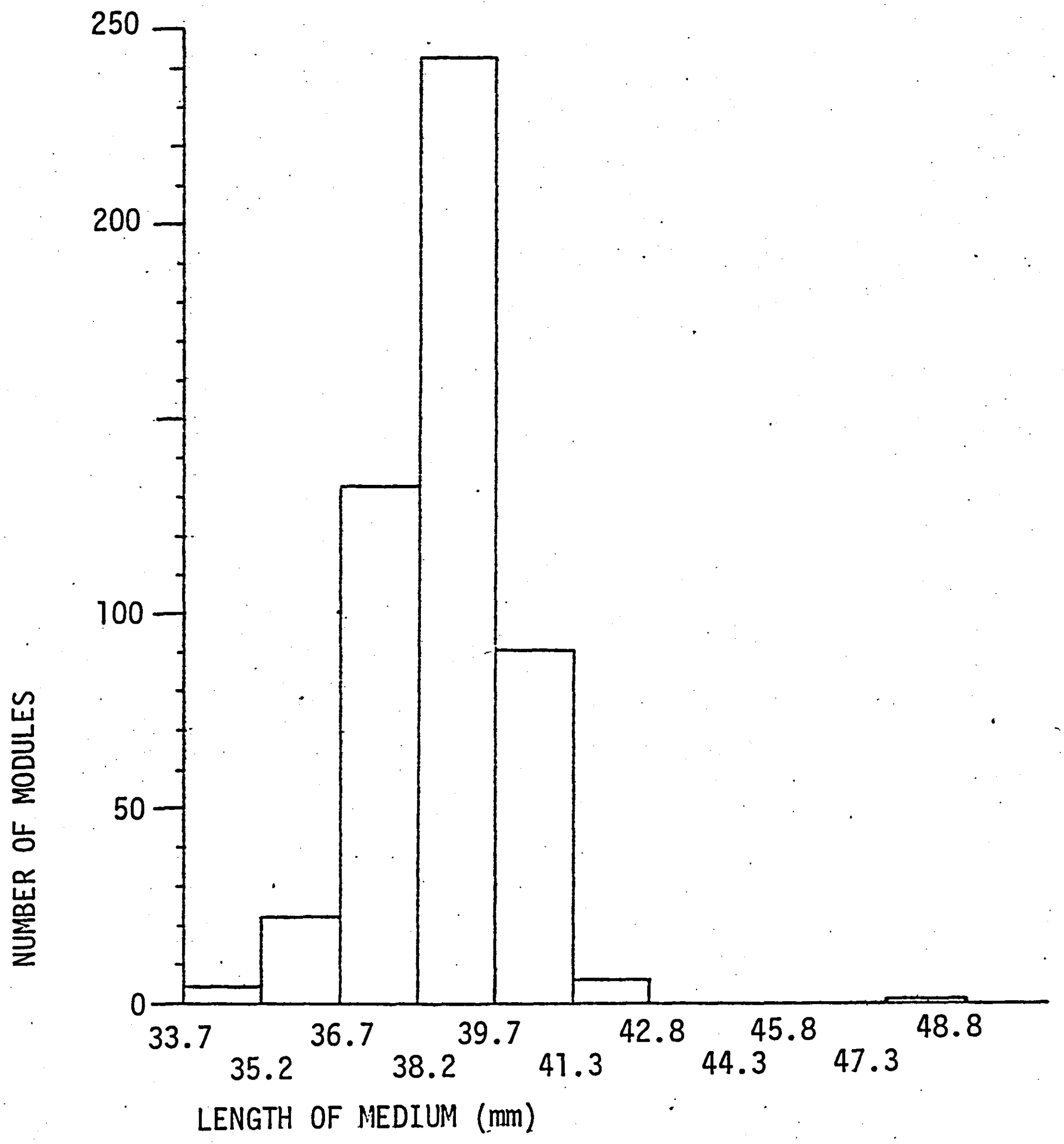
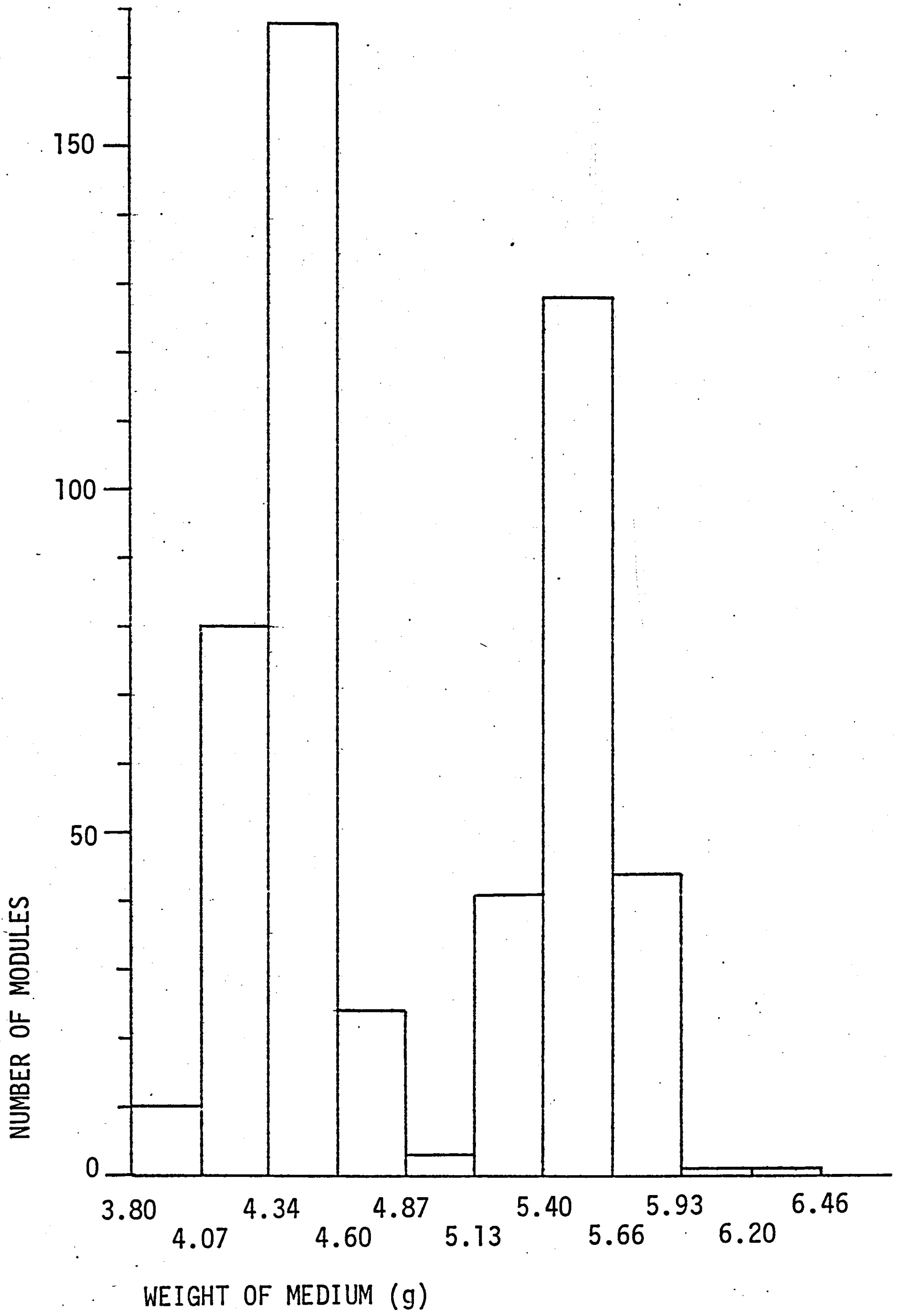


Figure 2.3: Frequency histogram showing the weight distribution of modules of Flocor RC (sample = 500 modules)



and moulds which were used in the manufacturing process of the medium.

Although fewer pieces of the slag medium were examined, several interesting facts emerged from the computer analysis. There was a strong correlation between volume and weight of the medium, (Figure 2.4), but no relationship existed between surface area and either weight (Figure 2.5) or volume (Figure 2.6) of the slag medium. The frequency histograms in Figure 2.7 show that both the weight and the surface area of slag have a normal distribution, while the skew distribution seen for the volume is due to the original selection procedure of the medium, when all the pieces of blast furnace slag below a certain size were rejected prior to packing the pilot filters.

2.3.1.4 Voidage

The voidage for both kinds of medium was determined directly using a cylindrical metal vessel with spouted outlets at two levels having a volume of 25 litres between the two outlets, Plate 2.3. Using the same method as Bruce (1968), the voidage was calculated by measuring the volume of water in the voids of 25 litres of medium. The results are given in Table 2.7.

2.3.1.5 Bulk Density

The bulk density of the medium (i.e. the weight of medium per unit volume) when wet and covered with film is the factor which controls the construction and maximum depth of percolating filters because of the load exerted on the foundations

Figure 2.4: Computed relationship between volume and weight of slag medium.

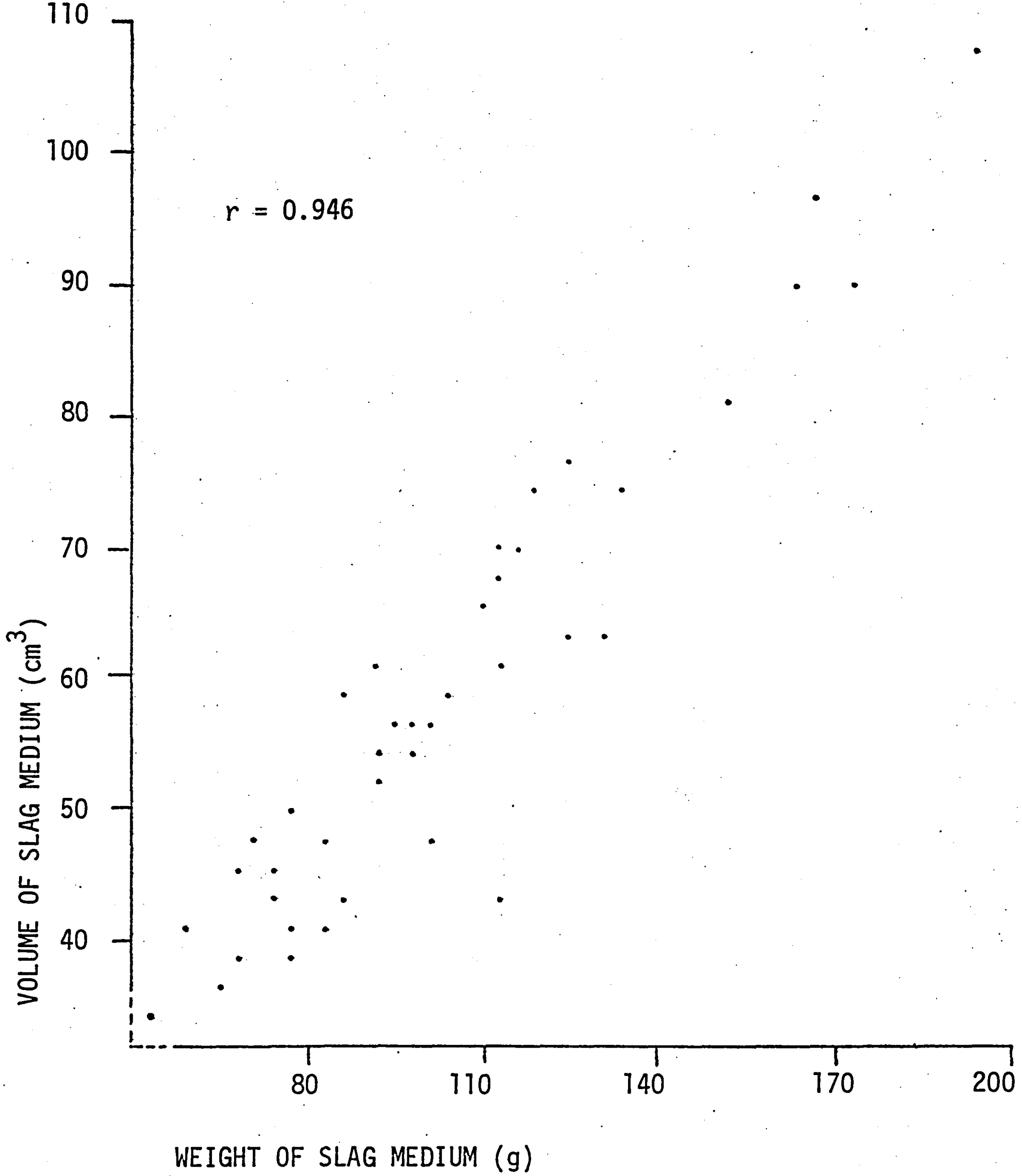


Figure 2.5: Computed relationship between surface area and weight of slag medium.

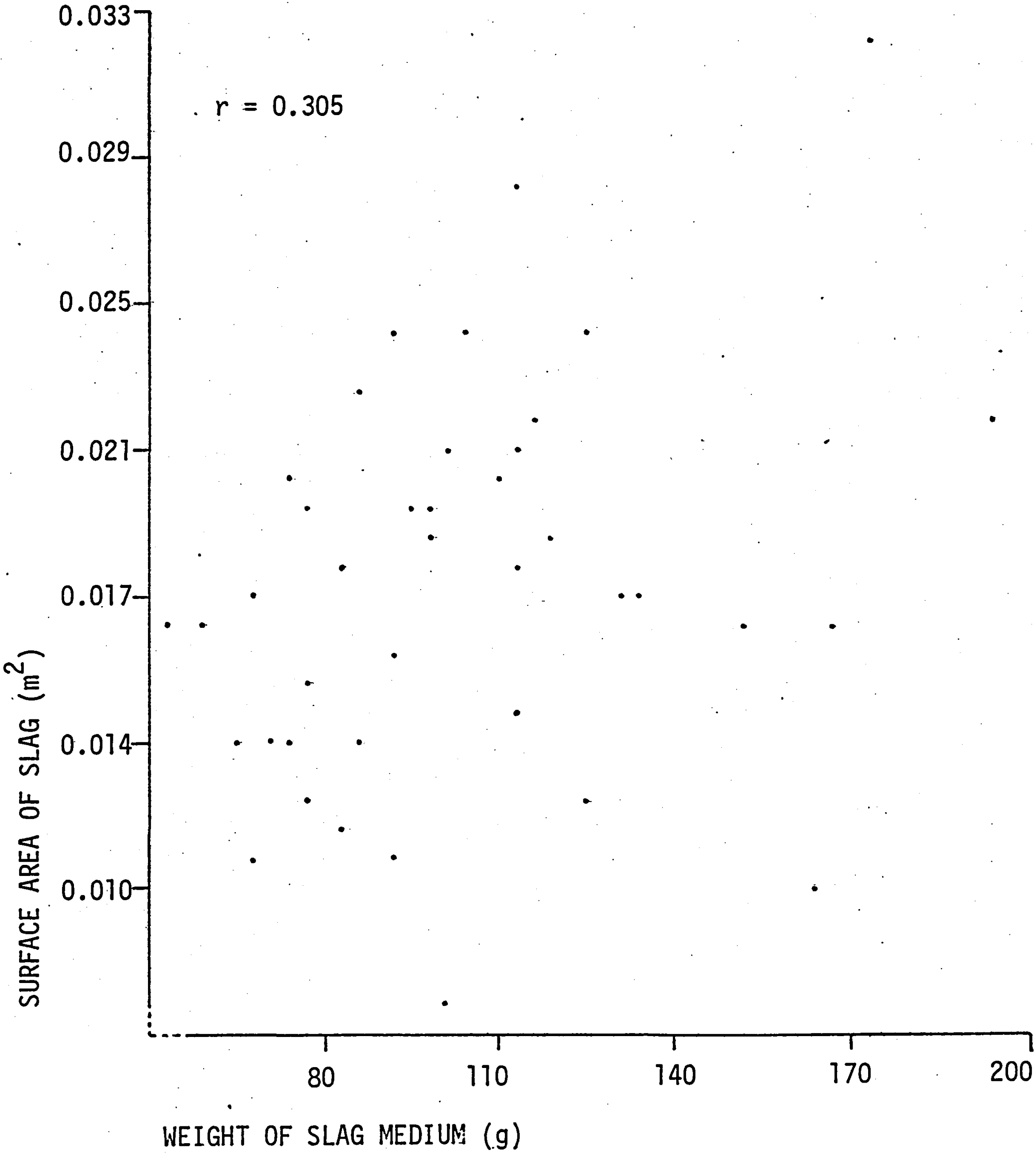


Figure 2.6: Computed relationship between surface area and volume of slag medium.

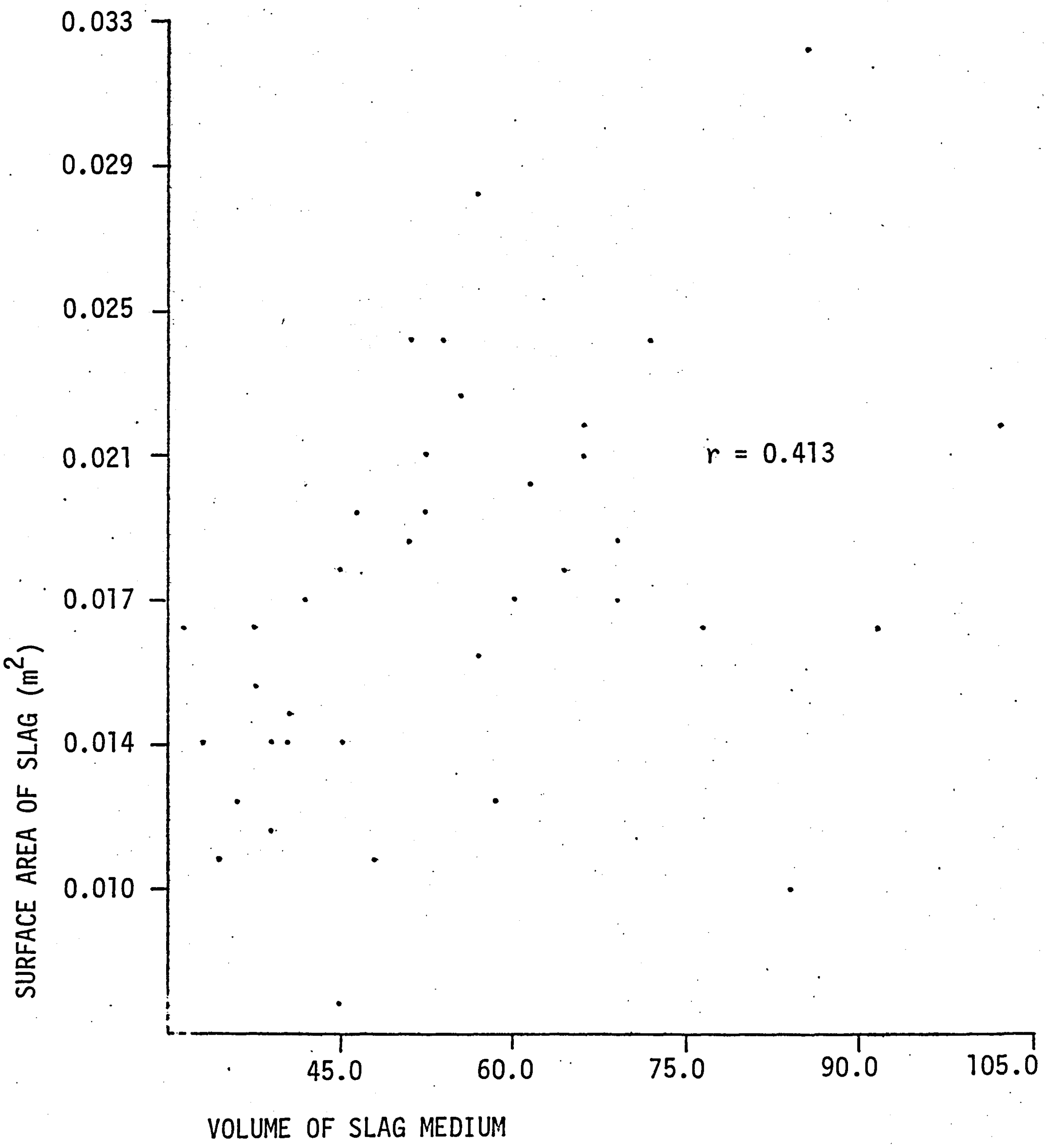


Figure 2.7: Frequency distribution of weight, volume and surface area of the experimental slag medium

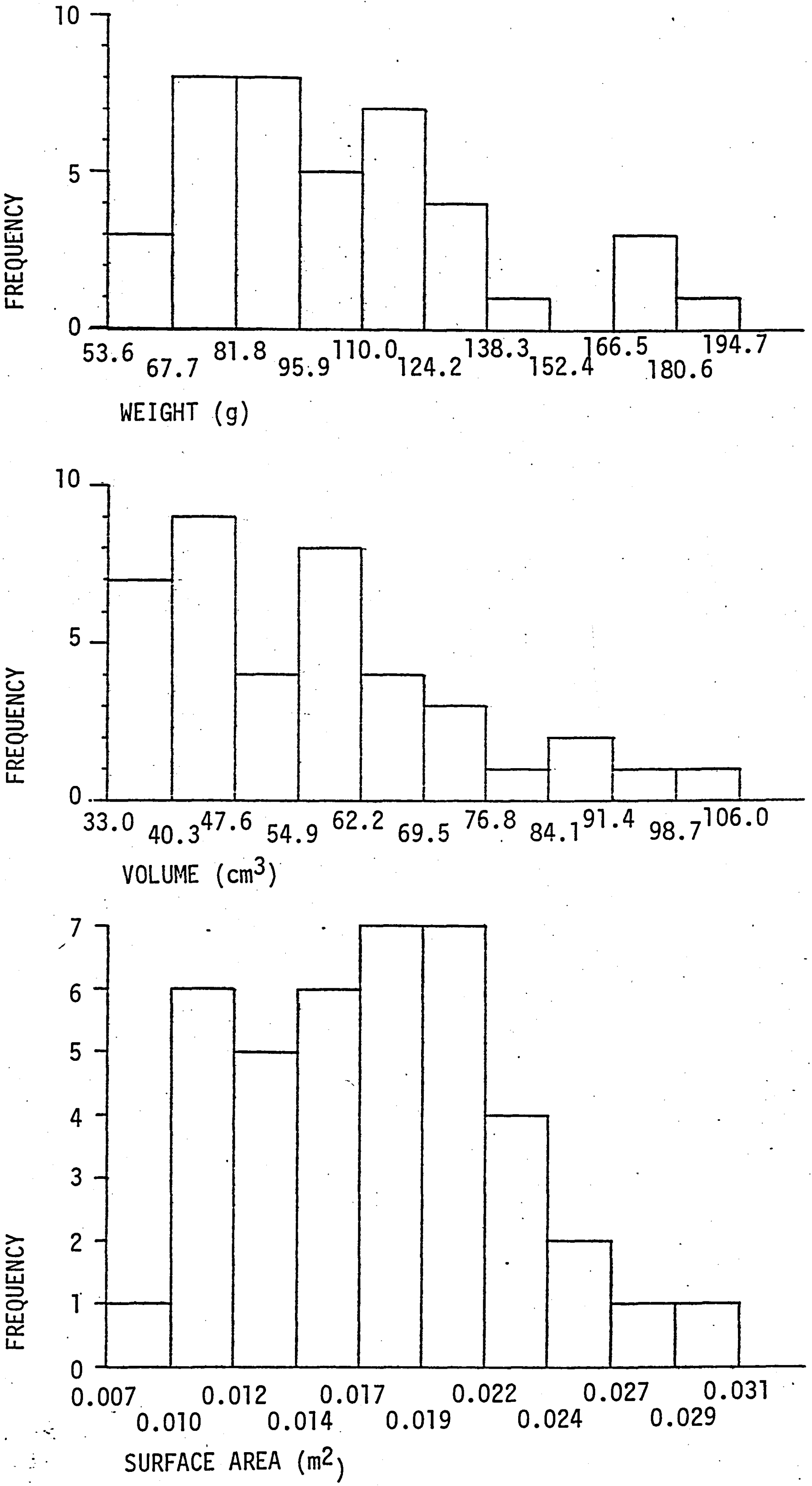
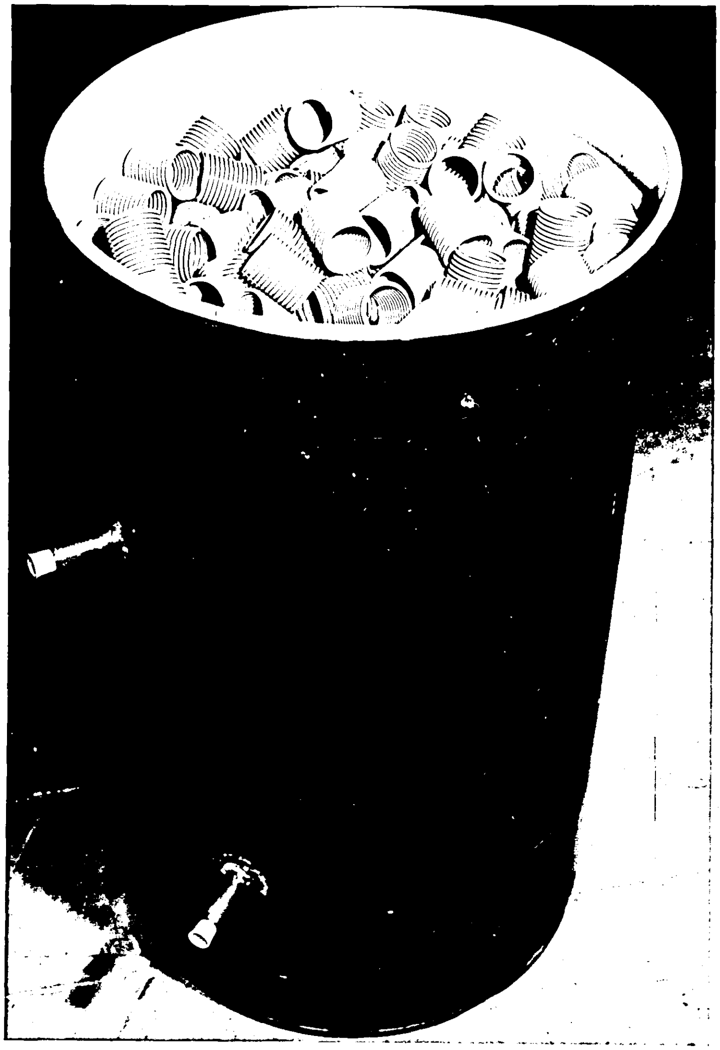


PLATE 2.3: 25 litre vessel used to calculate voidage of medium.



and walls of the filter. The maximum bulk density, usually considered to be the weight of the medium completely saturated with water (Pike, 1978), can be accurately determined by measuring the total weight of the wet film (Appendix II) at the time of maximum film accumulation, usually in February or March. The bulk density of the medium (a) when dry (b) at minimum and maximum film accumulation, and (c) when saturated with water, i.e. the maximum bulk density possible, is given in Table 2.9. The accumulation of film within the pilot filters is discussed in Chapter 6, and the total weight of the film accumulated each month is given in Table 6.18.

Table 2.9: Bulk density of experimental medium

	Dry weight kgm^3	Total bulk density due to film accumulation kgm^3		Weight when totally saturated with water kgm^3
		Minimum Film	Maximum Film	
Flocor RC	97.84	133.73 * 140.68 **	290.59 * 354.77 **	1004.84
Slag	886.31	1014.55 * 1050.01 **	1277.32 * 1180.33 **	1401.31

* Low rate period

** High rate period

2.3.1.6 Strength

Details of the physical strength of the Flocor medium have been reported by several workers. Rogers (1974) found that the medium was only compressed 1.6% when loaded at 400 kgm^{-2}, which is equivalent to a typical load for a 2m deep filter, and that the medium was tested up to 7000 kgm^{-2} without damage. More recent work showed that the modules of medium could withstand a compressive load in excess of 1.5×10^5 kgm^{-2} (Wheatley, 1976) and that a 1% compression of the medium occurred with every 500 kgm^{-2} loaded.

The Flocor RC medium used in the pilot filters was tested in two ways. Individual modules were tested to destruction using the triaxial compression test (British Standards Institution, 1975), and load cells with volumes of $0.0125m^3$ and $0.025m^3$ were used to test bulk volumes of the medium.

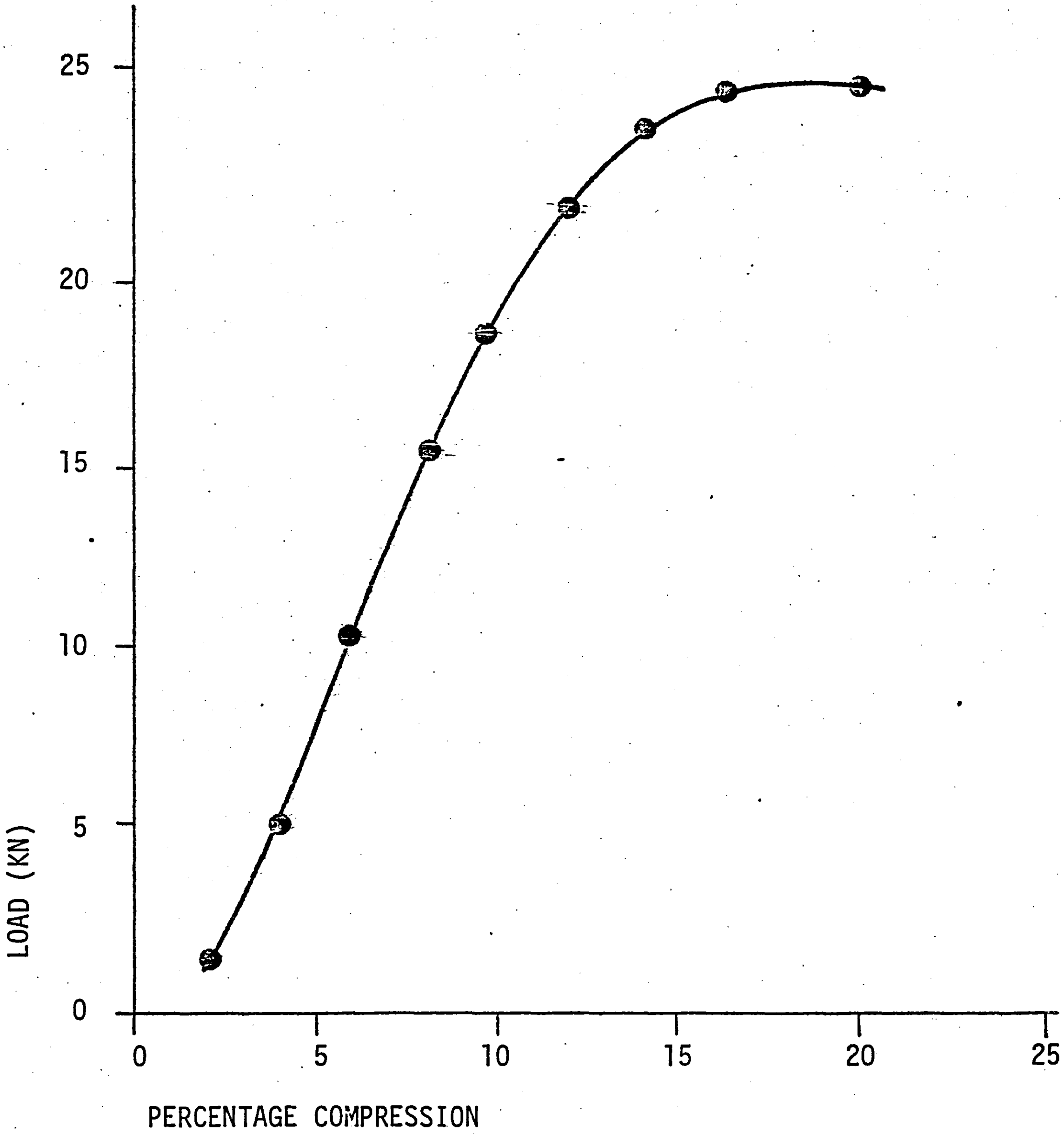
Using the triaxial compression test, it was found that a mean compressive force of 150 KNm^{-2} was needed before the modules began to deform (Table 2.10), i.e. no longer obeyed Hook's Law. This compressive force is equivalent to a mean load of 1.53×10^4 kgm^{-2} which is a factor of ten less than reported earlier by Wheatley (1976). The wide range of compressive strengths recorded in Table 2.10 may be due to the differences in the weight of the modules. It was mentioned earlier that two separate populations of medium were found in the original sample in approximately equal proportions (Figures 2.1 and 2.3).

The results clearly show that the medium obeys Hook's Law up to 10 - 14% compression when the medium begins to lose strength and becomes permanently deformed and damaged (Figure 2.8).

Table 2.10: Comparative strengths of Flocor RC and Blast furnace slag

	Flocor RC	Slag
	Compressive force KN m^{-2}	Point load force KN m^{-2}
	198.00	7584.50
	166.50	2758.00
	94.50	3102.75
	186.75	2240.88
	153.00	2620.10
	101.25	1379.00
		3102.75
		2689.05
Mean	150.00	3184.63
S.D.	43.34	1862.00
Range	103.50	6205.00
Minimum	94.50	1379.00
Maximum	198.00	7584.50

Figure 2.8: Percentage compression due to the load exerted on a module of Flocor RC medium.



The experiments using bulk volumes to measure the overall strength of the medium within the large load cells, showed that when a load was initially applied, compaction of the medium followed. When the load cells were loaded at 91.6 KNm^{-2} (9.34 x 10^{3} kgm^{-2}) the level of the medium dropped approximately 16%, rising to within 8% of its original level when the load was removed. Therefore, it appears that of the 16% recorded, 8% was due to true compaction of the medium (permanent) and 8% was due to compression (temporary).

Examination of the slag medium was confined to point loading on a number of different pieces of medium. The slag was found to be much stronger than the plastic medium, fracturing at the point of loading, at a mean load of 3.25 x 10^{5} kgm^{2}. Both types of medium were found to be extremely strong and well able to cope with the compressive forces exerted by the bulk volumes recorded in the filters.

2.3.1.7 Resistance to Temperature

Samples of both the slag and the Flocor media were kept for periods of up to six weeks at -15^{o}C and at 75^{o}C to see if prolonged exposure to temperature would affect their structure or strength. Both types of media were unaffected by prolonged exposure to these temperatures.

2.3.2 CHEMICAL NATURE OF THE MEDIUM

2.3.2.1 Stability

Polyvinylchloride was chosen by ICI Limited for its Flocor medium because it was thought to offer the best compromise between cost and stability (Chipperfield, 1967). To test this stability, 100 modules of Flocor RC were immersed in sulphuric acid (pH 2) and in sodium hydroxide solution (pH 10) for twenty days. The modules were checked at 24 hourly periods for any damage such as cracks or pitting. After 20 days the modules were washed, dried and then re-weighed. As there was no significant change in the mean weight of the sample and no apparent damage to the modules, it was concluded that the medium was extremely stable to extreme pH levels.

To test the stability of the slag medium, 40 pieces underwent the 'Sodium Sulphate Soundness Test' as laid down in the British Standard Specification 1438: 1971. Prior to the test the medium was washed to remove dust and loose particles, dried at 105°C and then weighed. The sample was immersed in a concentrated solution of sodium sulphate for four hours, before being removed and checked for soundness and cracks. This was repeated twenty times. When the samples were finally washed and tested, they were again dried and re-weighed. During the test no cracks or signs of unsoundness had been recorded, and the medium had only lost 0.5% of its original weight which is well within the criteria of soundness.

2.3.2.2 Leaching

Organo-metallic compounds are used both in preparation and in the stabilization of polyvinylchlorides. Many workers have investigated the amounts of metals leached out by water flowing over plastic media (Nicklas and Mayor, 1961; Peckham, 1971; Wheatley, 1976), and in every case the concentration of leached metals was extremely low, being well below concentrations normally found in settled sewage. Leaching declined sharply after the first few days of operation.

2.4 OBSERVATIONS OF THE MEDIUM IN USE

Observations and measurements relating to the media were regularly made during the operational period of the three pilot filters.

2.4.1 SETTLEMENT AND COMPACTION

Over the experimental period of two and a half years, it was noted that the depths of the pilot filter medium changed. The slag medium gradually compacted down a total of 100mm (5.6%). The depth of the plastic medium fluctuated, although compaction did not appear to take place under normal operating conditions. During low rate conditions the medium rose 40-60mm when the film accumulation was at its greatest and gradually returned to its original depth during the summer when the film accumulation was low. At higher loadings, however, some compression of the medium did take place, the depth reducing by 30mm when the weight of film was greatest. It is interesting to note, however, that no movement of the depth of the medium occurred in the mixed filter during the entire experiment.

2.4.2 SURFACE AREA UTILISATION

Rogers (1974) examined Flocor RC under similar experimental conditions to those experienced throughout the present investigation and estimated that 90% of the available surface area (330 m^2/m^3) was used. Wheatley in 1976 had thought that 90% of the medium was potentially usable with effective distribution.

Examination of medium from the first 250mm of the plastic filter showed that only 80% of the surface area was utilized at the time of maximum film accumulation (Table 2.11). Observations made during the monthly biological sampling when cores of the medium were removed, indicated that the amount of the available surface area being utilized was far less than 80% in the deeper regions of pilot filter. During the summer months at the lower loading of $1.68m^3m^{-3}d^{-1}$, areas of medium were found to be completely dry and devoid of any film. Excessive film growths on the plastic modules led to anaerobic conditions causing black staining due to metallic sulphides which are adsorbed onto the surface (Wheatley, 1976). The extent of this staining on the medium was less with depth within the filters and was rarely found inside the modules below depths of 1.0m, indicating that less of the surface area of the medium was being used, Plate 2.4.

Table 2.11: Area of Flocor modules covered in film during maximum film accumulation

Percentage of total area covered with film	%
40 - 50	0
50 - 60	12.7
60 - 70	23.7
70 - 80	13.6
80 - 90	30.9
90 - 100	19.1

(sample size = 110 modules)

PLATE 2.4: Staining of the surface of Flocor RC medium. The unused module on the left of the photograph shows the extent of staining to the surface of the medium completely covered with film for two years on the right. The central module indicates exact area of partial film attachment.

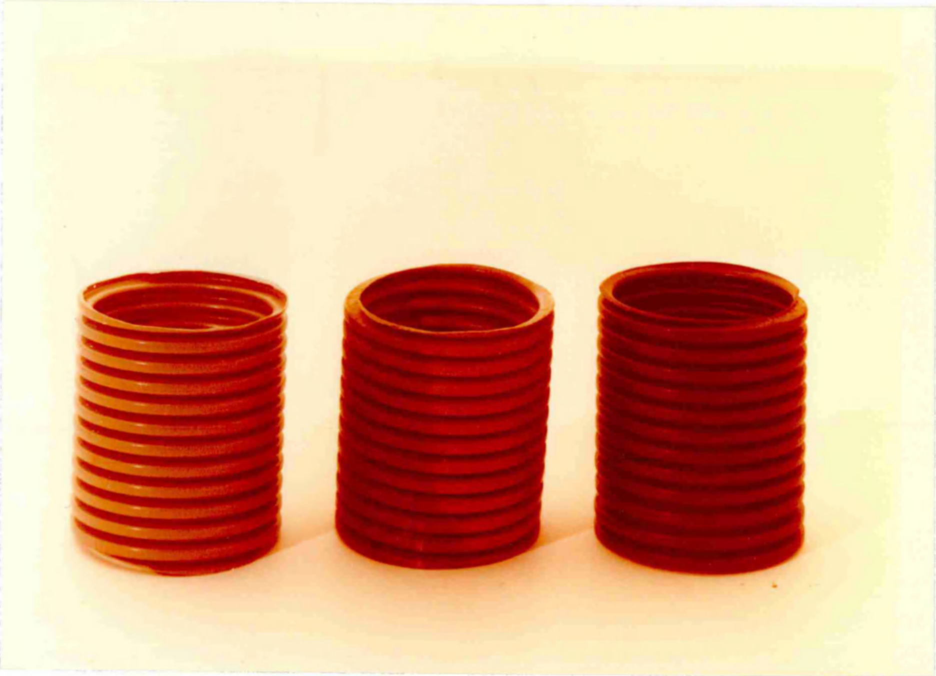


PLATE 2.5: Staining of the surface of the slag medium after two years of use in the pilot filters, compared with the unused piece of medium in the centre of the photograph.

The extensive growth of film on the surface of the majority of the modules examined had completely covered and filled the circular corrugations. These corrugations not only give the medium its high surface area, but also help in the redistribution of the effluent within the filter, because each corrugation retains a fixed volume of effluent and thus prevents large channels of flow (Hemming and Wheatley, 1979). The in-filling of the corrugations in effect reduced the available surface area by 50% in some cases. Nearly all the plastic modules had a dry area inside where no film or animals were found except for adult insects, the most common being *Psychoda alternata*, *Psychoda severini* and *Sylvicola fenestralis*. The slag medium appeared to have a much greater utilisation of its available surface area than the plastic, with areas only being free from active film where an accumulation of solids and debris occurred. Only a few dry areas were found in the slag and these were usually very small in size, and not considered to affect the total available surface area significantly.

Although the nozzles produced a near-perfect distribution of settled sewage onto the surface of the medium, during the low loading period large areas within the plastic filter were apparently dry, although at higher loadings the medium was completely saturated, except for the small dry areas inside the modules described earlier. This suggests that there is a minimum rate of application of settled sewage between the two main loading rates of 1.68 and 3.37 $m^3m^{-3}d^{-1}$ used during the investigation, which would ensure all the plastic medium was kept moist, and therefore be most efficient.

This did not apply to the slag medium which was always completely saturated.

2.4.3 FILM

During the summer the film accumulation in the plastic filter was at a minimum and it was during these periods when the large voidage allowed the medium to become 'over-ventilated', causing sudden temperature changes to occur within the filter. At times of heavier film accumulation the ventilation rate was reduced and the temperature of the plastic filter was less prone to sudden changes. When the film was heavy, there were no problems in the plastic with either surface ponding or clogging inside the filter except at certain months when thick surface mats of fungi, usually Subbaromyces splendens, caused localised ponding on the surface and led to huge accumulations of film inside all the filters, reviewed in Section 6.3. From observations, it was apparent that there was far better redistribution of settled sewage within the plastic filter at these times, and that the sewage tended to take short-cuts through the slag filter due to excessive accumulations of film below the surface. This is clearly illustrated by the retention test data which are discussed fully in Section 6.5. Although the film found on the surface of the slag filter was less dominated by fungal mats than the surface film of the plastic and mixed filters, the bacterial film became so thick that surface water collected and disappeared down small breaks in the film which acted as drains.

2.5 EFFECT OF USE: STATE OF MEDIA AFTER 27 MONTHS

After the completion of the operational period, small samples of media were removed from all three pilot filters and the various tests for strength and durability were repeated. Although all the physical and chemical characteristics of both media types were checked, no change in the strength or any signs of unsoundness could be found. The only visible sign that the media had been used was staining on both the plastic and slag media, caused by anaerobic conditions on the surface of the media while covered with film (Plates 2.4 and 2.5).

3.1 INTRODUCTION

Full scale experimentation involving percolating filters is usually impracticable or at least extremely difficult, not only because of the overall cost of modifying a full scale filter, but also due to the possible reduction of the purification capacity of the sewage works during the experimental period. There are many other problems such as the level of maintenance, alteration of the loadings and the enormity of closely monitoring a full scale unit.

The use of pilot scale percolating filters has been widespread and generally extremely successful. The use of these small units has in the past been restricted to three types of investigation, a) the examination of the treatability of sewages and the evaluation of proposed schemes prior to plant design and installation (Brown and Caldwell, 1973), b) for the development of existing schemes where it is proposed to introduce a filter for roughing/polishing, to test a new system such as recirculation or A.D.F. or to evaluate a new medium (Goldthorpe, 1938; Tomlinson and Hall, 1950; Hambleton and Kirby, 1974; Stracke and Baumann, 1975; Neale, 1978), and c) for research, by industry (Anon, 1974; Hemming and Wheatley, 1979), by the educational and research establishments (Isaac and James, 1964; Bruce and Merkens, 1970, 1973; Tariq, 1975; Wheatley and Williams, 1976; Cook and Herning, 1978) and by the Water Authorities (Banks and Hitchcock, 1976; Pullen, 1977).

3.2 SITUATION OF THE PILOT PLANT

3.2.1 PLANT AND CATCHMENT

The pilot plant was located at Long Lane Sewage Treatment Works, Treeton, which is situated 7 miles east of Sheffield and some 3 miles south of Rotherham just off the B6067 in South Yorkshire. Bounded by the M1 Motorway to the north and the River Rother, into which it discharges, in the west, this small treatment plant serves the South Rotherham districts of Whiston and Catcliffe. The works became operational in February 1974, and is a conventional filter plant with recirculation. Figure 3.1 is a layout plan of the works showing the position of the pilot plant. The maximum treatment capacity is 4,318.7 m^3d^{-1}, although the present works loading is slightly less than this (Table 3.1). Treeton S.T.W. has a large catchment area with a population in excess of 18,000 (Yorkshire Water Authority, 1976). The sewage is mainly domestic at present, but industrial development is taking place in the north-west of the catchment. There is a little infiltration water from nearby coalmines, and some road runoff from the motorway.

3.2.2 CHARACTERISTICS OF THE SEWAGE

The flow to full treatment at Treeton Sewage Works varied from 1,777 m^3d^{-1} up to the maximum of 4,319 m^3d^{-1}, with the excess flow being stored in the storm water tanks (Table 3.1). Apart

Figure 3.1: Layout plan of Treeton Sewage Treatment Works, indicating the position of the pilot filters.

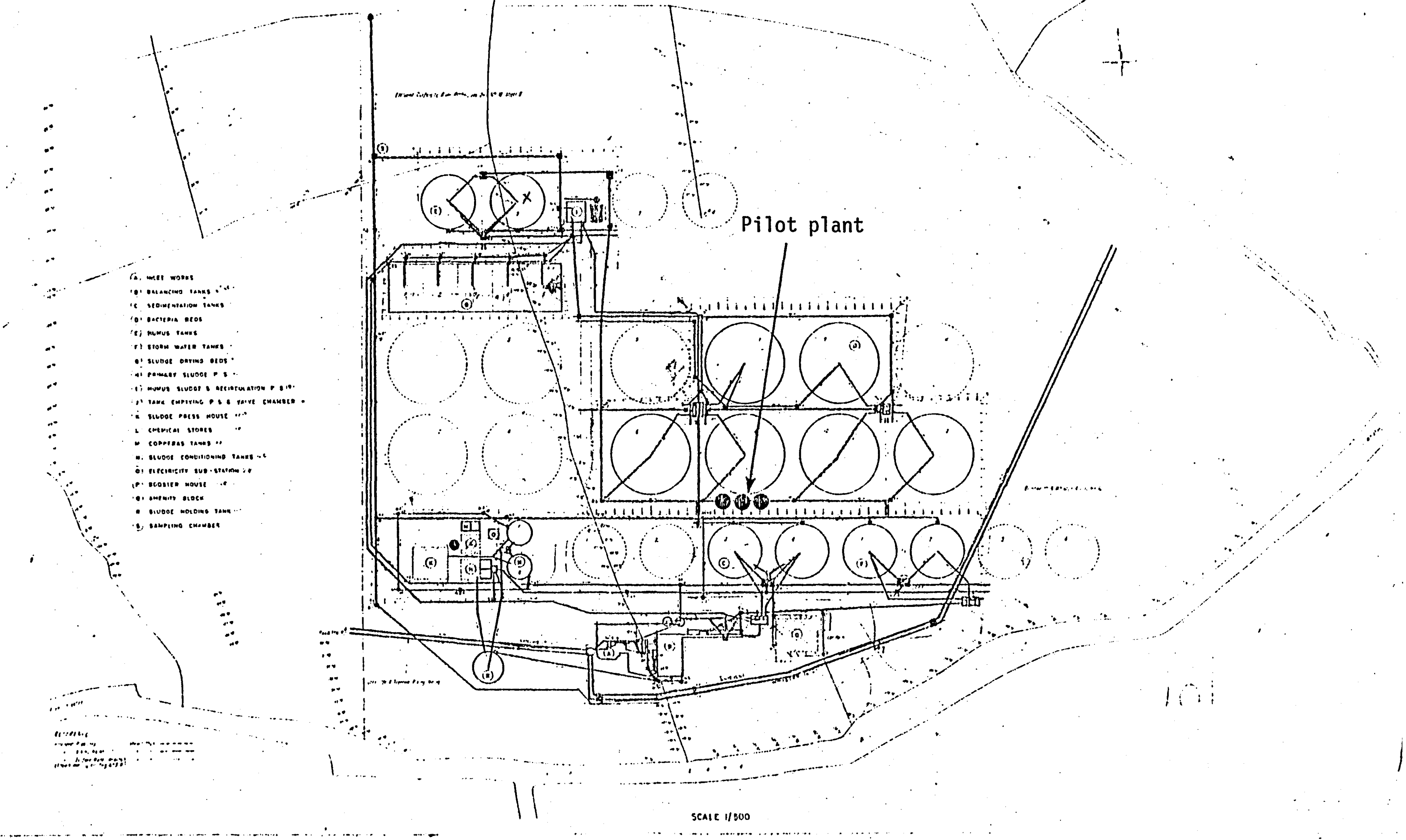


Table 3.1: Flow to full treatment at Treeton S.T.W. 1974-1979.

Mean daily flow to full treatment x 1000 m^3

	1974	1975	1976	1977	1978	1979	Monthly	
							Mean	S.D.
Jan		3.14	3.33	4.10	3.46	2.87	3.38	0.46
Feb		3.70	2.65	8.11	3.36	5.24	4.61	2.17
Mar		3.71	2.71	4.50	3.04	4.27	3.65	0.77
Apr		2.90	2.74	4.59	3.15	4.81	3.64	0.98
May		2.96	2.89	4.30	2.61	4.41	3.43	0.85
Jun		2.53	2.39	3.30	2.56	4.17	2.99	0.75
Jul	2.23	2.79	2.21	2.75	2.46		2.49	0.28
Aug	3.28	2.49	1.77	2.91	2.67		2.62	0.56
Sep	3.00	2.68	2.37	2.76	2.13		2.59	0.34
Oct	2.96	2.90	4.23	2.97	2.30		3.07	0.71
Nov	3.60	2.64	3.64	3.48	2.13		3.10	0.68
Dec	3.01	2.80	3.45	2.72	3.80		3.16	0.46
Total	18.08	35.24	34.38	46.49	33.67	25.77	38.73	
Mean	3.01	2.95	2.87	3.87	2.81	4.30	3.23	

from rainfall, the greatest influences on the flow were the various works operations such as cleaning screens, returning liquors and storm water. Minimum flow occurs during the early hours of the morning between 06.00 - 10.00 hours (Figures 3.2 and 3.3), reaching maximum flow between 15.00 - 18.00 hours. The diurnal pattern recorded in the present investigation supports the results of Painter (1958) who measured the variation in flow along a sewer.

The sewage is domestic in nature. The chemical quality of the settled sewage used as the influent to the pilot filters had a mean BOD of 172.5 mgl^{-1} and a mean suspended solids concentration of 122.0 mgl^{-1} over the 27 month experimental period (Table 3.2). The diurnal variations of BOD and suspended solids (Figures 3.2 and 3.3) and also the turbidity followed a similar pattern to the flow, the peak concentrations of the chemical parameters being recorded during the maximum flow between 15.00 - 18.00 hours, with minimum concentrations recorded from the early hours of the morning until about noon.

Full details of the influent quality are given in Appendix III, and the monthly means are shown in Figure 3.4. Maximum BOD concentration occurred during the months when the flow and rainfall were generally lowest and the dilution was least (Table 3.3). There was a direct relationship between rainfall and flow, and an indirect relationship between flow and BOD concentration.

The settled sewage contained above normal concentrations of iron and lead during periods of rainfall (Table 3.4), the

Figure 3.2: Diurnal variation in suspended solids, BOD of influent sewage to the pilot filters, compared with the variation in full flow to treatment to the main works.

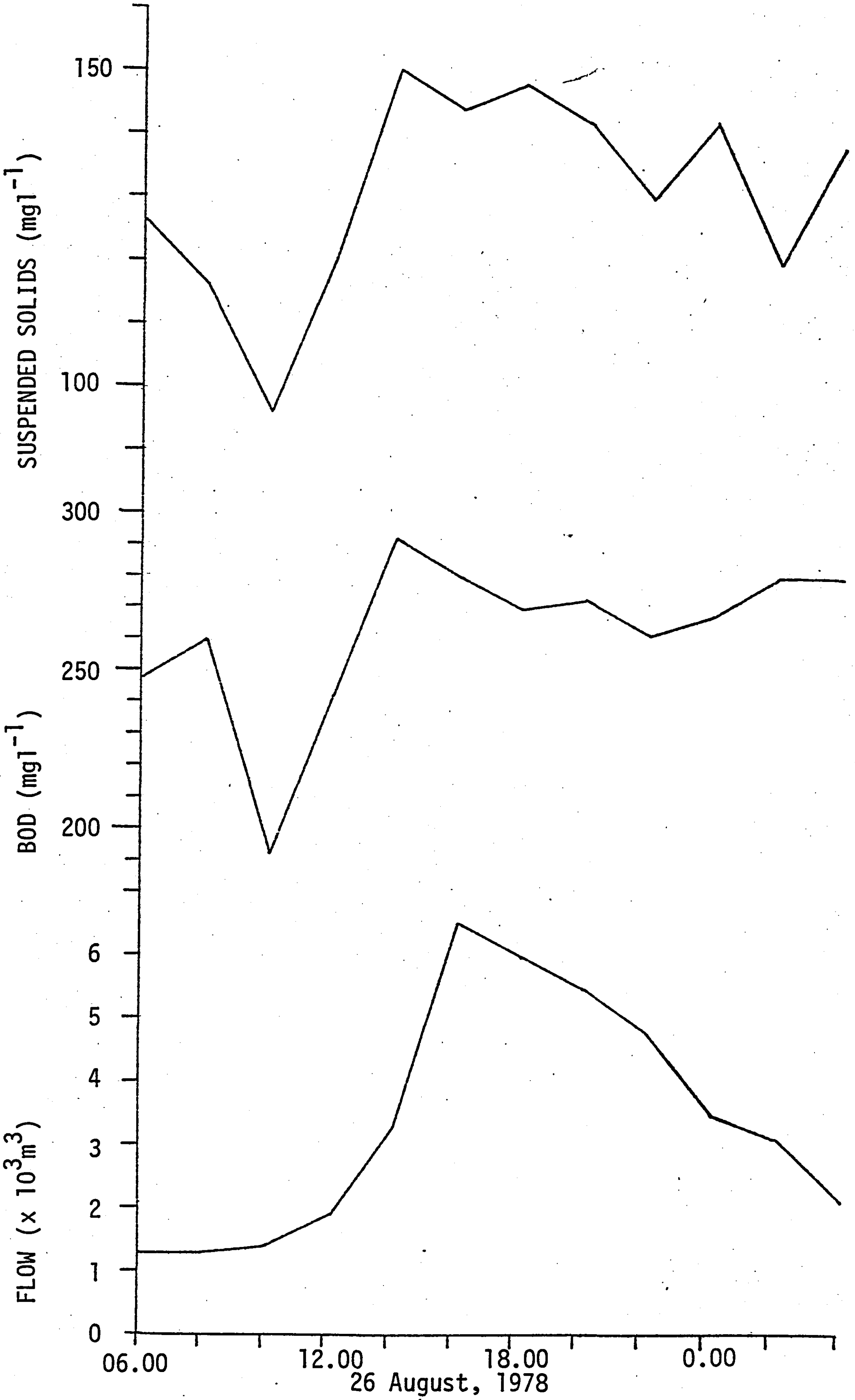


Figure 3.3: Diurnal variation in suspended solids, BOD of influent sewage to the pilot filters, compared with the variation in full flow to treatment to the main Works.

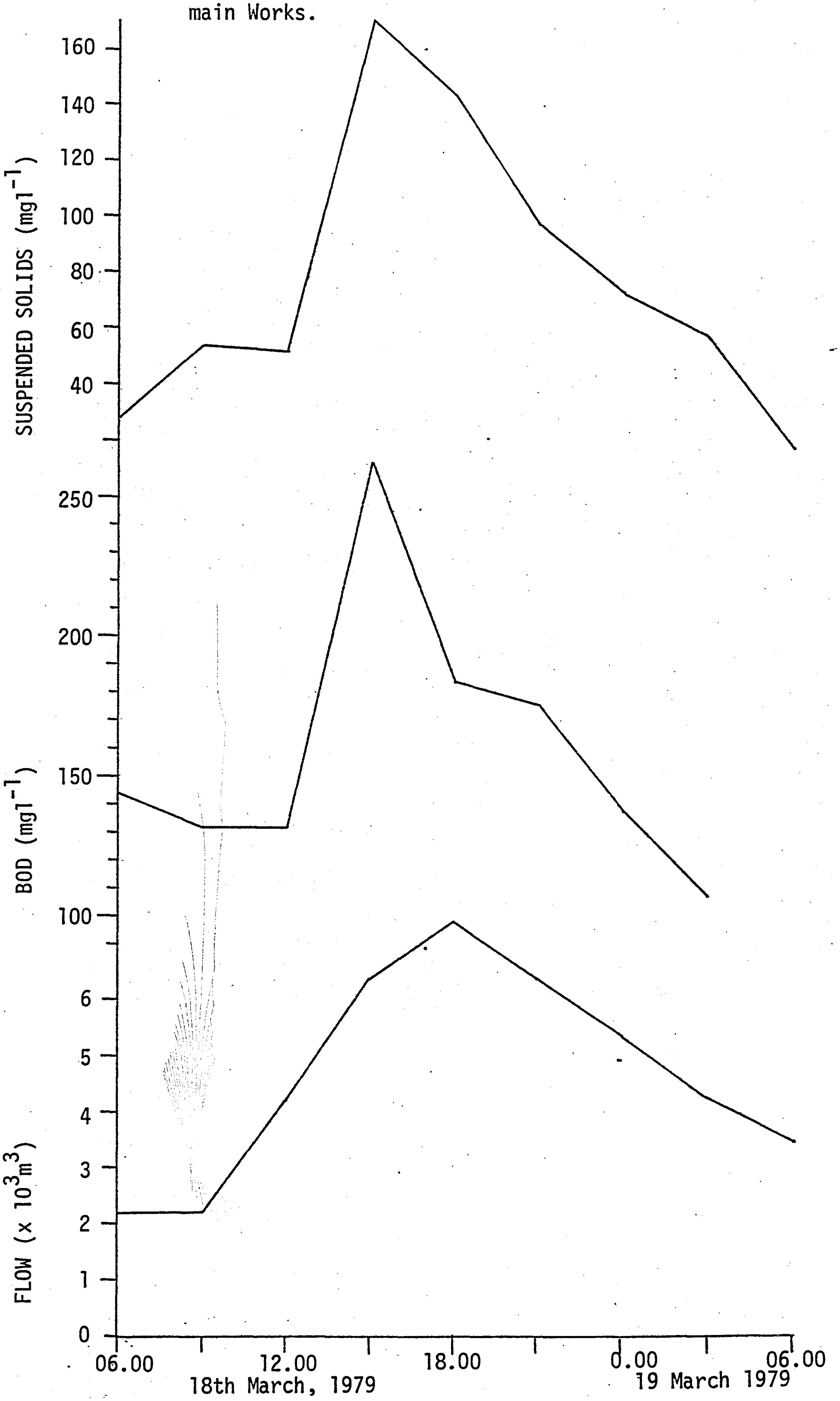
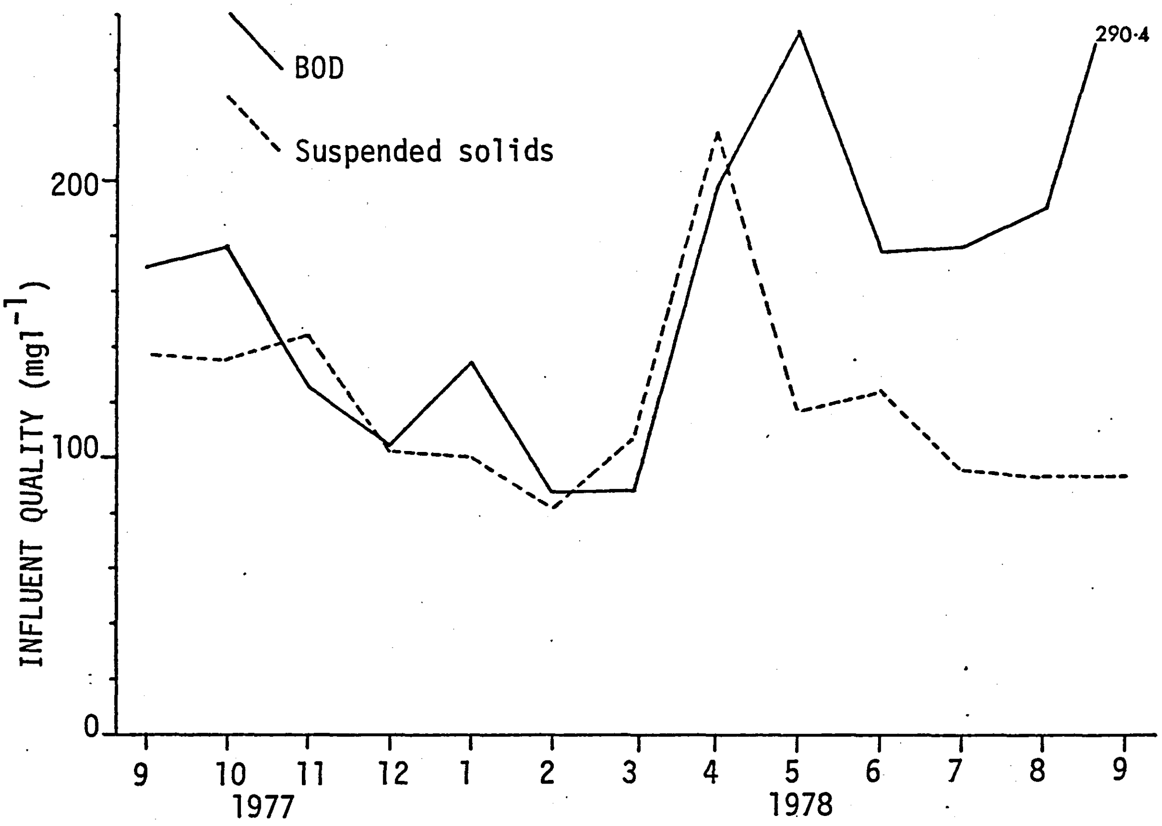


Table 3.2: Means and variation in the main chemical parameters of the influent settled sewage during the 27-month experimental period.

	BOD mgl^{-1}	Suspended solids mgl^{-1}	Ammonia mgl^{-1}	Total oxidised nitrogen mgl^{-1}	Permanganate value mgl^{-1}
Mean	172.5	122.1	26.7	1.77	36.44
Minimum	87.3	57.0	11.8	0.0	7.2
Maximum	313.4	222.9	41.7	9.1	69.9
Range	226.1	165.9	29.9	9.1	62.7
Standard deviation (SD)	62.6	37.7	8.72	2.54	14.67
Standard error (SE)	12.51	7.54	1.74	0.51	2.93
Number of samples (n)	106	111	50	50	51

Figure 3.4: Seasonal variation in quality of influent settled sewage during the low and high loading periods.

LOW LOADING (1.68 $m^3m^{-3}d^{-1}$)



HIGH LOADING (3.37 $m^3m^{-3}d^{-1}$)

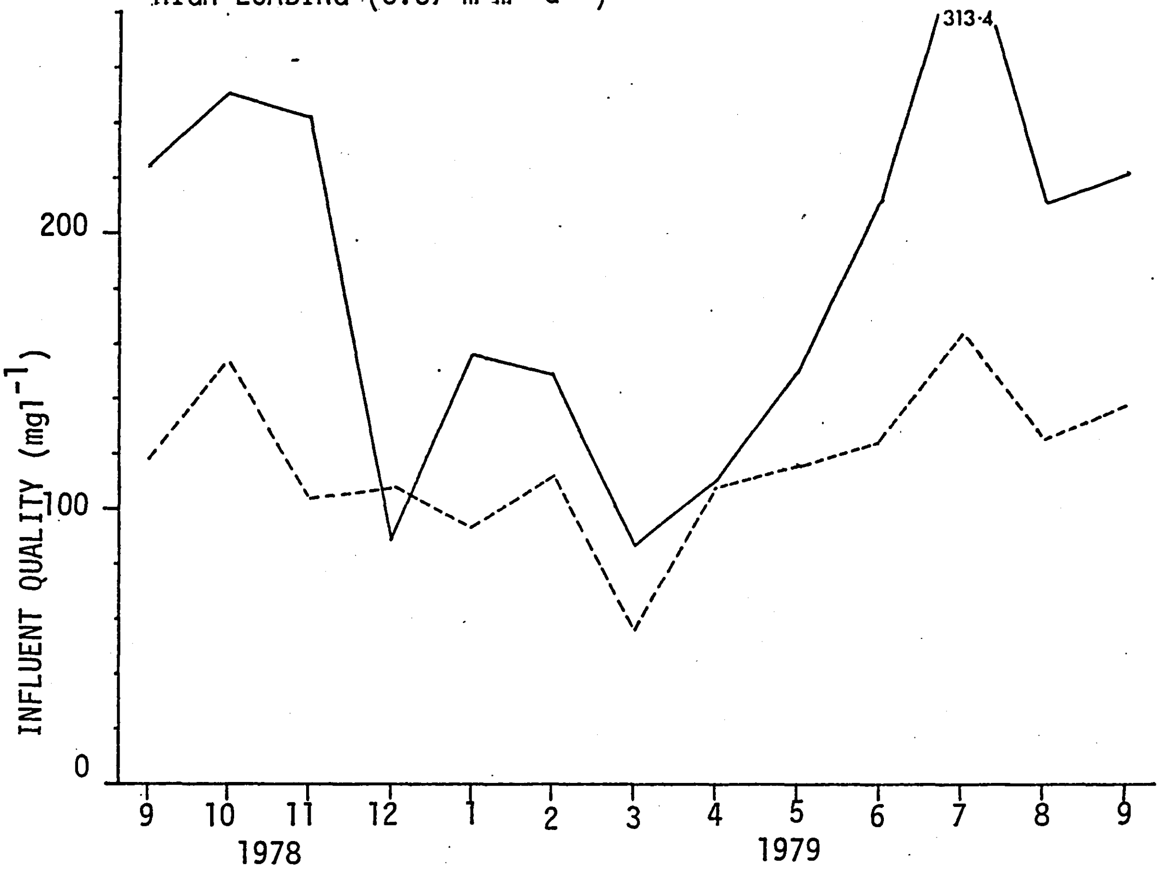


Table 3.3: Monthly variation in ambient temperature, mean rainfall and mean influent BOD

	Temperature: daily mean		Rainfall	Influent BOD
	Maximum (^oC)	Minimum (^oC)	(mm)	(mgl^{-1})
Aug 1977	20.0	11.3	46.8	152.8
Sep 1977	17.6	9.3	13.2	161.0
Oct 1977	14.6	7.6	24.3	175.7
Nov 1977	9.0	4.1	44.0	125.3
Dec 1977	7.9	3.3	48.2	104.0
Jan 1978	5.3	0.6	56.1	158.0
Feb 1978	7.4	1.8	69.0	87.7
Mar 1978	11.0	2.6	36.5	89.0
Apr 1978	9.7	2.8	34.2	198.8
May 1978	16.3	6.4	24.8	254.5
Jun 1978	18.3	9.2	58.5	173.6
Jul 1978	19.0	10.2	82.5	176.6
Aug 1978	18.9	11.1	50.4	190.5
Sep 1978	18.0	10.2	36.7	246.2
Oct 1978	15.5	8.4	8.2	249.8
Nov 1978	11.3	5.2	21.0	242.2
Dec 1978	5.3	1.1	171.0	87.4
Jan 1979	2.3	-2.9	49.2	156.0
Feb 1979	3.2	-1.3	59.9	149.4
Mar 1979	7.6	1.6	70.0	87.3
Apr 1979	11.6	4.1	46.3	109.0
May 1979	14.5	5.0	94.3	151.8
Jun 1979	19.4	9.0	10.0	212.5
Jul 1979	21.5	11.1	20.7	313.4
Aug 1979	20.1	10.2	79.7	210.6

Table 3.4: Means and variation of metals in the settled sewage from Treeton Sewage Works, during the 27 month experimental period. (Results are expressed in mgl^{-1})

	Iron	Chromium	Copper	Nickel	Zinc	Cadmium	Lead
Mean	0.74	0.01	0.05	0.24	0.16	0.01	0.85
Minimum	0.15	0.00	0.00	0.00	0.05	0.00	0.01
Maximum	1.30	0.01	0.16	0.33	0.84	0.10	1.78
Range	1.15	0.01	0.16	0.33	0.79	0.10	1.77
Standard deviation	0.40	0.00	0.02	0.06	0.06	0.00	0.45
Number of samples	8	8	8	8	8	8	12

former being due to infiltration from minewater and the latter due to the road runoff from the motorway. Increases in chloride were also recorded during the winter when the motorway was being salted.

There was considerable diurnal variation in final effluent quality from the pilot filters. Maximum percentage removals and best final effluents of BOD were generally achieved during 10.00 - 14.00 hours and of suspended solids during 08.00 - 10.00 hours at the lowest loading; while maximum percentage removals of suspended solids and BOD both occurred during 15.00 - 18.00 hours at the higher loading. The filters were generally most efficient during periods of maximum filter temperature.

The pilot filters were usually sampled at 08.00 hours, and as the filters were generally most efficient later on in the day, the results obtained do not reflect the maximum daily efficiency of the filters.

3.3 THE PILOT PLANT

3.3.1 DESIGN

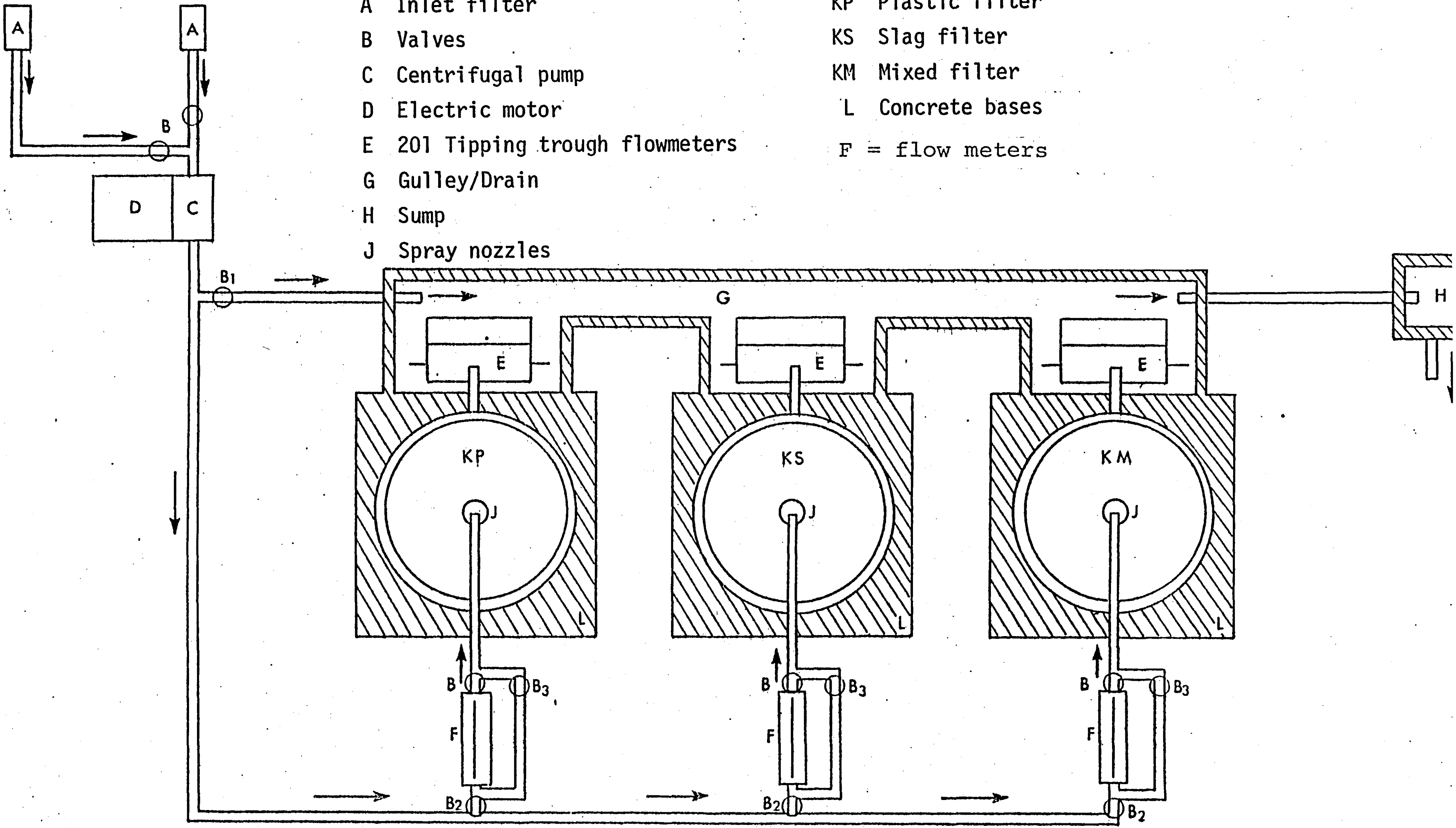
Three pilot scale percolating filters, each having a volume of 2.1 m^3, were constructed between the primary sedimentation tanks and the existing percolating filters at Treeton Sewage Works (Figure 3.1). Each pilot filter was filled with approximately 2 m^3 of medium. One contained Flocor RC, another 50 mm blast furnace slag and the third, blast furnace slag with a layer of Flocor RC on top, approximately 0.8 m^3 of plastic upon 1.2 m^3 of the mineral medium. The general layout of the pilot plant is illustrated in Figure 3.5.

The main design criteria for the pilot plant were:

i) A simple design requiring little maintenance
ii) Cheap and simple materials which are easily available
iii) The system should be reliable and capable of doing the job required
iv) The filters must be adaptable as well as durable
v) Must be easy and quick to construct, especially for those of limited engineering ability.

Although a number of alternative designs and materials were considered, it was decided that prefabricated concrete units met with most of the criteria listed above.

Figure 3.5: Plan view of the pilot plant



A	Inlet filter
B	Valves
C	Centrifugal pump
D	Electric motor
E	201 Tipping trough flowmeters
G	Gulley/Drain
H	Sump
J	Spray nozzles

KP	Plastic filter
KS	Slag filter
KM	Mixed filter
L	Concrete bases

F = flow meters

3.3.2 CONSTRUCTION OF TOWERS

Each pilot filter (Plates 3.1 and 3.2) was constructed from three reinforced concrete manhole sections 0.6 m long with an internal diameter of 1.6 m. The 90 mm thick walls allowed the sections to be stacked on top of each other, making each filter 1.8 m deep. By using prefabricated manhole sections, the height of the towers could easily be increased by adding extra sections either in 0.3 or 0.6 m units. Eden (1964) stressed the importance of making the depth of pilot filters, and the size of the medium, the same as that found in full scale treatment plants. Therefore the depth of the pilot filters was made the same as that of the large scale filters at Treeton Sewage Works. The basic design of the pilot filters is shown in Figure 3.6, which is a cross-sectional view of the mixed media filter. The manhole sections were sealed together using a waterproof mastic inside and grouting with cement and sand on the outside. Each filter was supported by twelve concrete blocks embedded into a reinforced concrete base which was 'dished' to allow the final effluent to drain away quickly. Support for the medium was provided by a fabricated circular steel grid at the base of each filter which rested on the inside of the concrete blocks supporting the concrete rings, with an extra supporting block at the centre of each grid. The grid was made in a standard diamond pattern out of 25 x 3 mm steel strips in two semi-circular sections, which when bolted together gave an overall diameter of 0.12 m (Plate 3.3). The gaps between the blocks allowed the medium to be well ventilated and also made access to the base of the filter possible (Plate 3.2).

PLATE 3.1: Pilot Plant at Treeton Sewage Treatment Works.

PLATE 3.2: Side view of mixed pilot filter. Total capacity of each filter was 2m^3.

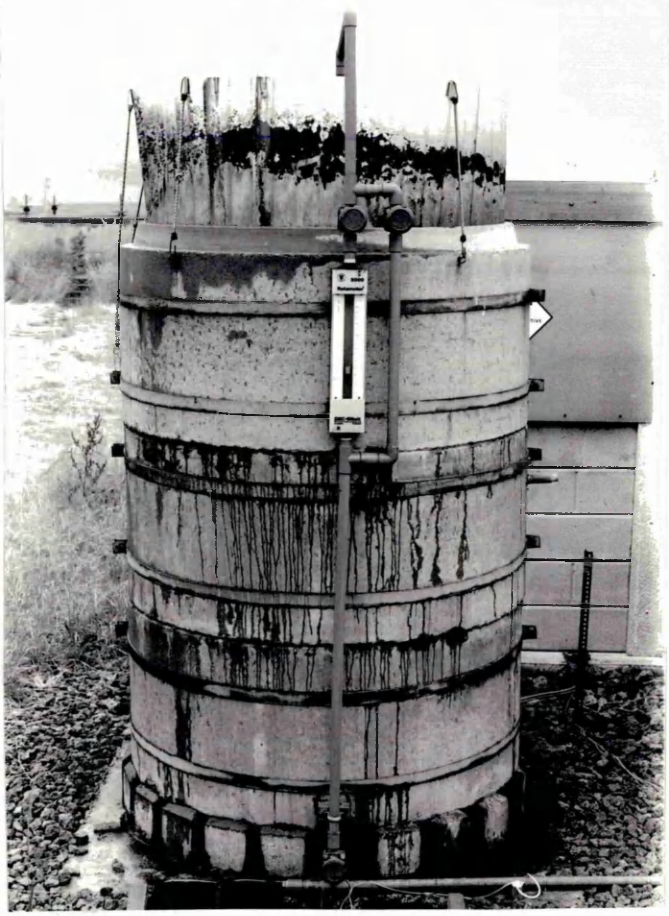
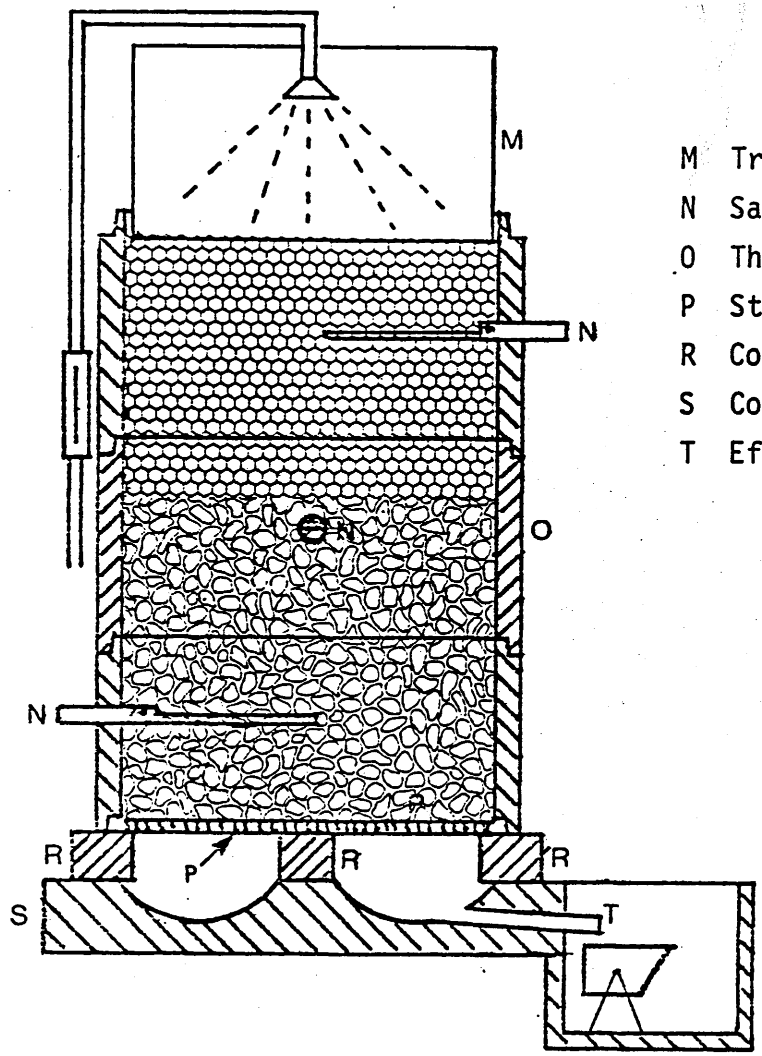
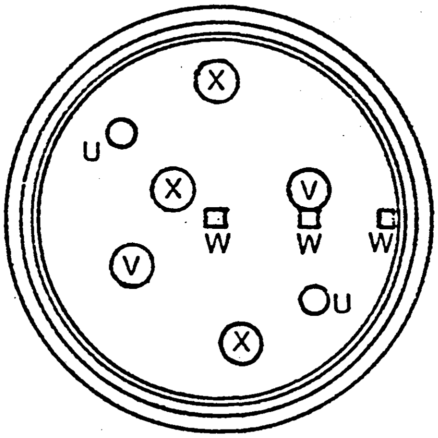


Figure 3.6a: Schematic section through the mixed media pilot filter



M	Transparent wind shield
N	Sampling ports
O	Three concrete manhole sections
P	Steel support grid
R	Concrete blocks
S	Concrete base
T	Effluent outlet

Figure 3.6b: Plan view of pilot filter indicating relative position of sampling facilities.



U	Aluminium access tube for neutron probe
V	Sampling baskets/column
W	Thermocouple cores
X	Extra sampling baskets for surface horizontal monitoring only

PLATE 3.3: 1.8m diameter supporting steel grid of one of the pilot filters during construction. The relative position of the perforated plastic sampling columns, the three wooden thermocouple cores and the two neutron probe access tubes can be seen.

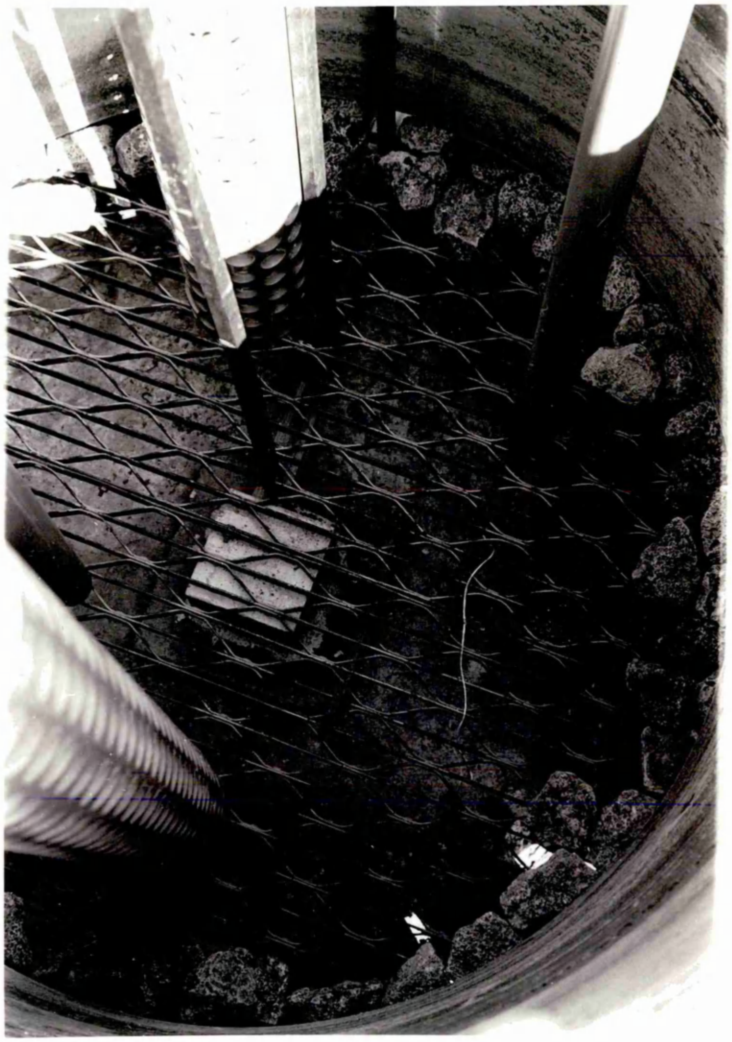
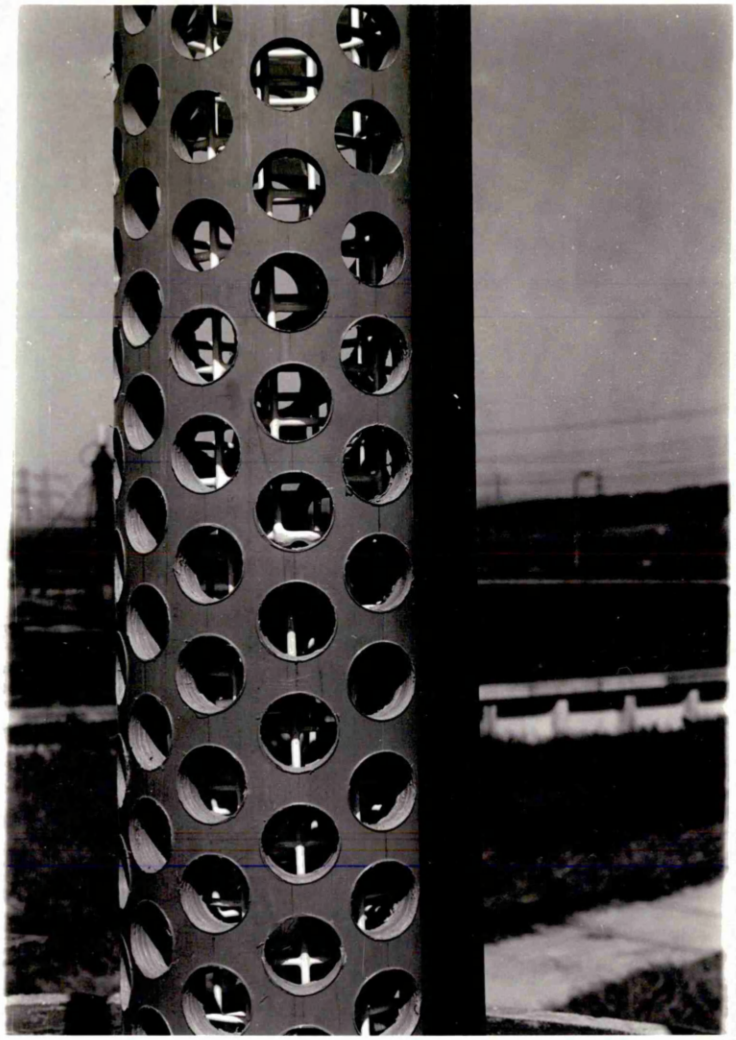


PLATE 3.4: 150mm diameter perforated sampling column containing the 'empty' sampling baskets, and the relative position of the central thermocouple core.



was decided to use larger holes, to imitate the conditions found within the medium itself, i.e. larger voids and smaller areas of contact. The particular diameter of the perforations in the sampling column ensured that none of the graded medium used in the pilot filters would be pushed through the holes during settlement, thus preventing the sampling baskets from being removed. The larger holes also allowed greater redistribution of the sewage and movement of loose solids and debris between the filter and the sampling column than the smaller holes in columns used in earlier experiments by Shephard (1967). It was also evident from the migration of certain species from the colder regions to the warmer central region of the pilot filters, that the larger holes allowed greater mobility of the filter fauna than the other systems. Each sampling column contained six closely fitting plastic coated wire mesh baskets, each 300 mm long and 146 mm in diameter, containing the appropriate medium for the filter. The third basket from the mixed filter contained the two different layers of media with the interface occurring centrally in the basket. This allowed the medium to be sampled above the interface, at the interface itself and directly below this region in the slag medium, referred to as samples M3T, M3M and M3L respectively in the Appendices. The baskets were removed by means of two plastic coated wires welded onto each sampling basket, which were just thin enough to run down between the baskets and the sampling tube. The supporting wires and the pieces of medium which protruded slightly through the holes, allowed film to accumulate and therefore prevented free passage of the influent through the small gap between the baskets and the perforated pipe. This arrangement allowed the medium to be sampled continuously down the entire depth of the filter. The position of the two sampling columns is shown in Figure 3.6b. The horizontal distribution of the fauna could only be measured within the top 305 mm of the filter, by placing sampling baskets at three other suitable places away from the other sampling and monitoring equipment.

3.3.4 MONITORING EQUIPMENT

Film accumulation was assessed both gravimetrically and by the neutron scattering technique (Sections 4.1.2 and 4.2.2). In order to facilitate the latter, two vertical 50 mm diameter aluminium access tubes, sealed at one end, for the neutron probe were fitted into each pilot filter. As was the case with the sampling columns, great care was taken to ensure that the access tubes were absolutely perpendicular. Each tube had to be kept dry and so the open end at the surface of the filter was sealed with a rubber bung when not in use.

It was felt that the temperature profile within each filter was of great importance in relation to both its ecology and performance. The temperature was monitored by 18 thermocouples placed at 305 mm intervals throughout the depth of each pilot filter. Vertical wooden rods contained the thermocouples in deep grooves which were sealed and then coated with a marine hypoxy-resin, and the junctions exposed by carefully filing the excess resin away. Three rods containing thermocouples (called thermocouple cores) were placed in each filter, one in the centre, another against the inside of the wall and the third between these two 0.3 m from the centre. The temperatures were recorded automatically at intervals of six hours using a thermocouple scanner, timer and chart recorder. The air, influent and effluent temperatures were also monitored continuously by using thermocouples.

The accurate positioning of the monitoring and sampling equipment within the filters was very important, and the relative position of the equipment is shown in Figure 3.6b (Plate 3.3). It was important that each of the devices should operate without interference from other nearby equipment. This was particularly important with the neutron probe access tube, as the instrument required a clear area of 200 mm radius around the tube. The neutron probe access tubes and the sampling columns with their baskets, were all placed equidistant between the outer wall and the centre of the filter, each replicate being on the opposite side of the particular filter in the same position. It was hoped that the results obtained would be comparable on a month to month basis, while any changes in horizontal distribution of the fauna would be recorded by the extra sampling baskets placed in the surface layer of the filters. In each filter, one of the sampling columns was placed adjacent to a thermocouple core, and it was hoped it would provide precise information relating temperature to the vertical distribution of the filter organisms found in that particular sampling pipe and its baskets.

3.3.5 SUPPLY AND DISTRIBUTION

A centrifugal pump situated at the base of the pilot filters provided the sewage feed to the pilot plant, withdrawn from two primary sedimentation tanks. The inlet pipes to the pilot plant were filled with large box screens (Figure 3.5-A) which were suspended 100 mm below the surface of the sewage in the sedimentation tank. This eliminated the possibility of any scum or floating debris being taken in, while at the same time ensuring that maximum settlement had taken place before the sewage was withdrawn. Each inlet pipe could be closed by a valve, ensuring a constant supply of sewage if one of the tanks happened to break down and had to be emptied. The base of the pilot filters where the pump was situated was some 2 m below the surface of the sewage in the sedimentation tank, thus ensuring that the pump had a minimum hydraulic head. The pressure in the 25 mm ABS delivery pipes was controlled by a by-pass valve on the pump (Figure 3.5-B1). As the pump was below the surface of the liquid in the sedimentation tank, a syphon ensured that there was always a flow of sewage passing through the pump. It was possible, therefore, by fitting an automatic restart, to have the pump restart immediately after power cuts without having to be reprimed by hand or having to visit the works to manually reconnect the power supply to the isolated pump.

The hydraulic loading was measured by rotameters which were fitted to the walls of each filter. In order to reduce the chance of the rotameter tubes becoming blocked, by-passes were fitted. With the rotameter by-pass valve closed

(Figure 3.5-B3), it was possible to correct the flow through the rotameter by first using the base valve (Figure 3.5-B2), and then diverting the main flow around the rotameter up to the distributor by opening the rotameter by-pass valve (Figure 3.5-B3) (Plate 3.2). The pressure required to produce the necessary distribution via the nozzles was controlled by restricting the flow through the pump's by-pass and the valve at the base of each filter. Each filter was loaded identically and the total flow through each filter monitored electronically by the final effluent draining into 20 litre tipping trough flowmeters.

By carefully altering the height of the distributor arm and the nozzles, perfect distribution could be achieved using Delavan Watson* solid cone spray nozzles (type BN). An even distribution to the surface was maintained so long as the nozzles did not become partially blocked, usually with small seeds, hair or other fibrous material.

3.3.6 MAINTENANCE

The pilot plant required a high level of maintenance and was visited daily to adjust and record the flows. The smallest nozzles, 6.35 mm, used during the low loading, required unblocking almost daily, while the larger nozzles, 9.53 mm, used at the high rate loading required clearing once every three

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*Delavan-Watson Ltd., Widness, Cheshire, England or four days. During the maturation period the largest nozzles used, 19.05 mm, never required cleaning during three months of operation. Cleaning the inlet strainers and flushing out the settled solids from the pipework was done regularly once a week to prevent blockage of the pipework. At the same time the rotameters were dismantled and cleaned. The transparent windshield which prevented the high winds from blowing the fine spray of sewage and the modules of plastic medium away, also allowed the light to the surface of the filter. This became coated with film and so was cleaned monthly, along with the tipping troughs which became thickly covered with the filamentous alga *Cladophora* sp.

Solids quickly accumulated in the sampling ports, and therefore they had to be scraped out and allowed to run for a short time before sampling. By keeping a comprehensive collection of spare pipework, distributor arms, nozzles, packing for the pump and other spare items, it was possible to keep the pilot plant running continuously from July, 1977 to September 1979 without any breakdowns.

3.3.7 PROBLEMS WITH PILOT PLANT

During the two years of operation a number of alterations have been made to the pilot plant.

The inlet strainers were made from expanded aluminium with a maximum aperture of 5 mm. The original strainers used were long and flat, 600 x 152 x 76 mm, and built on a wire base with a surface area of only 0.29 m^2. When the apertures of these strainers became partially blocked with debris, the pump would cause the strainer to collapse. These strainers were replaced with larger ones, 910 x 229 x 229 mm, which just fitted into the sedimentation tank between the scum containment baffle and the overflow weir. The larger strainer was built over a galvanised steel dexion frame to prevent collapse, and with the increased surface area of 0.89 m^2 each, solved the problem of providing a continuous supply of settled sewage to the pilot plant, and also reduced cleaning to once a fortnight.

Cracks which appeared in the concrete manhole sections after a few months of operation were most likely caused by thermal stresses set up within the concrete. To ensure the towers did not become unsafe, two large steel bands were clamped onto each section, i.e. six per filter. Although further cracks did develop, no leakage occurred, thus it was presumed that it was surface cracking only (Plate 3.4).

The mechanical counters on the tipping troughs proved totally unsatisfactory as they quickly rusted and eventually ceased operating. These counters were replaced with proximity switches which although highly reliable had a limited life of only 6 months owing to the fluctuating power supply experienced at the works.

Unlike Wheatley (1976) who insulated his pilot filters against the cold, it was felt that the 90 mm concrete walls were in themselves good enough insulators and that any further insulation of either the walls of the filters or of the pipework would produce false operating conditions which would be difficult to relate to the results collected at other times of the year. The rotameter tubes, however, were lagged with expanded polystyrene strips which were packed around each glass tube, to prevent them from freezing and inevitably cracking.

3.3.8 IMPROVEMENT IN THE SYSTEM

The design of any experimental equipment can benefit from modifications in the light of experience. Apart from the obvious improvements such as replicate filters, or filters with larger plan surface areas so that more sampling pipes could be added to give more details of the horizontal distribution at various depths, which in both instances would have increased the workload far in excess of one researcher, several smaller improvements could have been highly advantageous, if further financial support had been available during the investigation.

Access to the top of the filters, some 2.2 m above ground, was by ladder. Scaffolding would not only have been safer, but the provision of a platform near or at the surface of the filters would have meant quicker and easier sampling, and more overall observation of the surface. Experiments using infra-red photography had shown that the composition of the surface film could be monitored and recorded relatively easily, by taking a photograph. By using transparencies, it was possible to enlarge the view of the film by projection and thus trace the development of the major component species at the surface. The scaffolding could also have been utilised during the winter, by covering the sides with thick polythene, to protect the towers from drifting snow and heavy ice accumulations as well as making the routine maintenance more efficient and pleasant. Humus tanks would have been invaluable; although much information on the settling characteristics and volume of sludge produced were recorded, other tests such as capillary suction time and flocculation tests could not be carried out without the provision of proper humus tanks.

Fluctuations of the pressure in the pipework were caused by fluctuations in the power supply. Better flow control onto the filters would have been achieved if the pump by-pass had a pressure control outlet fitted, to maintain constant pressure in the pipework to the filters.

The temperature data were collected using a chart recorder. The provision of a data-logger would have meant easy transfer of the data to file on the computer and subsequent ease of analysis or recall. The present system has led to immense problems of transcribing the data from the charts onto punching forms, then the transfer of the data either by batch or terminal onto the computer.

There is in excess of 150,000 units of data recorded on chart. More scanning capacity, limited to 50 temperature measurements in the investigation, would have allowed more comprehensive information to be gathered as a number of thermocouples were not monitored continuously, but such extra information would have been less useful without data-logging facilities.

4.1 BIOLOGICAL SAMPLING PROGRAMME

The special biological sampling facilities built into each pilot filter have been previously discussed in Chapter 3. The two sampling columns in each filter allowed the vertical distribution of the film and fauna to be measured both quantitatively and qualitatively. Meanwhile the horizontal distribution of the biota was investigated by locating three extra baskets in the surface of each filter, thus providing details of distribution within the top 300mm.

Samples were obtained monthly, on or about the 15th of every month, over a total of twenty-three months of operation at two different loadings. Only one vertical sampling column per filter was examined each month; in this way each column was left undisturbed for two months. Either all the right-hand or all the left-hand columns were sampled in any one month. On alternative months, the surface baskets were also sampled, while on the other months the influent and final effluents were sampled and examined microscopically.

4.1.1 SAMPLING PROCEDURE

Each filter distribution system was turned off prior to sampling. The baskets were carefully removed, one at a time, from the sampling column by using colour-coded wires. Excess liquid was allowed to drain from the baskets and after five minutes each one was weighed. A 250cm^3 sample of medium and its attached film was taken from each basket; four pieces of medium were removed at random from approximately every 75mm throughout each basket. The sample was put into a labelled plastic bag which was sealed to prevent evaporation and loss of material. The remaining pieces of medium was carefully replaced in the baskets in the same order in which they had originally been removed, with the marked medium from the previous month's sampling taking the place of the sampled pieces. The sampling procedure for each filter was carried out within twenty minutes in order to minimise the damage to the rest of the biota. All the pieces of medium were carefully replaced, matching up the disturbed surface film so that only a small quantity of film was dislodged and washed away when the distribution system was switched on again. The samples were taken back to the laboratory where each bag was immediately checked for leaks, weighed, double-sealed and then stored at 4°C. This approach was adopted because the addition of preservatives such as formaldehyde or alcohol made identification of the micro-fauna, especially the Protozoa, extremely difficult.

The film was removed from all the medium samples within a few days of collection; the procedure used is summarised in Figure 4.1. The sample bag was opened carefully and the pieces of medium removed individually taking care not to allow any of the animals to escape (Plate 4.1). The loose film and associated animals were removed from the medium by gently brushing the surface with a soft brush in a shallow dish of water (Plate 4.2). Any large animals present were removed at this stage, identified and counted. This was to prevent them from being damaged during the more vigorous

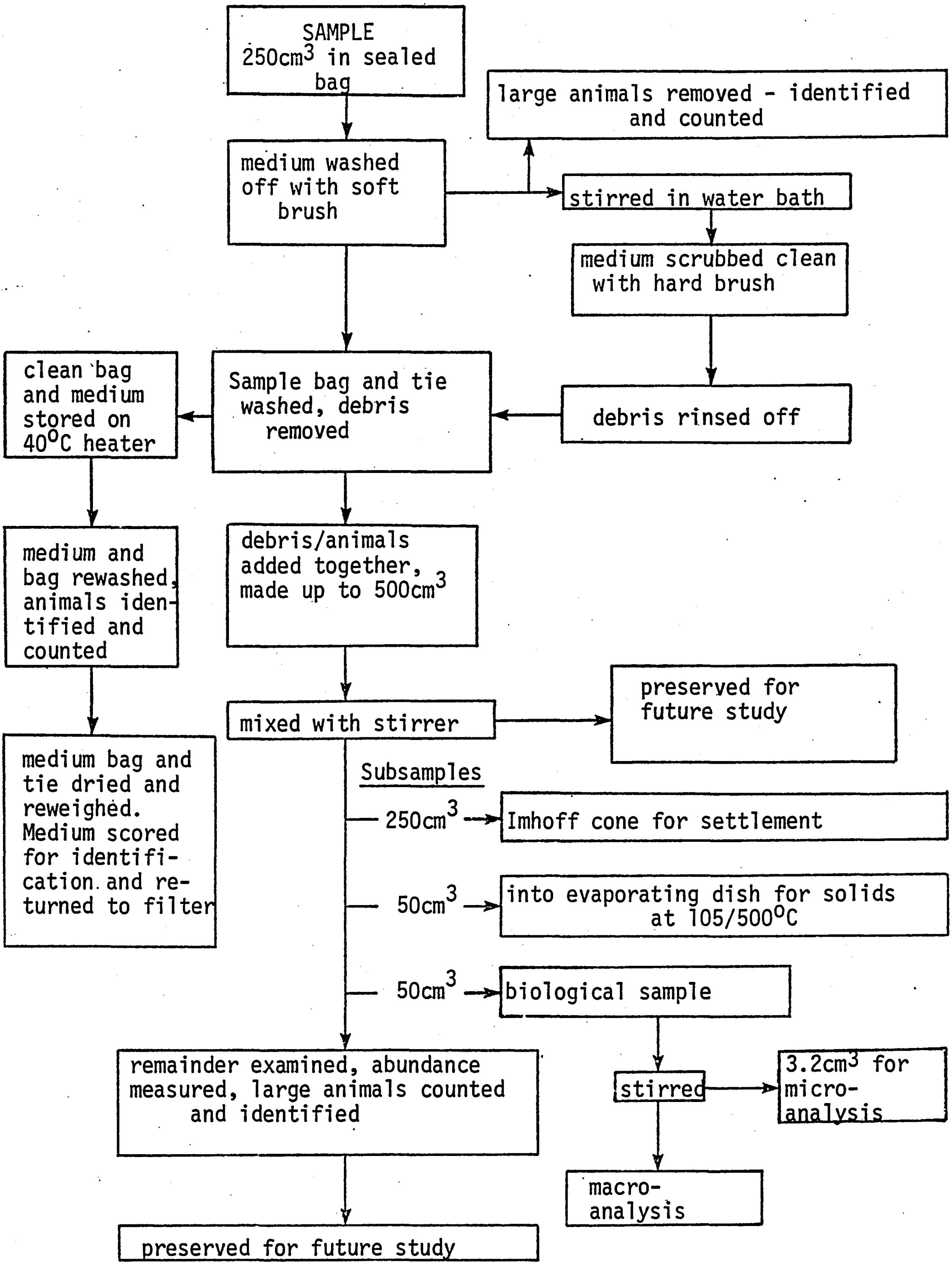


Figure 4.1: Flow chart to illustrate the processing of each sample of medium.

PLATE 4.1: Layout of equipment for removing the film from a sample of medium, seen to the left of the tray in the sealed sample bag.

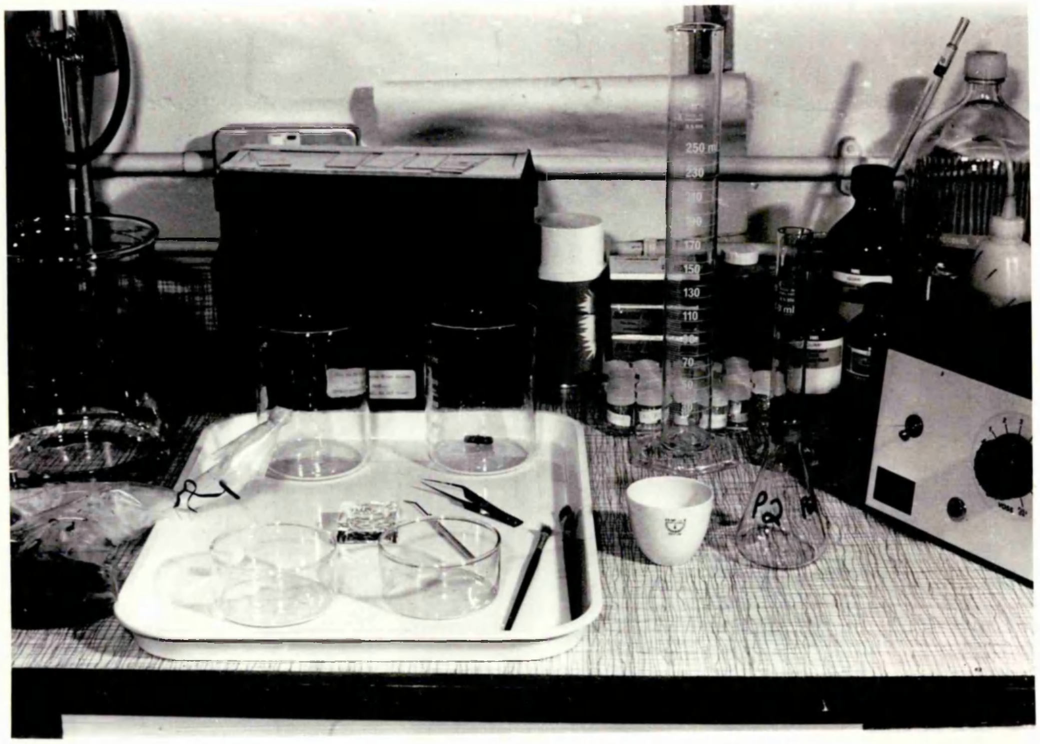
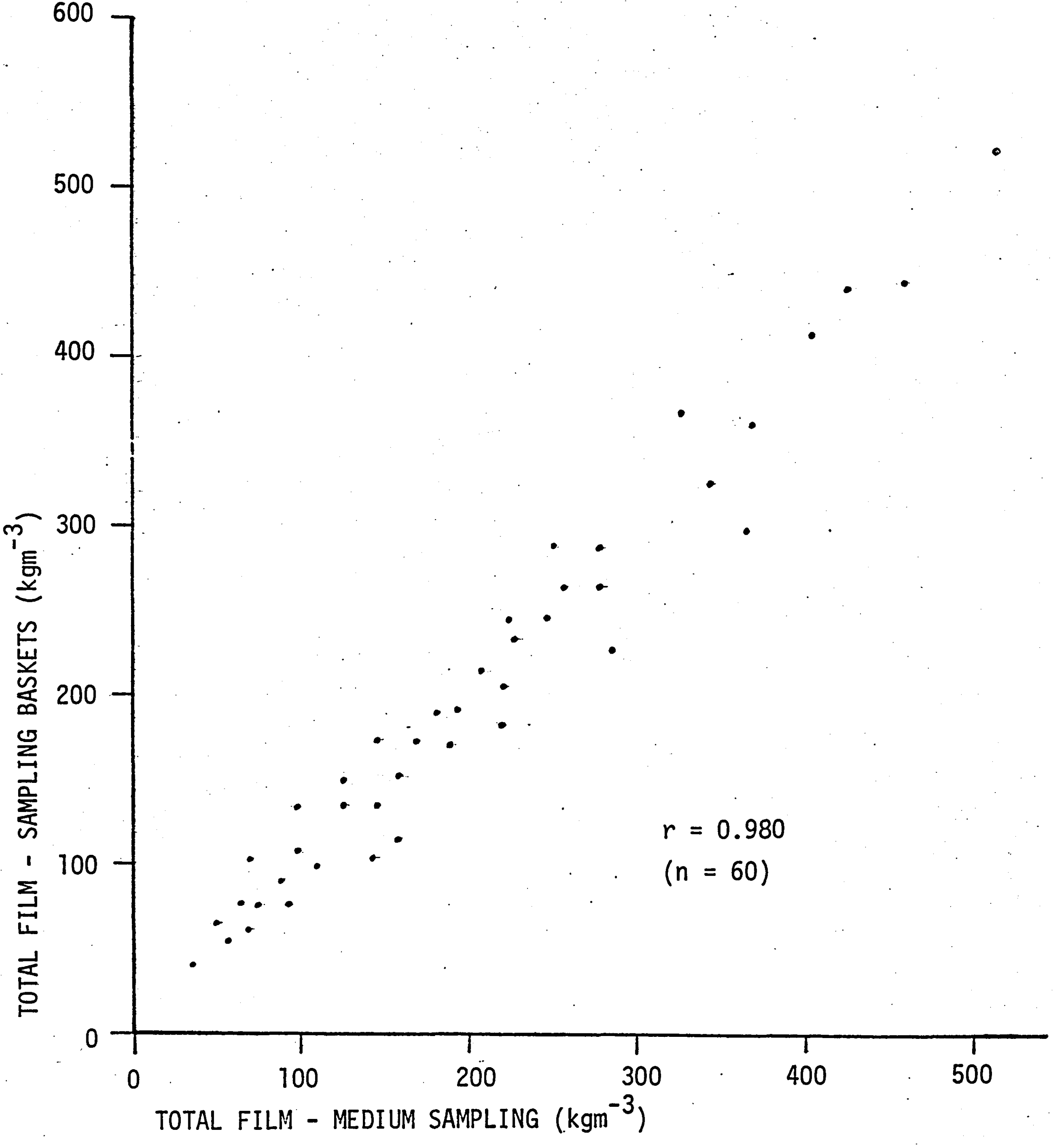


PLATE 4.2: Film being removed from a module of plastic medium initially using a soft brush

washing procedure later on. The piece of medium was then placed into a beaker and stirred vigorously using a magnetic stirrer while the next piece of medium was removed from the bag and brushed clean. The first piece of medium was then removed from the beaker and put into a second dish of water and scrubbed with a short-haired brush, which removed any tenacious film still adhering to the surface. The medium and the sample bag were finally rinsed with clean water to remove any remaining debris and the medium was then resealed in the bag. It was found that by standing the bags of freshly cleaned medium on a 40°C heater for about an hour, many animals, mainly Lumbricillus rivalis and dipteran larvae, not removed from deep within the pores of the slag medium, were driven to the surface by the heat. Both the bag and the medium were subsequently rewashed and the extra animals collected were identified and counted. The bags of clean medium were finally left to dry completely and were then reweighed. The weight of the film was calculated by subtracting the dry weight of the bag and its contents from the wet weight which had been measured immediately after the samples had been returned to the laboratory. Over a period of six months these results were compared with the biomass weights obtained by directly weighing the baskets using a spring balance. Because of the high significance of the correlation, Figure 4.2, the latter method was discontinued. All the debris, solids and animals removed from the four pieces of medium collected from each basket were added together and the total volume made up to $500cm^3$ with de-ionised water. The liquid sample

Figure 4.2: Computed correlation between total film determination by directly weighing the sampling baskets and by sampling the medium removed



was then mixed thoroughly using a magnetic stirrer and subsamples taken for the various analyses summarised in Figure 4.1. The subsamples taken for biological analysis were stored in sterile bottles at 4°C. The remaining $150cm^3$, left after all the various subsamples had been removed, were poured onto a white examination tray and an assessment of the relative abundance of the various organisms made. All the animals were identified and the larger ones were counted. Afterwards as much of the sample as possible was retained and preserved with formaldehyde for future study.

4.1.2 ASSESSMENT OF FILM AND SOLIDS ACCUMULATION

The accumulation of film at the various depths sampled in each filter was measured both by weight and volume. Total solids were measured by evaporating the $50cm^3$ sample (Section 4.1.1) in a weighed evaporating dish to dryness at 105°C for 24 hours (Department of the Environment, 1972). The dish was reweighed after cooling to room temperature. The quantity of volatile solids was determined by removing all the organic matter from the above sample by burning in a muffle furnace at 500°C for one hour (Allen, 1974), and then reweighing the dish after cooling to room temperature. Shephard (1967) when assessing film accumulation in percolating filters applied a correction factor for the macrofauna present. This was intended to take account of the large numbers of invertebrates found at certain times of the year which masked the true film accumulation. The use of such correction factors is discussed fully in Chapter 6.

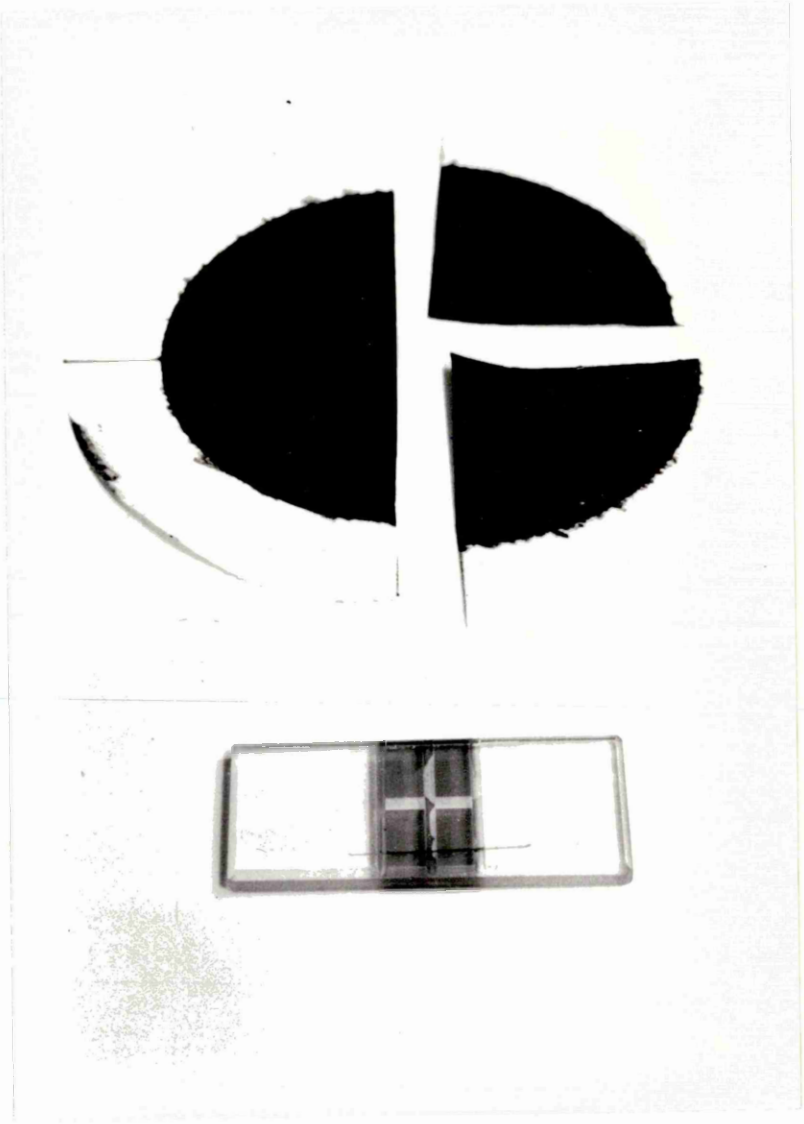
An assessment of the volume of solids present was made using the Imhoff cone method (Department of the Environment, 1972). The 250cm^3 subsample (Section 4.1.1) was allowed to settle for 45 minutes in the Imhoff cone, which was then gently twisted to remove any debris adhering to the glass sides. The quantity of solids settled after one hour was recorded. Although most of the larger invertebrates were removed prior to settlement the samples contained large numbers of organisms, and these were included in this assessment of film accumulation.

4.1.3 MICROFAUNA ANALYSIS

The 50cm^3 subsample taken for biological analysis (Section 4.1.1) was shaken to produce complete mixing within the container then, using a sterile pasteur pipette, a small volume was transferred to a counting chamber of the Mod-Fuchs Rosenthal type (Plate 4.3). A total area of 36mm^2 split up into 0.25mm^2 squares was examined for each sample under a Wild M20 microscope. Three magnifications were generally used, X100 for counting large micro-organisms such as Paramecium caudatum, nematodes and also large bacterial or fungal colonies and X200 for counting the other micro-organisms which were normally identified at X400. The depth of the sample under the coverslip of the counting chamber was measured by the microscope as being 0.1mm, therefore the total volume of sample examined per chamber was 3.6 x 10^{-6}1.

The microfauna could only be identified accurately when alive, and this did pose problems with the ciliate protozoans in particular, because of their greater mobility. This was

PLATE 4.3: Counting chamber for micro-analysis and Whatman 115 filter paper with macroinvertebrates removed by filtering, ready for analysis.



partly overcome by the addition of one percent nickel sulphate to the sample which had a narcotic effect on the protozoans. General use of this method was avoided where possible as the peritrichs and the suctorians were more easily identified when active. Problems also arose in the identification of the Fungi and filamentous bacteria, and in deciding how many cells or what length of filament constituted the presence of a countable and reproducible unit. Minimum limits were set. For a fungal hypha these were ten cells or six cells plus either growing tip or a conidium, and for the Bacteria, only filaments in excess of 0.2mm in length were counted.

The term microfauna was restricted to the Bacteria, Fungi, Algae, Protozoa, Nematoda and Rotifera. The numbers counted are all expressed as total number per 3.6×10^{-6}l in Appendix I and as total number per m^3 in the vertical distribution graphs in Chapter 5. The main identification keys used are listed in Table 4.1, while other keys used for specific species are given when relevant in the text of Chapter 5. Photographs were used as an aid to identification and proved invaluable for monitoring the changes in the surface film. By using colour transparencies, the photographs of the biological film could be enlarged and so throughout the experimental period the extent of film accumulation, dominant species, action of grazers and effects of surface ponding could be carefully examined and recorded.

4.1.4 MACROFAUNA ANALYSIS

The remainder of the subsample used above (Section 4.1.3) was shaken as before and poured into a Hartley pattern Buchner funnel, and the sample container rinsed out. The sample was gently filtered at low pressure through Whatman 113 , 150mm filter paper (Plate 4.3). The filter paper was cut into quarters and examined in a low form plastic dish under a Wild M3 stereo-microscope. The larger invertebrates such as dipteran larvae and enchytraeid worms could be identified, counted and removed at X6.4 magnification, while the other invertebrates had to be located before identification and counted by a systematic search using fine needles at X16 magnification. Mites were identified and counted by using a $1cm^2$ illuminated background plate which fitted under the plastic dish containing the filter paper; this allowed only a specific area to be illuminated and this was carefully searched at X40 magnification. A total area of $6cm^2$ was searched in this way, the $1cm^2$ areas being chosen at random on the four sections of the filter paper. Numerous species were identified and counted, and many individuals kept either for positive identification or for further investigation. All the chironomid larvae found were kept and their head capsules mounted for positive identification under the high power microscope. The adult psychodid flies were identified to species, but their larvae and pupae were not. Samples of the larvae and pupae were preserved so that identification to species could be done at a subsequent time if necessary. The identification keys used for the macrofauna are listed in Table 4.1. The number counted is expressed as total number per litre in Appendix II, and as total number per cubic metre in the vertical distribution graphs in Chapter 5.

TABLE 4.1 - REFERENCES USED FOR IDENTIFICATION OF THE MICRO AND MACROFAUNA FOUND IN THE EXPERIMENTAL FILTERS

MICROFAUNA GROUP	KEY REFERENCES
BACTERIA	
Zoogloel forms	Unz, 1971
Filamentous forms	Farquhar and Boyle, 1971a, 1971b, Eikelboom, 1975
FUNGI	Cooke, 1963. Tomlinson and Williams, 1975
ALGAE	Belcher and Swale, 1976. George, 1976
PROTOZOA	Kudo, 1932. Martin, 1968.
Sarcomastigophora	Calaway and Lackey, 1962. Page, 1976
Ciliophora	Curds, 1969
NEMATODA	Tarjan et al., 1977
ROTIFERA	Donner, 1966. Ruttner-Kolisko, 1972
General reference work : Edmondson, 1959	

MACROFAUNA GROUP	KEY REFERENCES
ANNELIDA	Brinkhurst, 1971
Enchytraeidae	Nielson and Christensen, 1959, 1961
Lumbricidae	Gerard, 1964
INSECTA	
Collembola	Lawrence, 1970
Diptera	Satchell, 1947, 1949. Coe *et al*, 1950. Bryce, 1960. Brindle, 1962. Mason, 1968. Bryce and Hobart, 1972.
ARACHNIDA	Evans *et al*., 1961
CRUSTACEA	Harding and Smith, 1974
MOLLUSCA	Janus, 1965

General reference work : Tomlinson, 1946

4.1.5 EFFLUENT ANALYSIS

Curds and Cockburn (1970) found that a greater variety of protozoan species were to be found in the effluent from the filters than in the film collected from the surface of the filter. Therefore, in order to obtain a comprehensive list of species present in the experimental filters and to discover which micro- and macro-organisms were being washed out of the filters, regular analysis of the effluent was carried out using the same methods as for the medium samples. The influent and final effluents were collected in two ways, normally by spot 1 litre samples and by using a plankton net.

4.1.6 FLY COUNTS

Conventional emergence traps (Solbe, Williams and Roberts, 1967) could not be used on the pilot filters due to the continuous dosing system using nozzles. Large sticky paper sheets, positioned between the filters were used initially to trap the flies, but these proved only partially successful. Identification was often difficult, especially of the smaller species, because as the flies struggled they often became covered in the adhesive used on the paper. Also many of the larger flies escaped from the paper, leaving the occasional leg or wing as evidence, and several species, although quite common, were never found on the sticky traps. Eventually an assessment of fly abundance in the immediate area around the pilot plant was made by catching as many flies as possible within a 60 second period, using a large entomological aspirator. These were then identified and counted. Other observations such as which species were in flight forming swarms or mating were also recorded, and these results are discussed in Chapter 5.

4.2 CHEMICAL SAMPLING PROGRAMME

Wheatley (1976) using 24 hour automatic samplers which collected hourly composite samples, found that significant variation in sample chemistry occurred, due not only to the changes in the composition of the hourly samples, but also to changes occurring during the long storage period. In order to obtain comparative results, single one litre spot samples were taken by hand at the same time either on Wednesday or Friday morning. Examination of the daily variation in the chemistry of the sewage over a fortnight showed that on Wednesdays and Fridays the sewage entering the works was of a similar chemical quality while on the other weekdays the composition of the sewage varied due to either works practice or to the composition of the incoming sewage, e.g. high concentrations of detergents due to household washing on Mondays and Tuesdays. By restricting the majority of the effluent sampling to one particular day, Wednesday, it was possible to eliminate the daily variation which although slight could have distorted the mean monthly effluent values. The different types of sampling methods employed in waste water analysis have been reviewed by Little (1973).

The sampling ports in the pilot filters (Chapter 3) allowed the sewage to be sampled as it passed through the filter in order that the relative removal efficiencies at the different depths could be studied. Thirteen samples were taken, the influent, port samples from each filter at 0.3, 0.9, 1.5 m depths and the final effluent at 1.8m.

Analysis commenced as soon as the filters became operational. Initially chemical sampling was done twice a week, but the frequency was gradually reduced as the filters matured and the performance became less erratic. After the first few months, the filters were behaving consistently enough for the sampling frequency to be reduced to three or four times a month. Two sampling schemes were finally employed. A full analysis was carried out once or twice each month when all the parameters listed in Section 4.2.1 were measured in all the available samples. A more restricted analysis was carried out two or three times each month on the influent and three final effluents only, measuring the biochemical oxygen demand (BOD), suspended solids, ammonia and total oxidised nitrogen. The frequency of the analysis carried out each month is summarised in Table 4.2.

The pH, BOD, and suspended solids determinations were all carried out on site in the field laboratory, while the rest of the samples were returned to the main laboratory at the Polytechnic so that a full analysis could be carried out. All the samples were analysed the same day and therefore no storage problems were encountered.

Analysis was carried out either on 'shaken' samples, that is, mixed samples with the settleable solids in temporary suspension or on 'settled' samples with the settleable solids removed. The minimum time for settlement, in order to remove the settleable solids was determined (a) by measuring the volume of settled solids over a timed period in an Imhoff cone and (b) by measuring the suspended

Table 4.2: Monthly frequency of Chemical Analysis

	FREQUENCY PER MONTH												
SAMPLES FROM ALL FILTERS	S/S	BOD 5	BOD (ATU)	PV	COD	NH_3	TON	Cl^-	PH	Sludge	Turb	$Cond^-$	Temp
SHAKEN INFLUENT	4	4	1	2	2	4	4	2	4	4	4	2	4
Port samples 0.3m	1	*	*							2			
0.9m	1	*	*							2			
1.5m	1	*	*							2			
FINAL EFFLUENT	1	*	*										
SETTLED INFLUENT	1	*	*										
Port samples 0.3m	2	2	1	2	*	2	2	2	2		2	2	
0.9m	2	2	1	2	*	2	2	2	2		2	2	
1.5m	2	2	1	2	*	2	2	2	2		2	2	
FINAL EFFLUENT	4	4	1	2	2	4	4	2	4	4	4	2	4

KEY:

S/S	Suspended solids mgl^{-1}
BOD 5	5-Day Biochemical Oxygen Demand mgl^{-1}
BOD (ATU)	BOD_5-Nitrification suppressed mgl^{-1}
PV	Permanganate value mgl^{-1}
COD	Chemical oxygen demand mgl^{-1}
NH_3	Ammonia mgl^{-1}
TON	Total oxidised nitrogen mgl^{-1}
Cl^-	Chloride mgl^{-1}
PH	pH
Sludge	Sludge cm^{-3}
Turb	Turbidity F.T.U.
$Cond^-$	Conductivity $mmScm^{-1}$
Temp	Temperature ^oC
*	Occasionally

solids of the effluent as the solids settled. The results are summarised in Table 4.3. Figure 4.3 indicates that maximum settlement in the shortest time for all three filters was 40 minutes.

The results of the chemical analysis were used to calculate monthly means and standard deviations to complement the monthly biological data. Diurnal variations in the sewage and in the performance of the filters were determined by carrying out 24 hour sampling programmes. One such programme was carried out at each loading. To measure the diurnal variation in effluent quality at the low loading, a restricted two-hourly programme of analyses was carried out measuring BOD, suspended solids, sludge production and temperature. In the second programme carried out during the high loading period, samples were taken every three hours. The extra time allowed more parameters to be measured; these were BOD, suspended solids, permanganate value, turbidity, pH, conductivity, flow to treatment, temperature, sludge production and some ammonia and total oxidised nitrogen determinations. The results are discussed in Chapter 6.

The temperature profile within each filter was monitored by the thermocouple scanner every six hours at midnight, 6.00, 12.00 and 18.00 hrs daily. Hourly profile scans were made over a few days, usually at times of extreme air temperatures, to determine the effects and rapidity of temperature changes within the three pilot filters. The air temperature, although occasionally monitored continuously along with the influent and final effluent temperatures using

Table 4.3: Settleability of solids with time

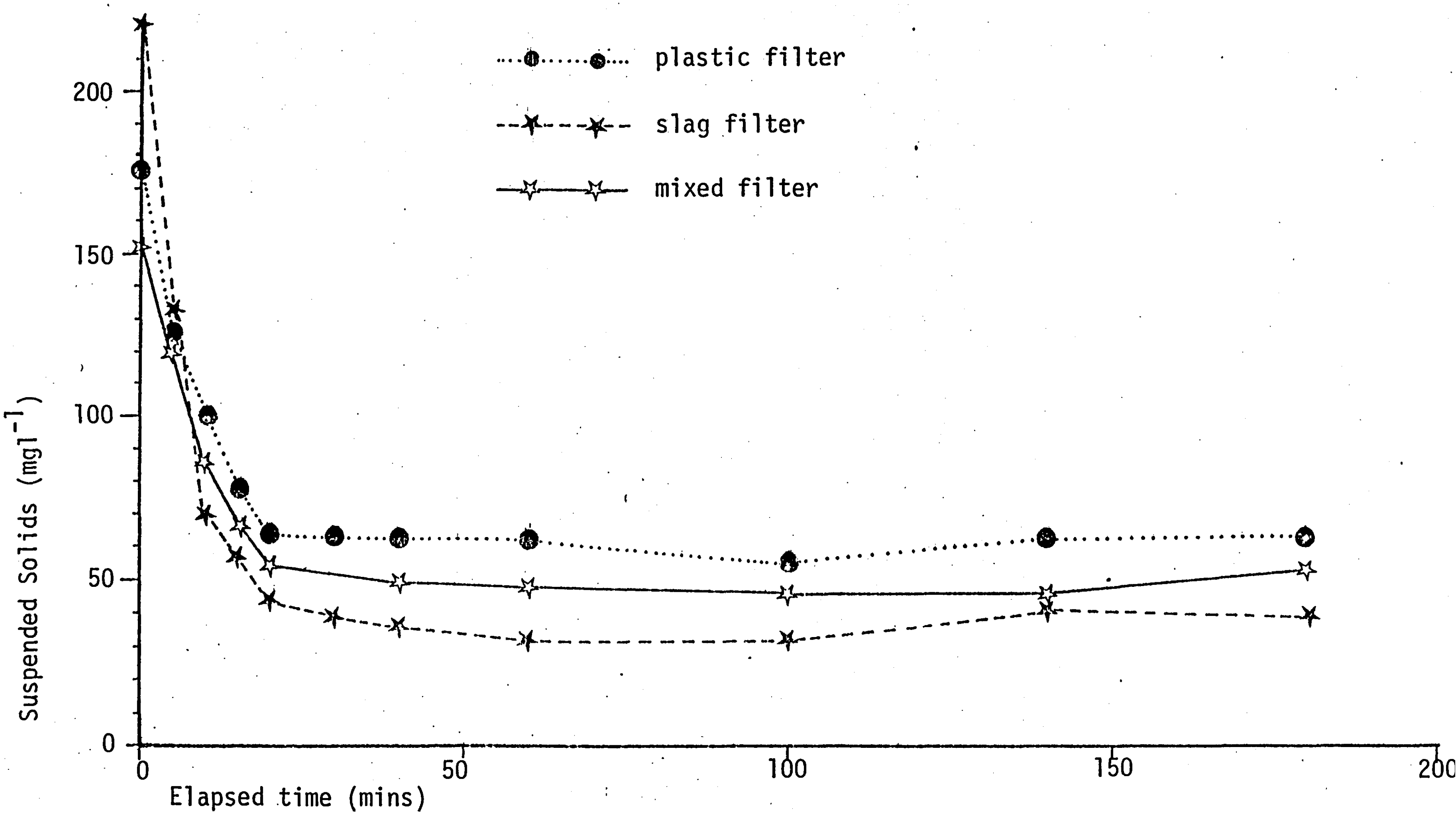
SUSPENDED SOLIDS (Filtration Method)

Time (minutes)	Influent (mgl^{-1})	Effluents from filters		
		Slag Medium (mgl^{-1})	Mixed Media (mgl^{-1})	Plastic Medium (mgl^{-1})
0	152	222	152	176
5	146	134	120	126
10	138	70	86	100
15	132	56	66	78
20	124	44	56	62
30	120	38	-	63
40	118	36	50	62
60	110	32	48	56
100	110	32	46	62
140	100	42	46	64
180	104	40	54	

SETTLEABLE SOLIDS BY VOLUME (Imhoff Cone Method)

Time (minutes)	Influent (mgl^{-1})	Effluents from filters		
		Slag Medium (cm^3l^{-1})	Mixed Media (cm^3l^{-1})	Plastic Medium (cm^3l^{-1})
0	0.00	0.0	0.0	0.0
20	0.00	4.4	1.3	2.6
40	0.01	4.7	1.5	2.7
60	0.05	4.8	1.5	2.7
100	0.15	5.0	1.5	2.7
140	0.35	5.1	1.6	2.7
180	0.42	5.4	1.6	2.7

Figure 4.3: Settlement of suspended solids with time



thermocouples, was normally measured and recorded on each daily visit using a maximum and minimum thermometer.

Retention tests were carried out every four months, while the neutron probe analysis was carried out monthly during the low loading period and less frequently, every four months, during the high loading period.

4.2.1 CHEMICAL ANALYSIS

4.2.1.1 Oxygen Demand

Three oxygen demand tests were routinely carried out. These were the biochemical oxygen demand (BOD), the permanganate value (PV) and the chemical oxygen demand (COD). All these tests assess the amount of oxygen required to degrade the organic matter found in wastewaters by either biological or chemical oxidation. The results from the various tests are closely correlated due to the varying degree of oxidation in each case. Such correlations are quite reproducible when purely domestic sewage is being tested, but differ considerably for industrial effluents (Water Research Centre, 1978).

Biochemical Oxygen Demand

This is the best known and most widely used measure of sewage strength, and still remains the most important. Originally intended to estimate the likely effect of a particular waste when discharged to a water course, the BOD has now become used to indicate polluting strength of a wastewater before and after treatment. The test is a measure of the amount of dissolved oxygen consumed by aerobic microbial oxidation of a sample over a specified period, usually five days at 20^oC. The biochemical nature of the test makes reproducible results difficult to achieve; standard deviations of 5 - 15% of the mean are common (Water Research Centre, 1978). The oxygen demand recorded depends on the kind of bacteria present, the time for the bacteria to acclimatize, as well as the biodegradability of the waste and whether or not any toxic or inhibitory substances are present. Nevertheless the results for the BOD test proved as reproducible as the other tests employed, having standard deviations within the range of 2 to 8% of the mean.

The standard dilution method for determining the BOD was used (Department of the Environment, 1972). The dissolved oxygen content of the samples was determined before and after incubation; the difference gives the BOD of the samples after allowance has been made for the dilution used. All the effluent samples from the pilot filters were diluted, usually by a factor of 60 for the influent and by a factor of 30 for the others, to ensure that between 30 - 40% of the original dissolved oxygen content was left after incubation. The dilution water was freshly prepared using ammonia-free deionised water containing the recommended reagents (Department of the Environment, 1972). If the dilution water used in the control tests had absorbed more than 500 ugl^{-1} of oxygen after incubation then all the results obtained using that particular dilution water were discarded. The normal range for blank titrations was 210 - 420 ugl^{-1}, and only exceeded the 500 ugl^{-1} maximum once. The samples were diluted and mixed in a 600 cm^3 automatic BOD mixing chamber because the reaction bottles used were not exactly 250 cm^3 in volume. One set of reaction bottles was then incubated in the dark for five days at 20°C; the dissolved oxygen concentrations of each of the replicate bottles were measured immediately.

The dissolved oxygen content was determined using the Alsterberg modification of the Winkler method. Sodium thiosulphate was standardised against iodate monthly. One percent starch glycollate was used as the indicator (Vogel, 1978). Many workers have modified the Winkler's method for use in the BOD test (Bryan, Ripley and Williams, 1976; Rees and Hilton, 1977; Reddy _et al_., 1978), but the titrometric method employed during the present investigation proved the simplest and most reliable of all the available test methods examined. Towards the end of the investigation, a dissolved oxygen electrode* specifically designed with a stirrer to fit into a BOD reaction bottle, was compared with the established Winkler method. Although the electrode method required only one reaction bottle and the advantages of a direct oxygen reading as well as the general cleanliness of the technique and ease with which it could be used proved to be attractive attributes, overall it was not found suitable for the occasional analysis carried out in this investigation. The greatest disadvantage was that it took considerably longer then the chemical method when only a small number of samples were processed. Also because some of the reaction vessels

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*Manufactured by Elecgronic Instruments Ltd, Surrey, England were used only once a month, each vessel had to be laboriously cleaned after use which was not the case when Winkler reagents were used because of the cleansing action of the strong acidified iodine solutions used. The other problems encountered of recalibration, changes in response times and the development of non-linear calibration characteristics with age are now well known (Water Research Centre, 1978b). The dissolved oxygen electrode for BOD reaction vessels is potentially an extremely useful instrument, but at present is still in the development stage.

The respirometric determination of BOD has been reviewed by Montgomery (1967). During the present investigation, a BOD respirometer block was regularly used as a comparison with the standard bottle method. It was also hoped to characterise the various samples by running the respirometers over longer incubation periods than the normal five days.

The E/BOD respirometer* continuously replaces oxygen used in the sample by a manometrically triggered electrolysis reaction. A schematic representation of the cell showing the basic operation of the system is shown in Figure 4.4. When electrolyte in the cell is in contact with the switch electrode, oxygen is not produced at the oxygen electrode. As the oxygen is chemically or biologically removed from the sample, and as any carbon dioxide, which may be released as a metabolic end product is removed from the air space by the potassium hydroxide pellets, a slight vacuum in the air

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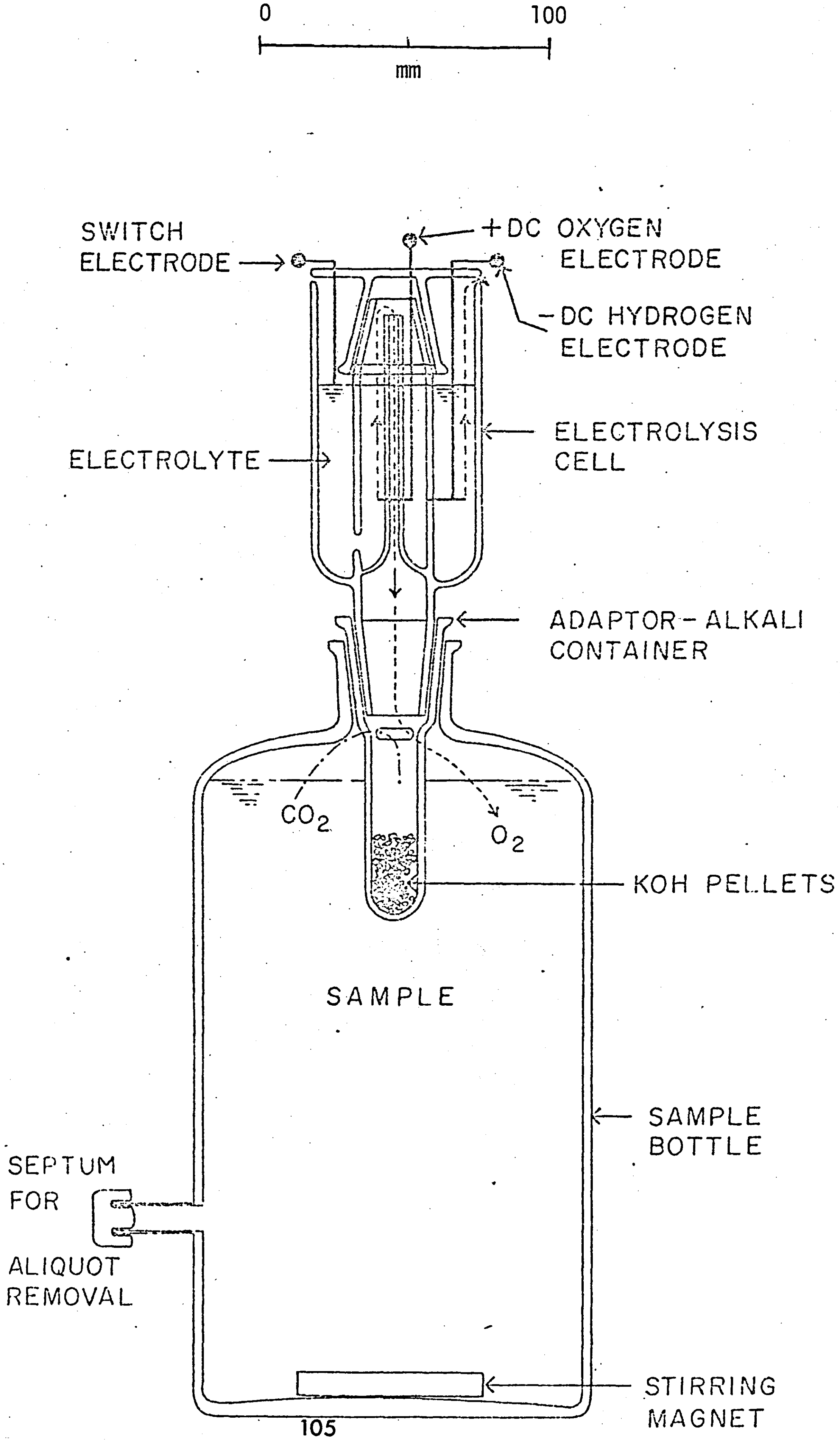
*Manufactured by Analysis Automation Ltd., Oxford, England

Figure 4.4: Schematic diagram showing the basic operation of the electrolysis system for measuring BOD



space is produced. This causes the electrolyte level to rise in the inner tube of the cell; at the same time the electrolyte level falls below the switch electrode. When contact with the switch electrode is broken, oxygen gas is generated to fill the partial vacuum until the electrolyte again makes contact with the switch electrode. When the electrolysis cell is generating oxygen to the sample, the current is monitored electronically, converted to milligrammes of oxygen supplied. This latter value is recorded on a counter.

Although it is simpler and quicker to obtain results using respirometric methods, the results are rarely comparable to those obtained using the bottle method (Tuffey et al., 1974). For example, in undiluted samples the BOD may be suppressed as any toxicity effects may be greater than in diluted samples (Montgomery, 1967). Also, Tebbutt and Berkun (1976) have recorded that biological activity during respirometric BOD tests may be affected by carbon dioxide deficiency. While Morrissette and Mavinic (1978) have shown that the rate of mixing during the test can have profound effects on the BOD value. The respirometric BOD results obtained during the present study are discussed in Chapter 6.

The oxidisable matter contained in sewage effluents chiefly consists of carbonaceous and nitrogenous compounds (Painter et al., 1961). During the BOD test the carbonaceous matter is degraded first and the nitrification of any ammonia present occurs subsequently. The amount of dissolved oxygen absorbed in five days gives only an arbitrary measure of the total carbonaceous BOD of the effluent and takes no account of the nitrogenous oxygen demand. Nitrification can affect the BOD test when partly nitrified effluents are being tested (Department of the Environment, 1971; Stones, 1972, 1976; Gudernatsch, 1977). In the present investigation, high rate filtration has been examined and in general the degree of nitrification has been low, therefore after dilution the effluent samples being tested would normally contain insufficient nitrifying bacteria to have any significant effect within the incubation period. Replicate BOD determinations with the nitrification suppressed by the addition of allylthiourea (Department of the Environment, 1972) to the dilution water were carried out monthly. The oxygen demand exerted by the nitrogenous matter during the BOD determinations carried out in this investigation was only between 1 - 5% of the total oxygen demand. When compared with the standard deviations achieved when testing the reproducibility of the BOD test, the demand for oxygen by the nitrogenous matter is insignificant.

Various workers have reviewed the problems inherent with the BOD test (Hawkes, 1963; Owens and Edwards, 1966; Mongomery, 1967; Stones, 1979). Although Flegal and Schroeder (1976) have tried to reduce the time for the test by increasing the incubation temperature, the 5 day BOD test at 20^{o}C remains a most valid and useful comparative measure of the organic strengths of sewage and treated effluents.

Permanganate Value

This is a measure of the oxygen consumed from acidified N/80 permanganate in 4 hours at 27°C. The test was carried out according to the standard method (Department of the Environment, 1972). As only partial oxidation of the organic and inorganic constituents takes place during the test, precise control is important in order to make the results comparable. Although the test is of limited value (Water Research Centre, 1978), it is extremely useful, not only because it is simple and completed within four hours, but because it also acts as a check for the BOD test and therefore monitors to some extent the total oxygen demand of the effluents under examination.

Chemical Oxygen Demand

An appreciable amount of carbonaceous matter is inert to both the BOD and PV tests and therefore is not revealed. The COD test, however, measures the chemical consumption of oxygen by refluxing the sample for 2 hours at 150°C in acid dichromate solution.

The procedure laid down in 'The Methods for Examination of Waters and Associated Materials' (HMSO, 1977) was used. The problem of chlorides causing positive interferences in the test was occasionally encountered during the winter months, but this was overcome by the addition of mercuric sulphate as catalyst. Due to a lack of time and refluxing equipment, COD determinations were limited in number.

However during the final months of the investigation, greater numbers of COD values were determined using the sealed tube method and a newly acquired Digestion Block*. The sealed tube method (Best and Casseres, 1978) allows large numbers of COD determinations to be carried out under identical conditions, and the results are extremely reproducible with standard deviations within 0.5 to 1.5% of the mean.

The COD test is faster and more reproducible than the BOD or PV tests and is a better measure of the total organic load (Stones, 1974). In the absence of interferences, it gives the value to which the BOD would tend if incubation continued until all the organic matter had been degraded. The COD test is gradually replacing the traditional use of the BOD test, especially in the assessment of levels of industrial pollutants and the cost of treatment charged to industry. (Dart, 1977).

The relationship between BOD, PV and COD is examined in Chapter 6.

4.2.1.2 Ammonia and Oxidised Nitrogen

Biological oxidation of ammonia, derived from the degradation of urea and proteins, to nitrite and nitrate with the subsequent reduction of these oxidation products to gaseous nitrogen, takes place within percolating filters. The degree

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*Manufactured by Grant Instruments (Cambridge) Ltd., Barrington, Cambridge, England.

of nitrification is to some extent a measure of the filter's ability to cope with the organic loading applied to it.

The distillation and titration method for determining the ammonia and total oxidised nitrogen concentrations was used as described by Jenkins (1950a, 1950b). Ammonia is distilled in a Kjeldahl apparatus from the diluted sample made alkaline by the buffer light magnesium oxide and is trapped in boric acid solution. The residue from the determination of ammonia still contains the oxidised nitrogen, present both as nitrate and nitrite, which is reduced to ammonia by the addition of Devarda's alloy and redistillation. The ammonia is collected as before in indicating boric acid solution and determined by titration with standard sulphuric acid.

Much has been written concerning the effect of various buffers during the ammonia distillation. In the U.K. the recommended buffer is light magnesium oxide (Department of the Environment, 1972) while in America the standard buffer is borate (American Public Health Association et al., 1977). Jenkins (1977), reviewing the analysis of nitrogen in fresh and waste waters compared all the available buffers and found that only phosphate and borate buffers exerted satisfactory control, while light magnesium oxide produced high pH values at the end of the distillation which theoretically could decompose the organic nitrogen into ammonia. Careful comparative tests using a sample of known ammonia and total oxidised nitrogen concentrations were carried out in the laboratory to compare the borate and magnesium oxide buffers.

The results obtained showed that the light magnesium oxide was a suitable buffer for this test, and so it was used during the present investigation.

The results obtained for concentrations of ammonia in excess of 1 mgl^{-1} have been very reproducible although concentrations of less than this were more erratic. The ammonia concentration in water samples will change when stored for any length of time. Verstrate and Alexander (1973) reported changes in the ammonia concentration due to heterotrophic nitrification. The effects of storage on the concentration of ammonia in sewage samples was recently reviewed by Riemann and Schierup (1978) who compared the effects of preserving ammonia in solution using mercuric chloride and sulphuric acid. In the present investigation, if samples had to be kept for ammonia analysis on the day after collection, the samples were stored at 4°C. Samples stored in this way retained their original ammonia concentration. If storage for periods longer than overnight was necessary, samples were fixed using concentrated sulphuric acid (Unesco, 1978).

In the recent harmonised monitoring scheme run by the Department of the Environment, the distillation method for the analysis of ammonia and total oxidised nitrogen was shown to produce accurate and reproducible results (Water Research Centre, 1977, 1977b).

Originally it was hoped to monitor ammonia and nitrate concentrations in the samples by using ion-selective electrodes. The ammonia probe used was (Model 8002-2) developed by Electronic Instruments Ltd.* to measure the ammonia concentrations in solution while the nitrate probe (Model 92-07) was a liquid membrane electrode developed by Orion Research Inc.**. Neither of the probes proved satisfactory, requiring constant recalibration, a problem also encountered by Ip and Pilkington (1978). The samples were often at different temperatures and drift was encountered at these different temperatures, a characteristic which is discussed fully by O'Herron (1977). There was poor correlation between the results from the electrode and the distillation method, and therefore the instrumental system was abandoned in favour of the chemical method.

4.2.1.3 Chloride

The sewage works at Treeton received road runoff from the nearby motorway and therefore during the winter salting operations the chloride concentration in the samples increased considerably.

Two methods were employed to measure the chloride ion content of the samples, an ion-selective electrode and determination by titration with mercuric nitrate. The Orion (407A) specific ion meter with a chloride ion electrode were used for routine samples and for the determination of chloride during the initial retention tests carried out on the pilot filters (Section 4.2.4). The electrode method did not produce reproducible results; during periods of use in excess of one hour, large drifts were recorded and the

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*Electronic Instruments Ltd., Surrey, England
**Orion Research Inc., Cambridge, Massachusetts, U.S.A.

instrument required recalibration. Its use was discontinued early in the investigation.

In the titration method which was used regularly on all the samples and in the retention test, the mercuric ions react with the chloride ions to form a highly stable and soluble complex. The end point is detected by the use of diphenyl/carbazone as an indicator which forms a blue-violet complex with an excess of mercuric ions (Vogel, 1978).

4.2.1.4 pH

Wescott (1978) evaluating the relative merits of pH meters found that the best instrument was a digital rather than an analog instrument. A digital pH meter* with a manual temperature control was used in conjunction with a combination pH electrode with an internal silver-silver chloride reference cell. To prevent dissolution of the silver chloride film, the normal potassium chloride filling solution used for the electrodes was saturated with silver chloride.

4.2.1.5 Suspended Solids

Suspended solids are discrete particles in suspension ranging from those which are easily settleable to the colloidal. Traditionally one of the most important wastewater parameters, suspended solids is largely removed by efficient sewage treatment.

The filtration method was used to determine the suspended

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*Model 102D, manufactured by Ecologic Instruments Inc., Bohemia, New York, U.S.A.

solids of both the influent and effluent samples (Department of the Environment, 1972). Melbourne (1964) showed that better reproducibility was possible if the papers were washed prior to use to remove any loose fibres, and if they were used smooth side uppermost. Whatman GF/C filter papers were used because of their high retentiveness, retaining particles larger than 1.2um, and also greater stability during washing. The papers were dried for two hours at 105°C and allowed to cool in air for five minutes before weighing. Normally 50 cm^3 of the sewage samples were used.

The paper quality and the method were checked at frequent intervals by using macerated glass fibre filter papers in suspension as a standard for the test (Croft, 1978). It was found from these standardisation experiments that although the filter papers have a high wet strength, it was best to use low vacuum pressure to avoid damaging the paper, and thereby altering its weight while filtering the samples.

The results are expressed in milligrammes of total suspended solids per litre of sample.

4.2.1.6 Settleable Solids

A measure of the settleable solids by volume in the influent and final effluents were regularly made using one litre Imhoff cones (Department of the Environment, 1972). The settling rate was also recorded by plotting settlement against time.

Monthly determinations of the weight of solids that settled from all the samples were made by measuring the total suspended solids, by the filtration method (Section 4.2.1.5), in samples before and after settlement.

4.2.1.7 Turbidity

The turbidity of the settled samples was made routinely using an Ecologic Instruments 104 Turbidimeter*.

Fresh standards for calibrations of the turbidimeter were prepared for each sampling period using stock solutions of hexamethylenetetramine and hydrazine sulphate (Department of the Environment, 1972). Turbidity is measured in formazin turbidity units (F.T.U.).

4.2.1.7 Conductivity

The electrical conductivity of a liquid is related to the concentration of dissolved mineral salts.

The conductivity meter** used had a range of 1 $uScm^{-1}$ - 300 $mScm^{-1}$. The glass cell used with the meter had a scale correction resistor so that the true conductivity was read directly from the instrument. The meter was calibrated using standard solutions of potassium chloride at 25^oC (Allen, 1974). Conductivity is measured in micro-siemen $uScm^{-1}$.

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*Ecologic Instruments Inc., Bohemia, New York, U.S.A.

**Model P335, manufactured by Portland Electronics, Surrey, England.

Conductivity measurements were regularly used to estimate the chloride concentration in the effluents from the pilot filters during the retention tests (Section 4.2.4). The relationship between conductivity and chloride was established by plotting a calibration curve, using standard solutions of chloride. The calibration curve, Figure 4.5, was used to convert all the conductivity results into chloride values.

4.2.2 NEUTRON SCATTERING

The accumulation of film within a filter sets a limit to the loading which can be imposed upon it. Therefore, regular observation of the film is extremely important if maximum operational control of the filters is to be maintained.

The amount of biological film retained in the filters was determined both gravimetrically (discussed in Section 4.1.2) and by the neutron scattering technique (Harvey, Eden and Mitchell, 1963).

Two aluminium access tubes were fitted into each pilot filter during construction and these allowed the neutron probe to be lowered to any depth within the filters.
Once the access tubes had been fitted there was no further disturbance to the medium in that region of the filter, and so it was possible to monitor the changes in film accumulation over the experimental period without disturbing or damaging the film itself.

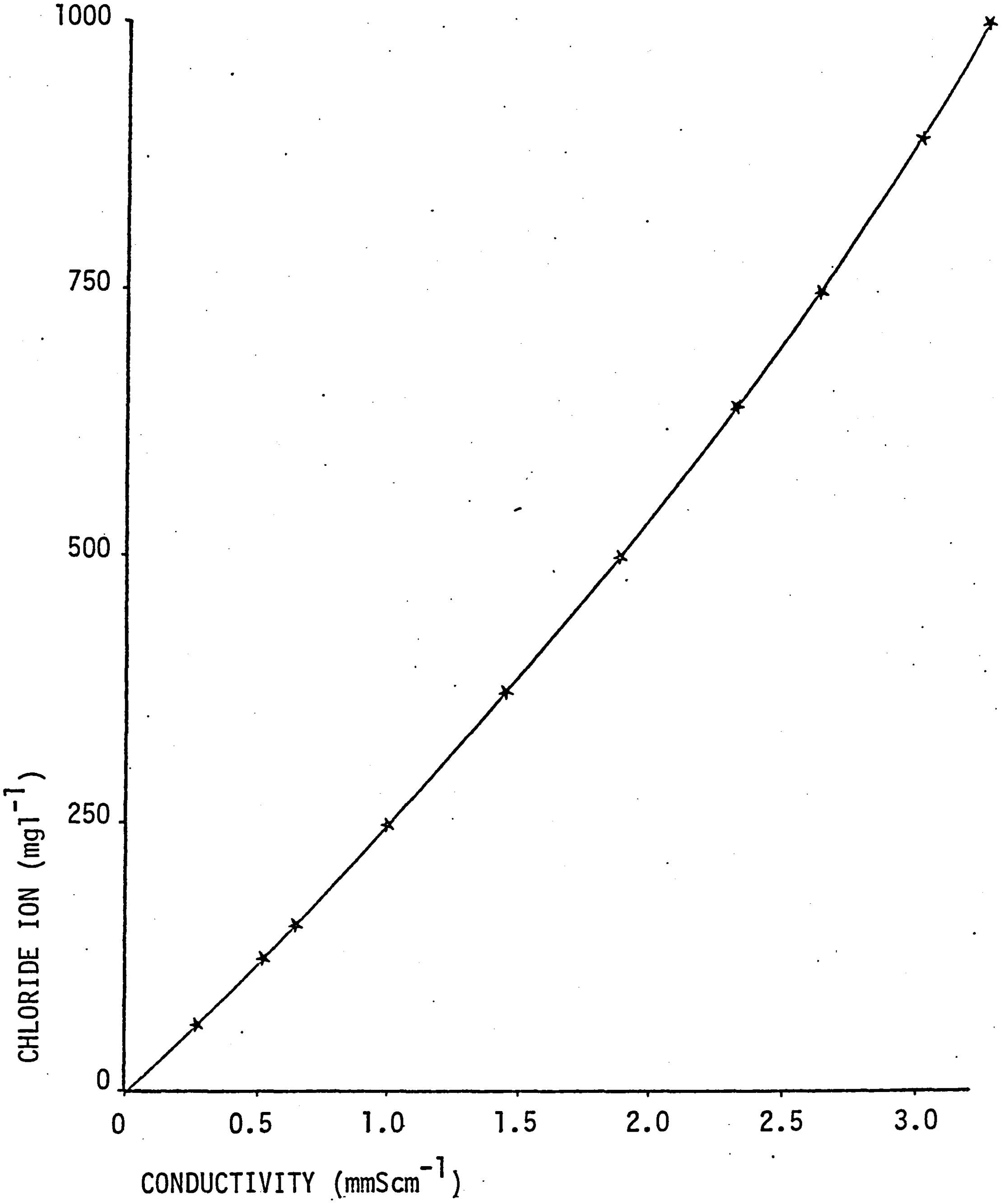
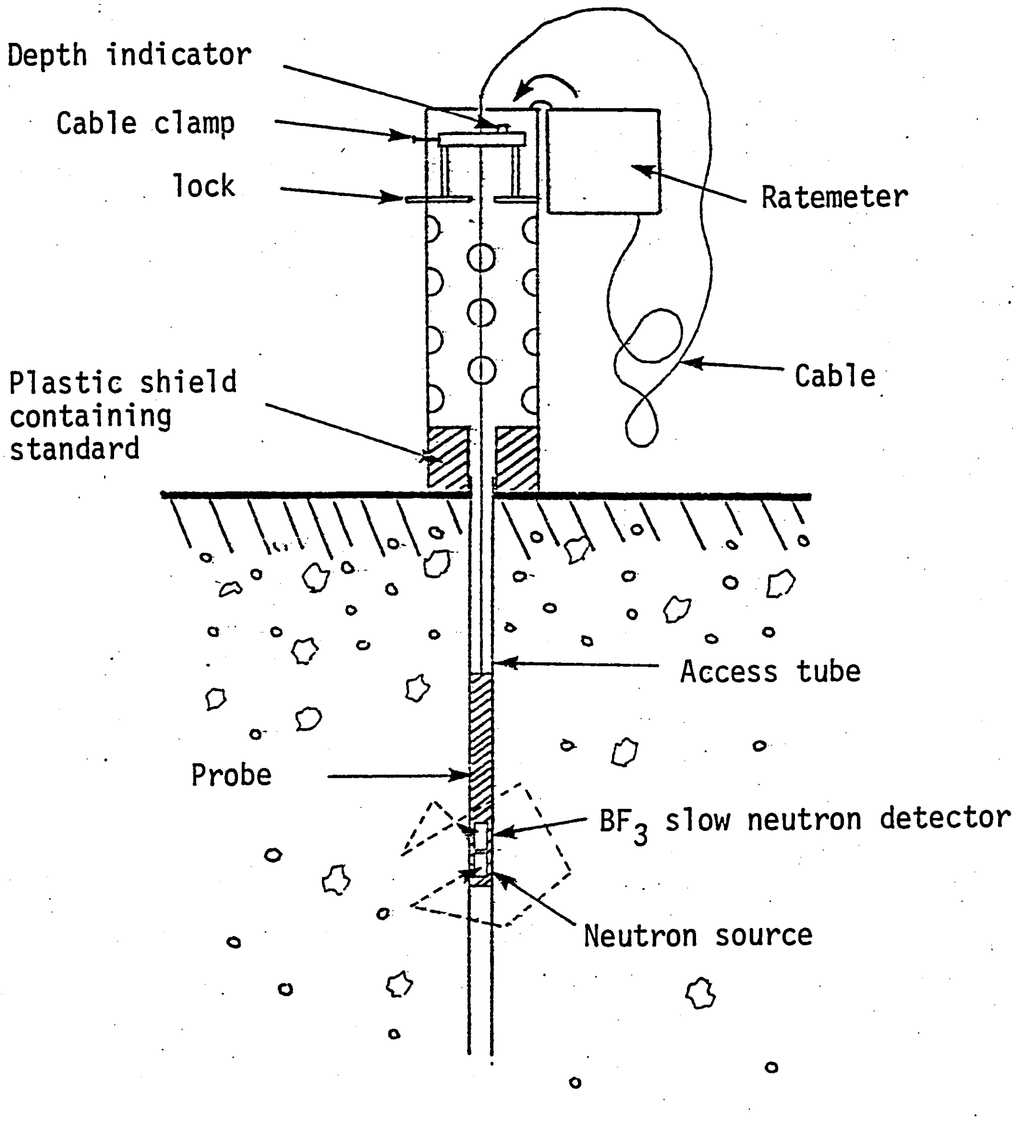


Figure 4.5: Conductivity-chloride calibration curve

The neutron probe, which is in fact a Wallingford soil moisture probe of the type described by Burn (1961), measures the abundance of hydrogen ions. The probe incorporates a sealed radio-active isotope, Figure 4.6, which is a source of fast neutrons. A 'cloud' of slow neutrons is formed when fast neutrons collide with hydrogen atoms, and a detector within the probe detects slow neutrons reflected by the hydrogen atoms in any water present (Bell, 1973). As the filter medium itself is devoid of any hydrogen, it is possible, once all the excess water is drained out of each filter by shutting down the distribution system, to regard the hydrogen content as being equivalent to the amount of film present (film is approximately 96% water).

The probe was calibrated by filling drums with a capacity of 210 litres, with the two different types of medium used in the pilot filters. The large size of the drums prevented any interference from the sides of the drums if the access tubes were centrally placed. The emitted neutrons can only travel about 150mm from the source in saturated conditions and 300mm at 10% saturation, so that the overall diameter of the drums had to be at least 750mm. The instrument was calibrated by measuring the scattering at 0% and 100% saturation, and the plotted calibration curves are shown in Figure 4.7. The calibration results illustrate a marked difference between the calibrations obtained for the two different types of medium. Therefore, the appropriate calibration curve had to be used when converting the probe readings into percentage saturation of the voids. Particular care had to be taken in the mixed media filter to locate the

Figure 4.6: Diagram of neutron probe in use.



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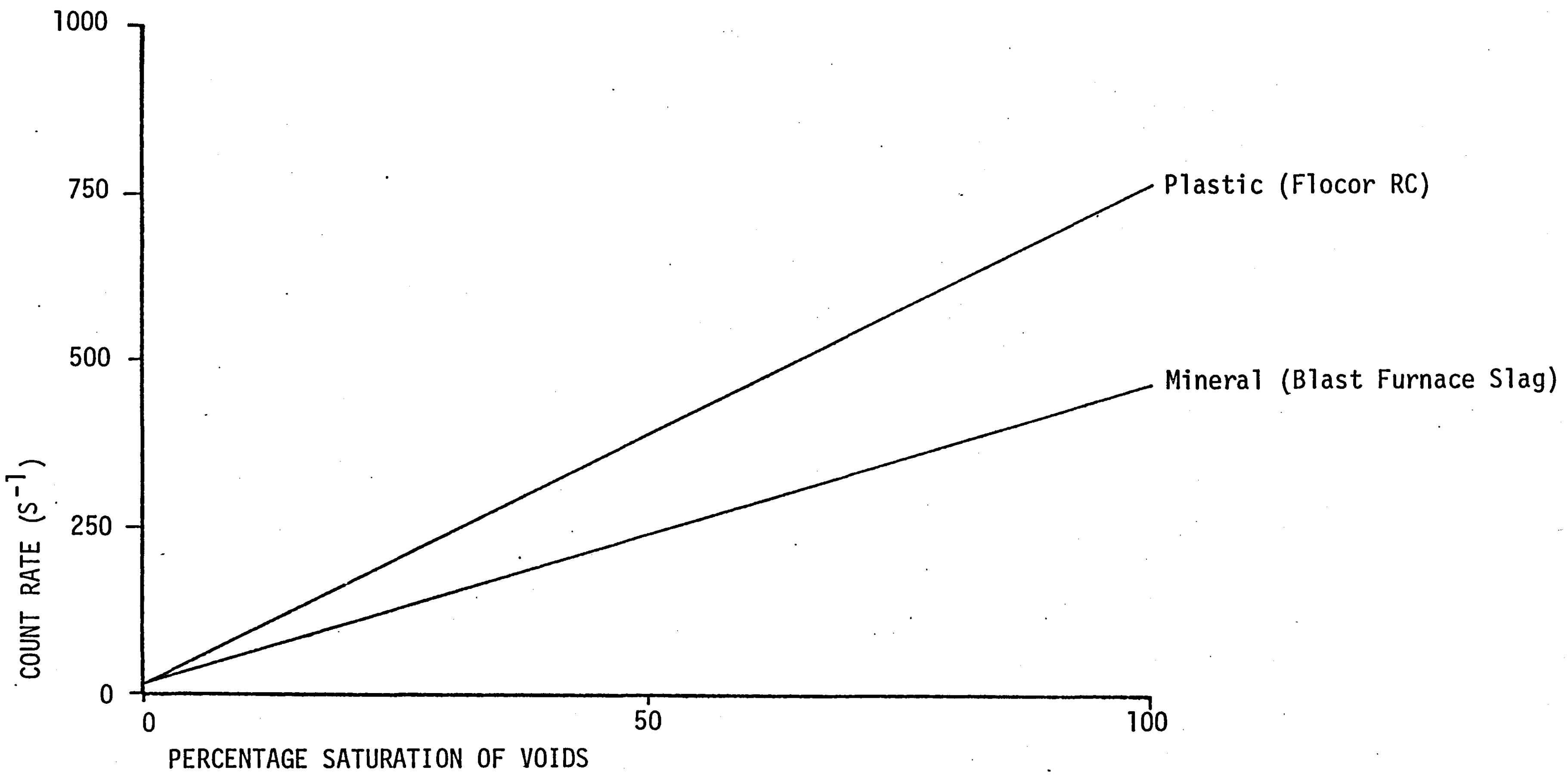


Figure 4.7: Calibration curves for the neutron probe using the plastic and mineral medium.

interface accurately before conversion of the data.

The principle and method of this technique is discussed by Bell (1973), and its use to estimate the film accumulation in percolating filters examined by Harvey, Eden and Mitchell (1963).

Five readings were taken every 200mm in both the access tubes of each filter. Each reading shown on the digital counter of the probe was a mean count per second integrated over a 16 second sample period. The replicate access tubes allowed the film accumulation to be studied from either side of the filters, although a mean of the two average readings at each depth was taken to represent the mean percentage saturation of the voids. A background count was made when the probe was being used and this value was deducted from the data obtained from the filters before the percentage saturation of the voids was calculated from the calibration curves.

Problems were encountered with surface interference and it was generally found that the first 200mm reading was subject to error. Experiments carried out using the calibration drum found that interference from the surface was negligible at depths below 300mm.

The probe was used every month during the low rate loading of the pilot filters, usually the day before the biosampling and the gravimetric determinations of the film weight were made. In this way it was possible to compare directly the neutron scattering results with both the total film weight and the total and volatile solids values. Retention tests were also carried out at this time. All these results are discussed in Chapter 6. During the high rate phase of the investigation when the filters were loaded at 3.37 $m^3m^{-3}d^{-1}$, the use of the neutron probe was reduced to once every four months. This was to enable more time to be spent analysing the biological data but at the same time still obtaining information concerning the seasonal variation in the film accumulation as measured by the neutron scattering technique. This technique produced reproducible results and was quick and relatively easy to use. It has been widely used to estimate the film accumulation in filter beds and is now widely accepted (Bruce _et_ _al_., 1967).

4.2.3 TEMPERATURE

The temperature within the filters is extremely important because it controls the rate of microbial oxidation and therefore is related to the performance of the filters. The temperatures of the influent and final effluents were measured using a mercury in glass thermometer with a range of -10 to +30°C, whenever samples were collected for analysis. Thermocouples, copper-constantan (Cu/con) type, were fixed to the distributors and to the effluent drains so that any relationship between the influent and the final effluent temperatures for each pilot filter could be monitored with the use of a thermocouple scanner.

A maximum and minimum thermometer was positioned on the central filter and the temperature range was recorded daily. As described in Chapter 3, each pilot filter contained three cores of thermocouples, one core down the centre of the filter, another against the outer wall and the third positioned between the two. The latter was against one of the columns which encased the sampling baskets. Each core contained six thermocouple junctions which were positioned to coincide with the centre of each sampling basket. By positioning the thermocouples in this way, a temperature profile of each filter could be obtained enabling the temperature to be directly related to the fauna within the pilot filter.

4.2.4 RETENTION TIME ANALYSIS

The longer there is intimate contact between the sewage and the active film then the better the final effluent quality. Therefore, the duration of liquid retention within the filter is an extremely important and useful parameter.

Traditionally, retention time is determined by a tracer technique, although tracers can only measure their own retention and not necessarily the retention characteristics of waste liquids (Eden _et al_., 1964). Originally dyes, salt solutions or ammonium salts were used (Tomlinson and Hall, 1950), but these often suffered from prolonged retention due to adsorption onto the film. In the late 1950's however, experiments with radioactive tracers, showed them to be ideal for retention analysis. This was because (a) only small quantities of such tracers are required, (b) of the ease and sensitivity of detection, and (c) the negligible tendency of some of the radioactive substances to be adsorbed onto the film (Eden and Melbourne, 1960; Eden _et al._, 1964).

Since that time most of the research on retention time has involved the use of radioactive tracers (Sheikh, 1970; Kshirsagar _et al._, 1972) although Tariq (1975) published a method to calculate the mean time of retention by measuring the influent and drainage rates. The main problem with Tariq's method was that the filter had to be shut down in order to measure drainage characteristics. In the present investigation, the problems of obtaining permission to use radioactive tracers, arranging for tracers, detection and handling equipment and organising technical assistance trained in handling radioactive material on a suitable day for the test to be run, and also the cost of such an operation, proved insurmountable. After careful examination of the available non-radioactive tracers, it was decided that sodium chloride should be used, as the adsorption rate of chloride by the film appeared to be relatively constant, especially over a short period. A saturated solution of 300 gl^{-1} of sodium chloride was used.

The concentration of chloride in the influent was monitored regularly throughout the experiment, and before the tracer was added to each filter the final effluent was sampled and the chloride level determined over a ten minute period. The difference between the two values was used as a correction factor for all the chloride levels recorded in the influent samples during the experiment. 450 cm^3 of the tracer was added to each filter by filling the pipework. Perfect distribution onto the surface was obtained by increasing the pressure within the pipework before opening the top valve. The time taken to drain and refill the pipework with the tracer took only between one and two minutes and therefore the filters were only non-operational for a very short time. As soon as the influent and tracer began to flow onto the bed, a stop-watch was started and sampling began. 125 cm^3 samples were taken every minute for the first ten minutes, in case some of the sewage was short circuiting through the filter, and then every five minutes for the next eighty minutes. After this time, effluent samples were taken at thirty minute intervals until the chloride concentration had returned to normal. The corrected concentration of chloride in the influent was subtracted from all the effluent results so that only the chloride originating from the tracer was recorded.

During the first retention test experiments, three methods of analysing the chloride present were compared; these were by titration with mercuric nitrate, by ion-selective electrode and also by conductivity (Sections 4.2.1.3 and 4.2.1.8). Figures 4.8 and 4.9 clearly show that a good correlation existed between the chloride concentrations determined by titration and the conductivity. But a poor correlation existed between the titration and ion-selective methods, Figure 4.10. The problems using the chloride

Figure 4.8: Computed correlation between chloride concentrations in the final effluents recorded by titration and derived from conductivity measurements.

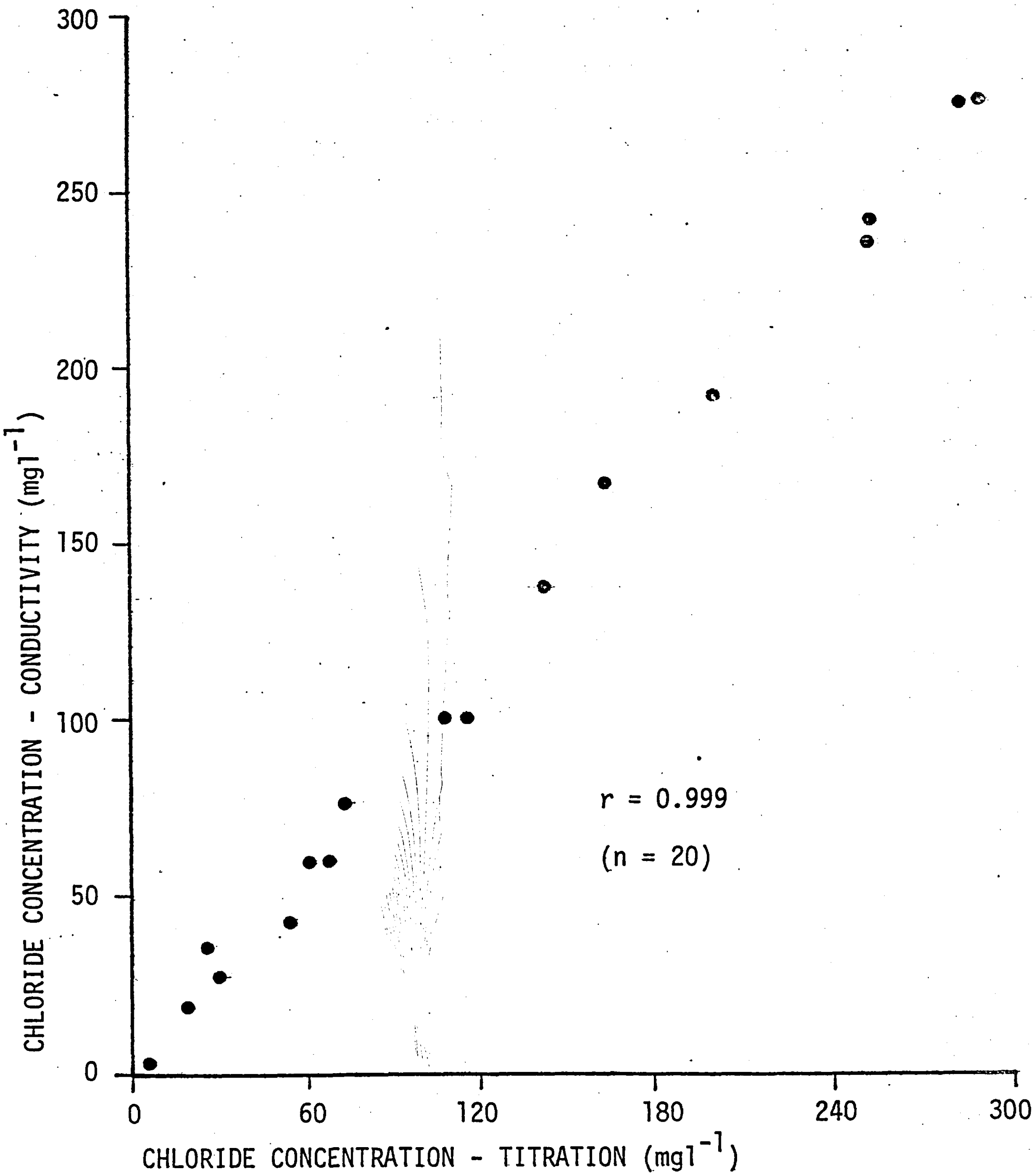


Figure 4.9: Computed correlation between chloride concentration in final effluents recorded by two different methods, conductivity and titration

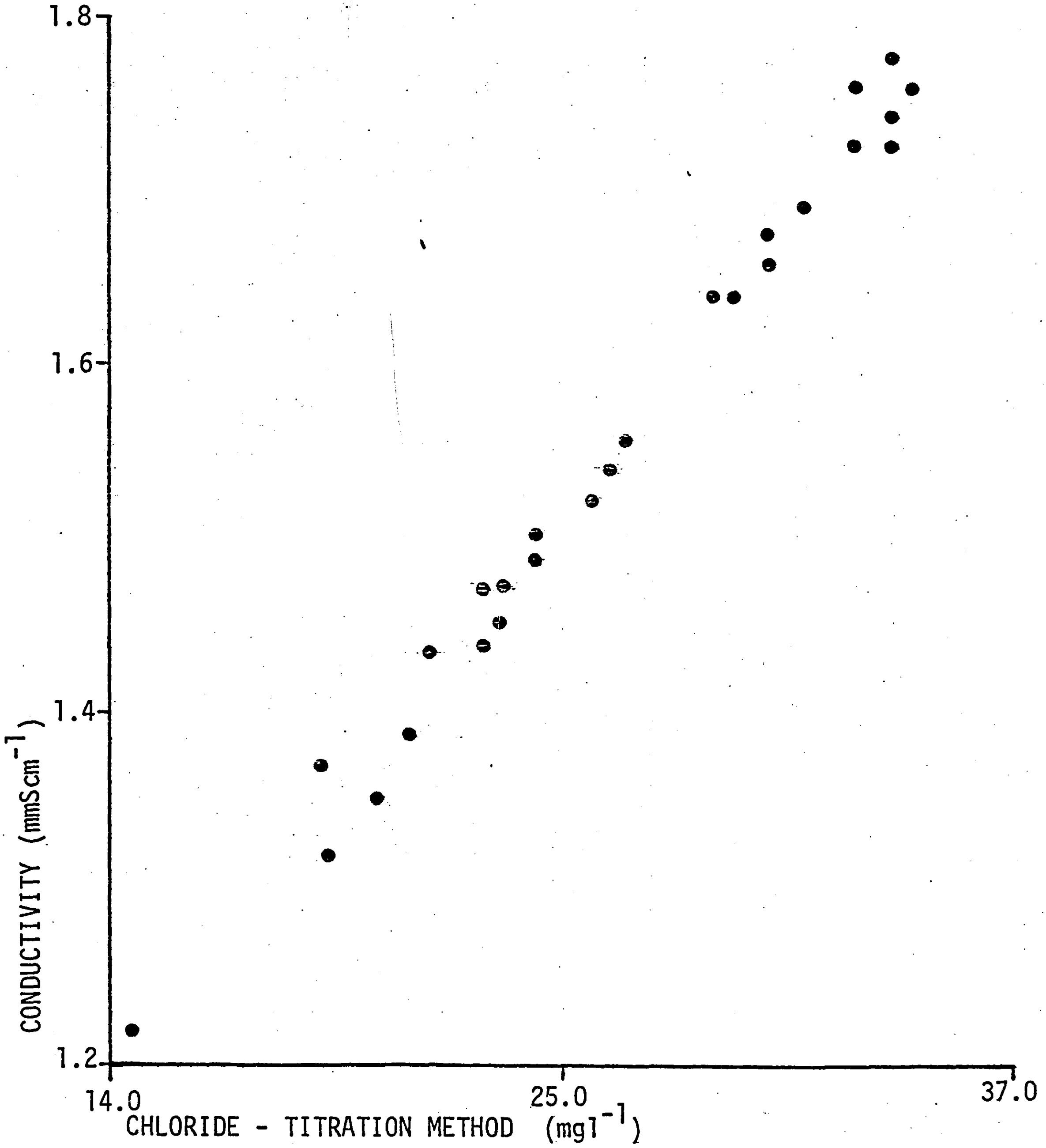
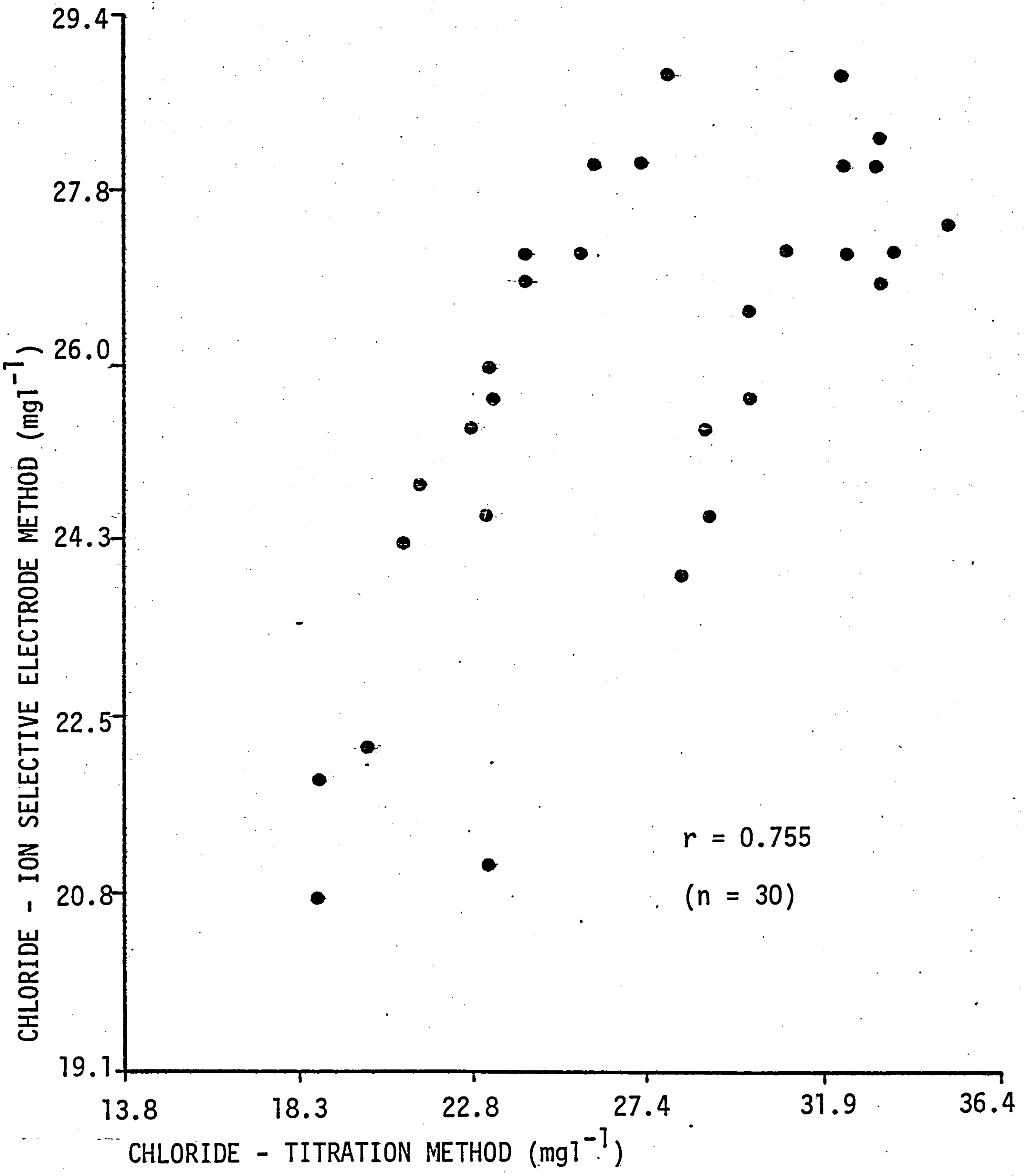


Figure 4.10: Computed correlation between chloride concentration in the effluents recorded by two different methods, titration and ion-selective electrode.



ion electrode and meter have already been discussed in Section 4.2.1.3, these being drift and possibly interference caused by other ions present.

The method finally adopted to measure the chloride concentrations during these tests was the conductivity cell and meter, because it was possible for all the retention tests on the pilot plant to be carried out by one person in a single day. It was also a simple method of negligible cost, extremely quick, produced reproducible results and without risk of contamination by radiation to either the operator or the environment. In order to monitor the results derived from the chloride-conductivity calibration curve (Figure 4.7) occasional titrations were carried out during the tests to check the chloride concentrations and in all cases, good correlations between the two were achieved.

Lawton and Eggert (1957) examined the effect of high concentrations of sodium chloride on filter film, and discovered that the film suffers shock effects when wastes with a high concentration of salt are applied to them. However, although very big concentrations of this tracer were used, it was only a pulse load of 450cm^3 and the salt was rapidly diluted within the filter. Twice during retention tests, all the final effluent samples were retained and examined back at the laboratory to see if the high sodium chloride levels had affected the filter organisms. There was no increase in the number of organisms washed out from the filters and the Protozoa and other microfauna appeared to be as active as though under normal operating conditions.

Because of the ease and the simplicity of the test and its negligible effect on the filter bed ecosystem, retention tests were carried out whenever it was thought they would provide useful information, for example at times of bad performance, when the film accumulation was greatest and immediately after sloughing.

The analysis of the results is described and discussed in Chapter 6.

4.3 MATHEMATICAL AND STATISTICAL ANALYSES

The aim of these analyses was the understanding of the interrelationships between the individual species, faunal groups and the various environmental parameters measured in the three pilot filters.

The correlation coefficient was used as an index of the degree of association between variables and it was assumed that all the pairs of data tested in this way approximately conformed to a bivariate normal distribution. All the pairs of data tested were plotted on scatter diagrams, and the dispersion of the data examined for other possible non-linear relationships.

Linear regression analysis was carried out on the chemical data, and the value of one variable was measured in terms of the associated variable in the form of $y = a + bx$. Regression lines were plotted and these exhibited the linear regression of y on x, the slope of the line being the regression coefficient of y on x which is the average amount y increases for a unit increase of x (Parker, 1973; Bailey, 1979).

The significance of observed differences during specific loading periods were assessed by using the 'one tailed' t-test. When the level of significance was less than 10% ($p < 0.10$), then the null hypothesis was rejected and a significant difference recorded (Elliott, 1977).

All the raw chemical data were recorded directly onto computer files. Means, standard deviations, standard error of means, maxima, minima and ranges were calculated for all variables, using all the recorded data from each filter during each particular loading. The regression analysis was also calculated using all the available data. Monthly means were determined and used in the correlation analysis with the other environmental and biological data. All the biological and solids measurements from the various depths sampled in each filter were used to calculate the mean number of individuals per litre of medium for each month. For each loading period the means, standard deviations, standard errors of means, maxima, minima and ranges were calculated for all variables, using these monthly means. Correlation analysis and the t-test were calculated using the monthly means, and matrices of the correlation coefficients constructed. All the daily temperature records were used to determine the monthly and annual means, maxima, minima and ranges of ambient filter, influent and final effluent temperatures.

5.1 INTRODUCTION

The ecology of the percolating filter has been widely discussed and reviewed by previous workers (Holtje, 1943; Hawkes, 1963; Shephard; 1967; Hussey, 1975; Wheatley, 1976), and the role of the individual groups involved in the process has been fully examined in a recent review by Curds and Hawkes (1975).

The function of this chapter is to examine and discuss the results of the present investigation in relation to previous research, and to assess the effect on the filter ecosystem of replacing the surface medium of a slag filter with a 750mm layer of plastic medium.
For convenience, the animals were split into two groups for examination (Section 4.1), the microfauna and the macrofauna. The microfauna consist of the Bacteria, Fungi, Algae, Protozoa, Rotifera and the Nematoda. Population densities relating to the microfauna are expressed in the text as the total number of individuals per 3.6×10^{-6} litre.
However, when not used in the text (e.g. when plotted on the vertical distribution graphs) the microfauna and the macrofauna are expressed as the total number of individuals per cubic metre of medium. The macrofauna consist of the Annelida, Insecta, Arachnida and Crustacea. A few other invertebrates which were recorded occasionally in the pilot filters are also included in this group. All the macrofauna are expressed as the total number of individuals per litre of medium. The biological results are given in full in Appendix II.

A considerable amount of attention is paid to the Protozoa in this chapter (Section 5.5) because (a) it was the group with most species and (b) the group was better than the others in reflecting the environmental and subsequent biological changes.

The results span two consecutive experimental periods; the first was of twelve months when all the filters received the lower loading of 1.68 $m^3m^{-3}d^{-1}$ which was equivalent to an organic loading of 0.28 kg BOD $m^{-3}d^{-1}$. The second period spanned a further eleven months, and the loading to the filters was doubled to 3.37 $m^3m^{-3}d^{-1}$, equivalent to an organic loading of 0.63 kg BOD $m^{-3}d^{-1}$, which is referred to in the text as the higher rate of loading. It has also been convenient to classify the film accumulation into three categories, light (< 5 kgm^{-3}), moderate (5 - 8 kgm^{-3}) and heavy weights (> 8 kgm^{-3}). A summary of the correlation analysis for each major species is normally given in the text and where necessary, the level of significance of the correlation is given in brackets. The angle of the slope is indicated by +(positive) or -(negative), and the level of significance is given numerically as 1. ($P < 0.05$ = significant), 2. ($P < 0.01$ = highly significant) and 3. ($P < 0.001$ = very highly significant).

In the present investigation, a total of 69 different species (including unidentified species) were recorded; a full list of all the species appears in Table 5.1. The mean species diversity for each filter at both loading rates is compared in Table 5.2 below. At both loading rates the greatest

TABLE 5.1: List of species recorded from the pilot filters

BACTERIA
Zoogloeal forms, mainly *Zoogloeal ramigera*
Sphaerotilus sp.
Leptothrix sp.
Beggiatoa sp.

FUNGI
Subbaromyces splendens Hesseltine
Sepedonium sp.
Fusarium aquaeductuum (Radimacher and Rabenhorst) Saccardo
Geotrichum Candidum Link

ALGAE
Chlorella sp.
Scenedesmus sp.
Stigeoclonium sp.

PROTOZOA: SARCOMASTIGOPHORA

Bodo sp.
Amoeba sp. mainly *Amoeba radiosa* Ehrenberg
Euglena sp.

PROTOZOA: CILIOPHORA
(Holotrichia)
Trachelophyllum pusillum Perty-Claparède and Lachmann
Hemiophrys fusidens Kahl
Hemiophrys pleurosigma Stokes
Chilodonella cucullulus (Müller)
Chilodonella uncinata Ehrenberg
Colpoda cucullus Müller
Uronema nigricans (Müller) Florentin
Glaucoma scintillans Ehrenberg
Colpidium colpoda Stein
Colpidium campylum (Stokes)
Paramecium aurelia Ehrenberg
Paramecium caudatum Ehrenberg

(Peritrichia)
Vorticella microstoma Ehrenberg
Vorticella convallaria Linnaeus
Vorticella vernalis Stokes
Opercularia minima Kahl
Opercularia microdiscum Faure-Fremiet
Opercularia coarctata Claparède and Lachmann
Epistylis rotans Svec

(Spirotrichia)
Stentor roeseli Ehrenberg
Aspidisca costata (Dujardin) = *cicada*
Tachysoma pellionella (Müller-Stein)
Oxytricha ludibunda Stokes

Table 5.1 (contd)

(Suctoria)
Acineta cuspidata Stokes
Acineta foetida Maupas
Podophrya maupasi Bütschli
Podophrya carchesii Claparède and Lachmann
Podophrya mollis Bütschli
Sphaerophrya magna Maupas

NEMATODA

ROTIFERA

(Bdelloidea)
Philodina roseola Ehrb.

(Monogononta)
Lecane sp.
Dicranophorus sp.

ANNELIDA

(Oligochaeta)

Enchytraeidae
  Enchytraeus buchholzi Vejdovsky
  Lumbricillus rivalis Levinsen

Lumbricidae
  Dendrobaena rubida (Sav.) *f. Subrubicunda* (Eisen)
  Eiseniella tetraedra (Savigny)

INSECTA

(Collembola)

Isotomidae
  Isotoma olivacea-violacea gp.

(Coleoptera)
Hydrophilidae
  Cercyon ustulatus (Prey.)

Staphylinidae
  Unidentified sp.

(Diptera)
Anisopodidae
  Sylvicola fenestralis (Scop.)

Psychodidae
  Psychoda alternata Say.
  Psychoda severini Tonn.

Table 5.1 (contd)

Chironomidae
Hydrobaenus minimus Mg.
Hydrobaenus perennis Mg.
Metriocnemus hygropetricus Kieff.

Ephydridae
Scatella silacea Lw

Sphaeroceridae
Leptocera sp.

Cordyluridae
Spathiophora hydromyzina Fall.

(Chilopoda)
Lithobius forficatus Linn.

CRUSTACEA
(Cyclopoida)

Cyclopidae
Paracyclops fimbriatus-chiltoni (Thomson)

ARACHNIDA
(Acari)

Acaridae
Histiostoma carpio (Kramer)
Rhizoglyphus echinopus (Fumouze and Robin)

Anoelidae
Histiostoma feroniarum (Dufour)

Ascidae
Platyseius italicus (Bertese)

(Araneida)
Linyphiidae
Unidentified sp.

MOLLUSCA
(Gastropoda)

Limacidae
Agriolimax reticulatus (Müll.)

Table 5.2: Mean monthly species richness at different loadings. (Figure is mean number of identified species)

	SLAG FILTER	
	LOW RATE	HIGH RATE
Microfauna	13.50	16.82
Macrofauna	9.67	8.63
Total species diversity	23.17	25.45
Range	17 (14-31)	15 (20-35)
No. of months sampled	12	11

	MIXED FILTER	
	LOW RATE	HIGH RATE
Microfauna	17.00	16.91
Macrofauna	10.58	10.46
Total species diversity	27.58	27.37
Range	12 (23-35)	20 (18-38)
No. of months sampled	12	11

	PLASTIC FILTER	
	LOW RATE	HIGH RATE
Microfauna	14.83	15.00
Macrofauna	12.00	11.09
Total species diversity	26.83	26.09
Range	17 (20-37)	18 (18-36)
No. of months sampled	12	11

diversity was recorded in the mixed filter. At the lower rate, this filter had a greater number of species of microfauna than either the slag or plastic filters. Although the increased loading resulted in an increase in the species richness of the slag filter, it remained relatively constant in both the mixed and plastic filters, Table 5.2.

5.1.1 HORIZONTAL DISTRIBUTION

The horizontal distribution in the top 300mm of the pilot filters was monitored every two months by the provision of three extra sampling baskets sunk into the surface of each filter (Section 3.3.3). A complete biological and solids analysis was carried out on the four surface baskets in each filter. The baskets were coded R, C, L, and 1, the latter being the top basket of the sampling column, with the prefix S, M or P for the slag, mixed and plastic filters respectively.

The results of the horizontal distribution is given in full in Appendix II. All the available data from each filter were collated and the bimonthly abundance in the surface baskets determined. The data for all the baskets in each filter were compared at either loading by using the t-test; and the significance of the differences calculated. The computed t-values were generally very small with only eight significant differences being recorded from all the filters at either loading and all the biological groups measured. Only four of these significant differences recorded were at the 5% significant level or less (Table 5.3). No significant differences were recorded between the horizontal distribution and any of the biological organisms in the plastic filter. The differences that were recorded were in three

Table 5.3: Significant differences in horizontal distribution in the top 300mm of the biological groups and species measured. The level of significance is expressed as the value of P between the four surface baskets in each filter.

	LOW LOADING ($1.68m^3m^3d^1$)	Value of P	HIGH LOADING ($3.37m^3m^3d^1$)	Value of P
Subbaromyces splendens	MC v Ml ML v Ml	0.05 0.05	ML v Ml SC v SL	0.10 0.10
Zoogloeal bacteria			SR v SL SL v Sl	0.05 0.10
Enchytraeidae	SR v Sl SC v Sl	0.10 0.01		

animal groups only, the Zoogloeal bacteria, the fungus *Subbaromyces splendens* and the Enchytraeidae. No significant differences in horizontal distribution were recorded in the majority of biological groups examined, including the Psychodid larvae and astigmatid mites. The number of significant differences recorded were very small and isolated, therefore it was concluded that the results obtained in the sampling columns were also representative of the whole filter, at least in the top 300mm of the filter.

5.2 BACTERIA

The basic trophic level found in percolating filters is composed of aerobic bacteria which constitute the major proportion of the active biomass. These bacteria are predominantly saprophytic; however, a number of autotrophs are also found, e.g. Nitrosomonas and Nitrobacter which oxidise ammonia and nitrite respectively. The rapid exchange of nutrients and catabolites between the aerobic bacteria and the influent sewage, in which they are suspended, is due to their high surface area to volume ratio. This, coupled with their potentially fast doubling rates (Maynard-Smith, 1969), indicates how effective the aerobic bacteria are at oxidising the organic matter which has been adsorbed onto the structure of the film.

The bacterial flora in percolating filters is similar to that found in activated sludge, the dominant aerobic genera being the gram negative rods, Zoogloea, Pseudomonas, Achromobacter, Alcaligens and Flavobacterium (James, 1964; Harkness, 1966; Pike and Carrington, 1972).

5.2.1 ZOOGLOEAL BACTERIA

The zoogloeal forms of bacteria were the most commonly recorded microorganism, being found every month in each filter (Plate 5.1). Zoogloeal bacteria are widely associated with sewage treatment, in particular with percolating filters

PLATE 5.1: Zoogloeal bacteria.
(X500)

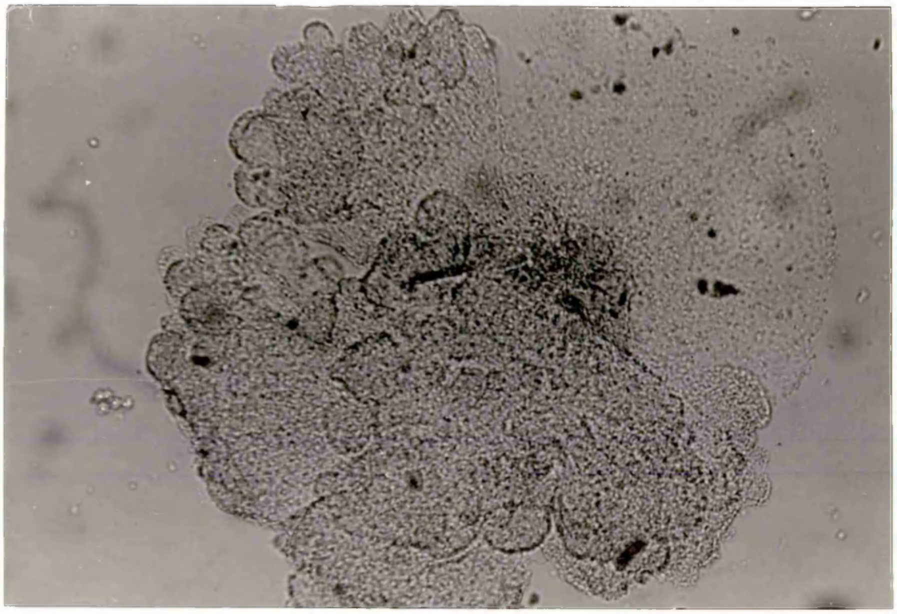


PLATE 5.2: Surface growth of the fungus *Subbaromyces splendens* on the plastic filter medium.
(X0.5)

(James, 1964; Bruce et al., 1970; Hussey, 1975; Wheatley, 1976) and also rotating discs (Pretorius, 1971; Torpey et al., 1971). The identity of this kind of bacterium however still remains obscure (Harkness, 1966), although much research on its growth characteristics, nutrient requirements and classification has been carried out (Crabtree and McCoy, 1967; Friedmann and Dugan, 1968; Unz and Dondero, 1967, 1967b; Unz and Farrah, 1976).

The abundance of zoogloeal bacteria is summarised in Table 5.4a. In each filter there was an enormous increase in the abundance of zoogloeal bacteria with the increase in the loading rate. The values for the mean population density were similar at each loading; although the mean zoogloeal population density recorded for the low loading period were probably over-exaggerated in the slag and plastic filters by the extraordinary high abundances recorded at the commencement of sampling. Seasonal variation in the monthly population density of zoogloeal bacteria is shown in Figure 5.1. At both loadings the same seasonal pattern was observed, with maximum abundance occurring during the winter months and minimum abundance occurring during the summer months. The seasonal variation in population density is correlated with the film accumulation in both the mixed and plastic filters (Table 5.4b), and a clear association is discernible between the abundance of zoogloeal bacteria and the film up to moderate accumulations. Howell and Atkinson (1976) recorded how the rate of adsorption of organic matter from the influent sewage decreased as the film approached maximum accumulation. Therefore at times of maximum

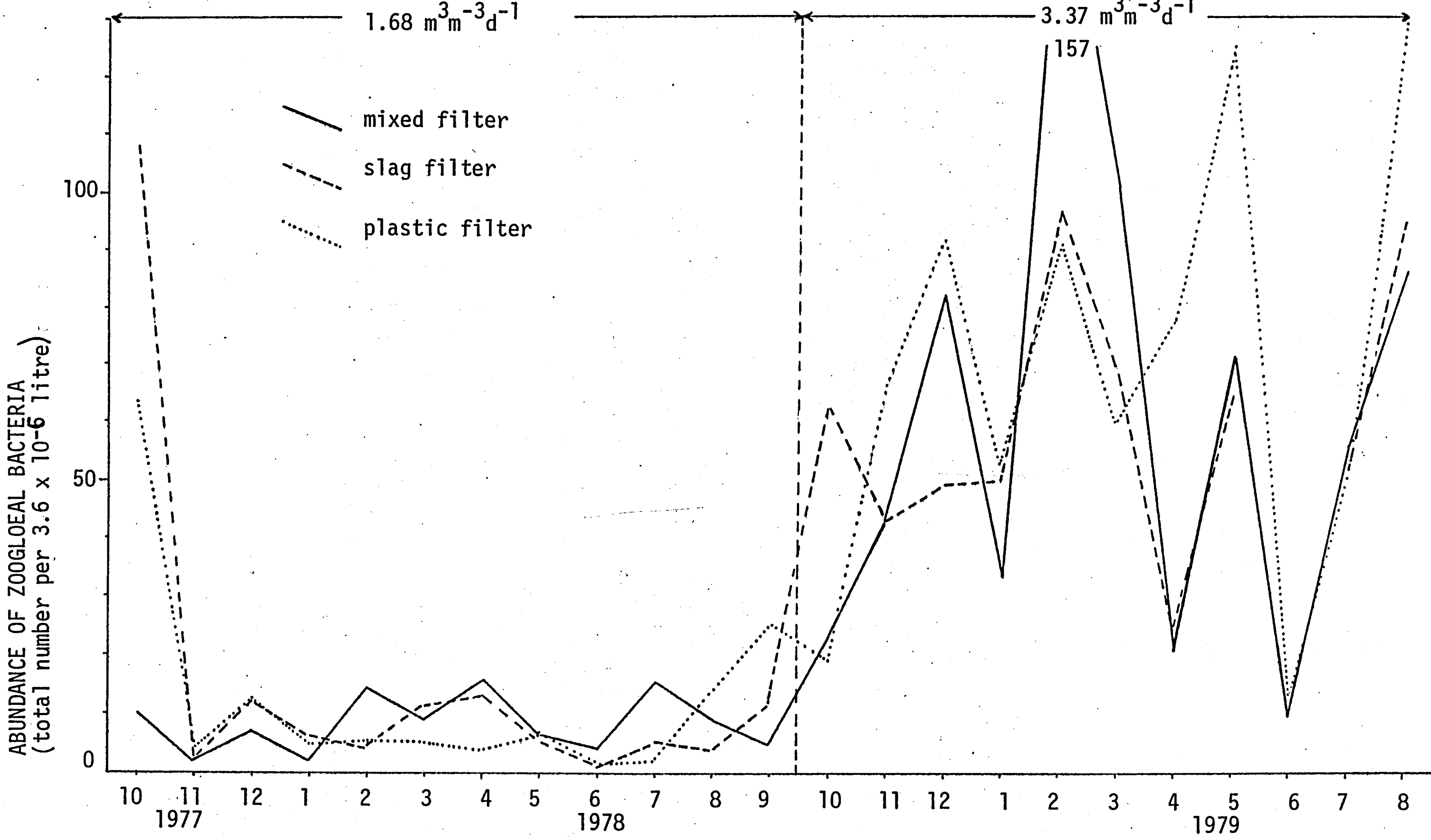
Table 5.4a: Mean monthly abundance of zoogloeal bacteria (expressed as total number per 3.6 x 10^{-6} litre)

	Slag Filter	Mixed Filter	Plastic Filter	No. of months sampled
Low Loading ($1.68m^3m^{-3}d^{-1}$)	15.25	8.25	12.17	12
High Loading ($3.37m^3m^{-3}d^{-1}$)	60.09	62.36	70.73	11

Table 5.4b: Correlations between zoogloeal bacteria and various biological groups and environmental parameters

	SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Low Loading (12 months)		Nematoda (1+)	Subbaromyces (3+)
High Loading (11 months)	Sarcomastigophora (3+) Colpidium colpoda (1-)	Film weight (3+)	
Both Loadings (23 months)	Sarcomastigophora (2+) Organic load (1+) Opercularia microdiscum (1+) Paracyclops (1-) Acari (1-)	Film weight (3+)	Film weight (2+) Sphaerotilus natans (3+) Subbaromyces (1+) Paracyclops (1-) Opercularia microdiscum (1+)

Figure 5.1: Seasonal abundance of zoogloeal bacteria in the pilot filters during low and high rate loadings.



accumulations of film, less organic matter was being removed in the top 300mm of the pilot filters, this being the normal area of maximum organic matter adsorption (Section 6.2.2). This allowed more organic matter to penetrate further into the filter, extending the depth at which the zoogloeal bacteria was recorded. The vertical distribution graphs clearly show that the zoogloeal bacteria were restricted to the top 300mm of the filter for most of the year, but that during periods of maximum film accumulation it was recorded at lower depths within the filter, Figures 5.2 - 5.4. The removal of BOD and suspended solids was associated with the occurrence of zoogloeal bacteria, and the depth at which maximum abundance of the bacteria occurred coincided with the depth of maximum removal (Section 6.2.1). At the higher loading rate the zoogloeal bacteria were extended throughout the depth of the filters (Figures 5.5 - 5.7), due to the greater organic load and the greater surface area of medium covered with heterotrophic bacteria removing the organic matter present. This increased the mean occurrence of the zoogloeal bacteria at the higher loading, which is reflected in Table 5.4a. Significant correlations were recorded between the zoogloeal bacteria and the fungus <u>Subbaromyces</u> <u>splendens</u> and also the filamentous bacterium <u>Sphaerotilus</u> <u>natans</u> (Table 5.4b). When present, both species were observed to increase the rate of film accumulation by adsorption and trapping solids, which led to the subsequent increase of zoogloeal bacteria.

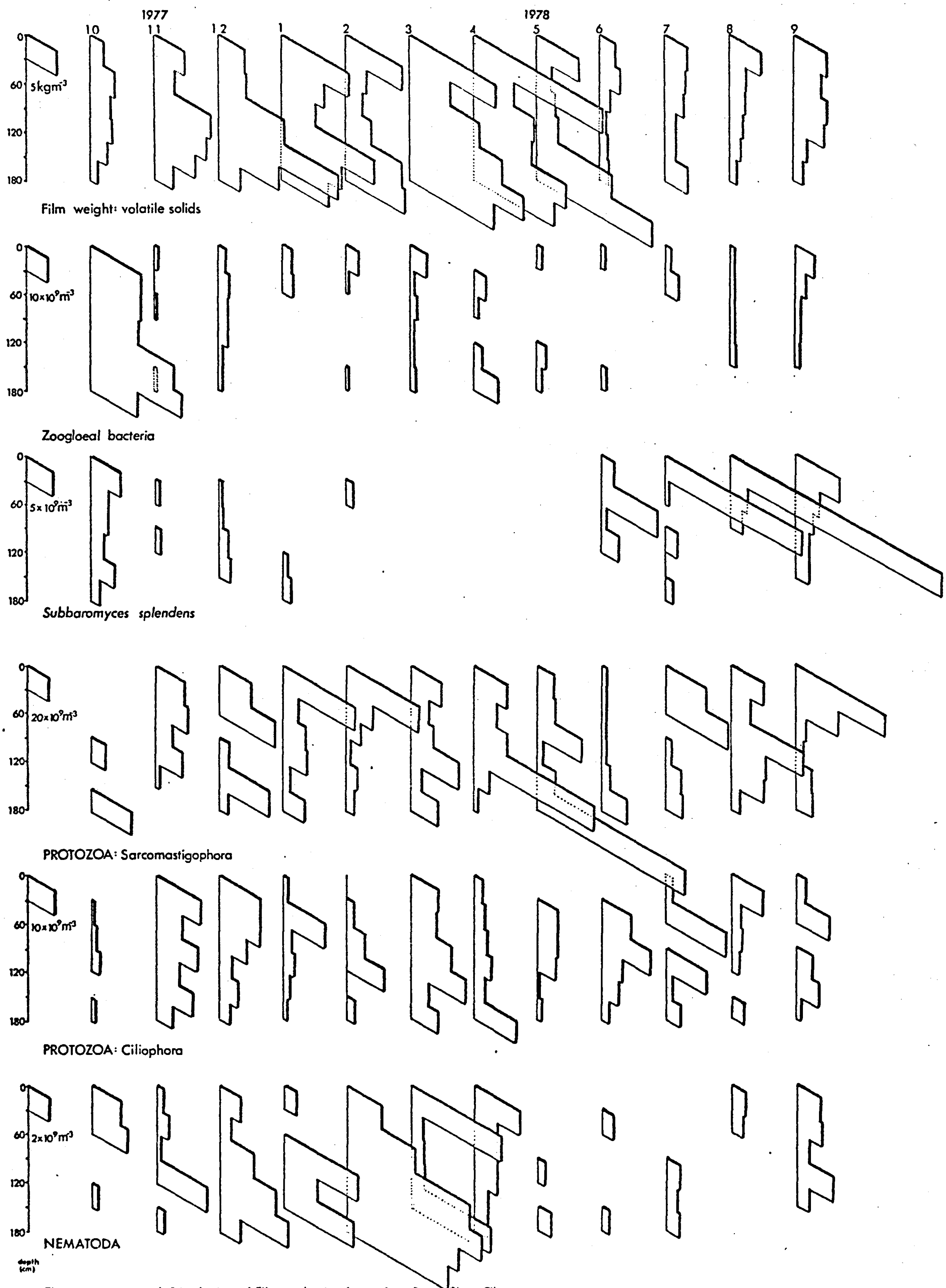
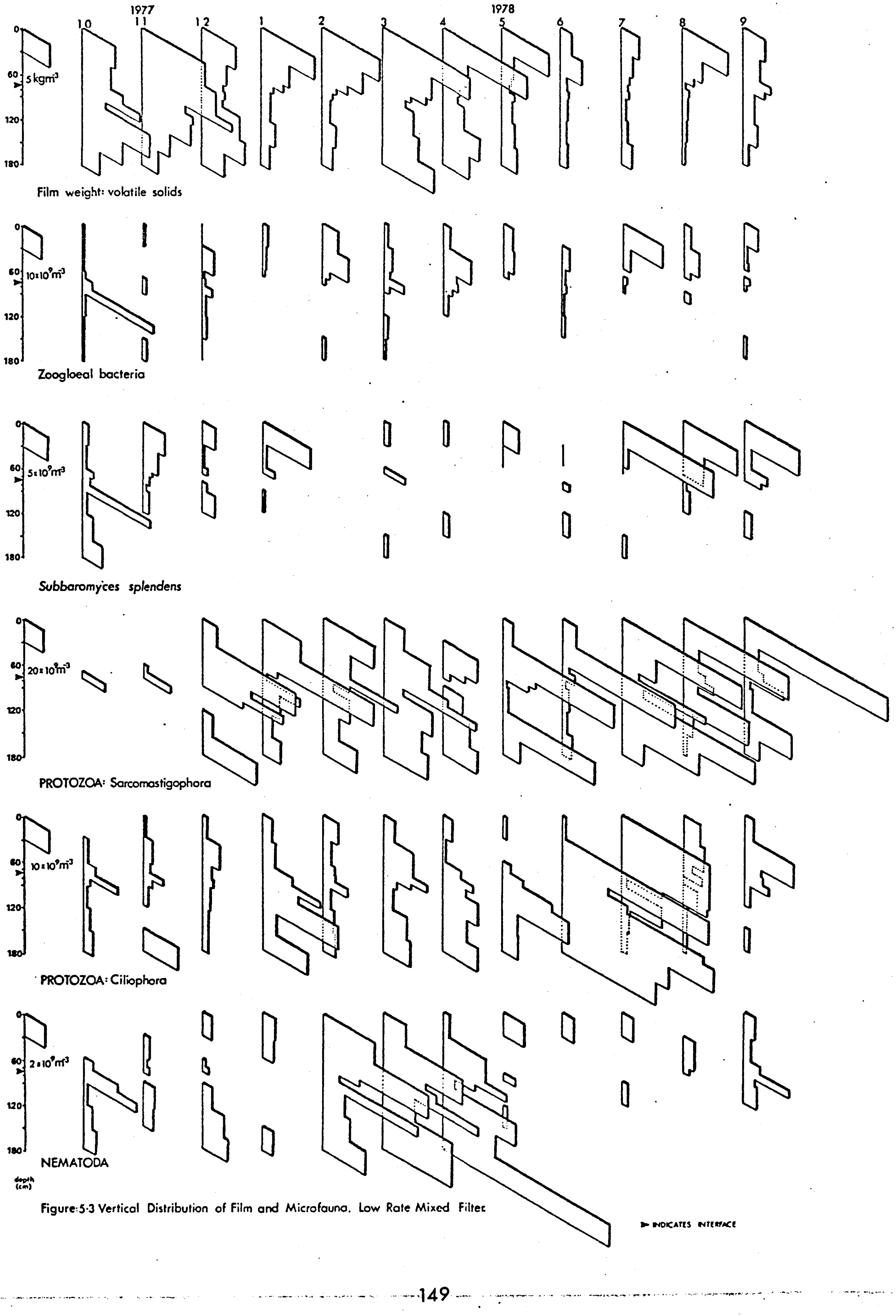


Figure: 5·2 Vertical Distribution of Film and Microfauna, Low Rate Slag Filter.



Film weight: volatile solids

Zoogloeal bacteria

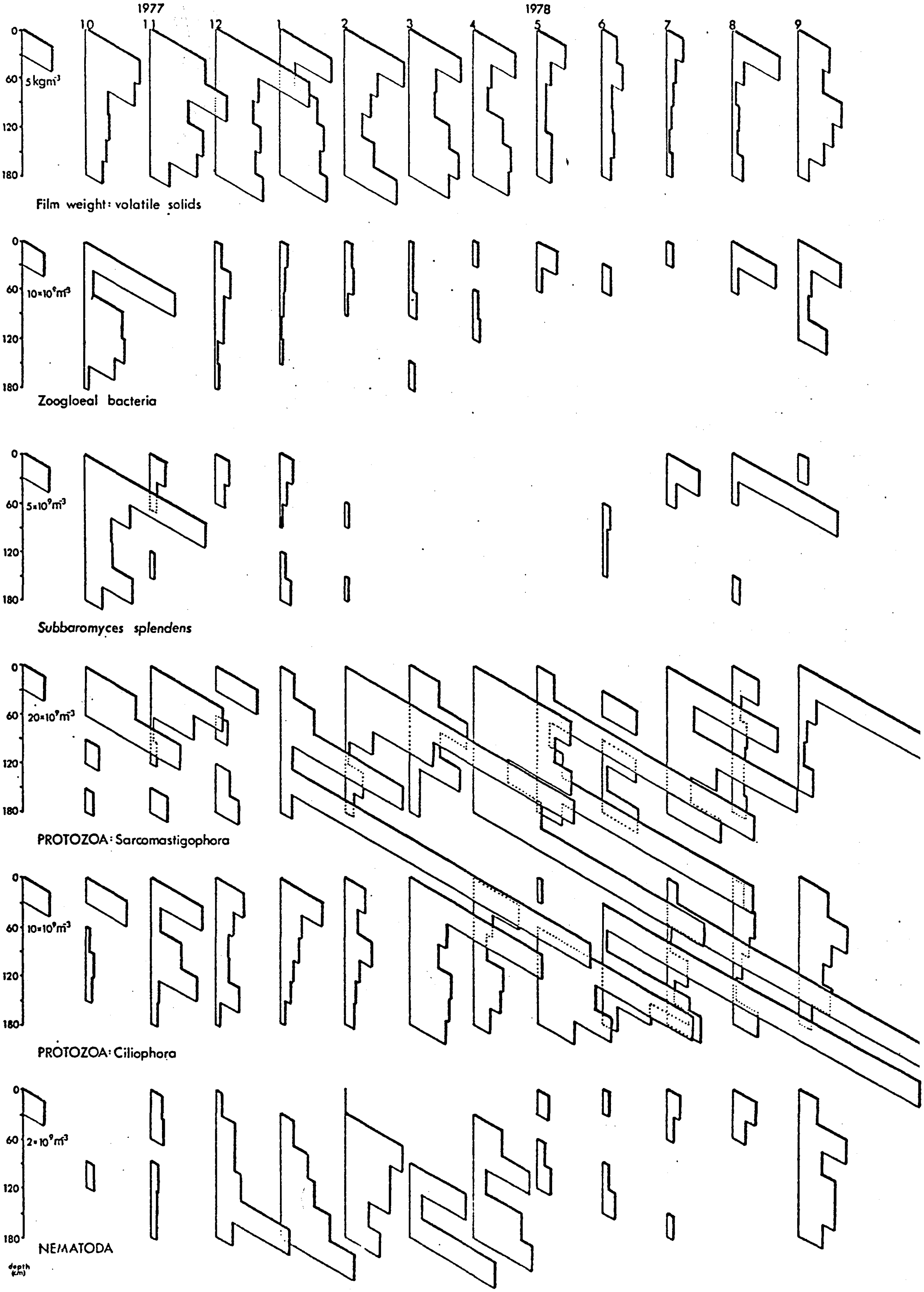
Subbaromyces splendens

PROTOZOA: Sarcomastigophora

PROTOZOA: Ciliophora

NEMATODA

Figure 5·3 Vertical Distribution of Film and Microfauna. Low Rate Mixed Filter



Film weight: volatile solids

Zoogloeal bacteria

Subbaromyces splendens

PROTOZOA: Sarcomastigophora

PROTOZOA: Ciliophora

NEMATODA

Figure: 5·4 Vertical Distribution of Film and Microfauna, Low Rate Plastic Filter.

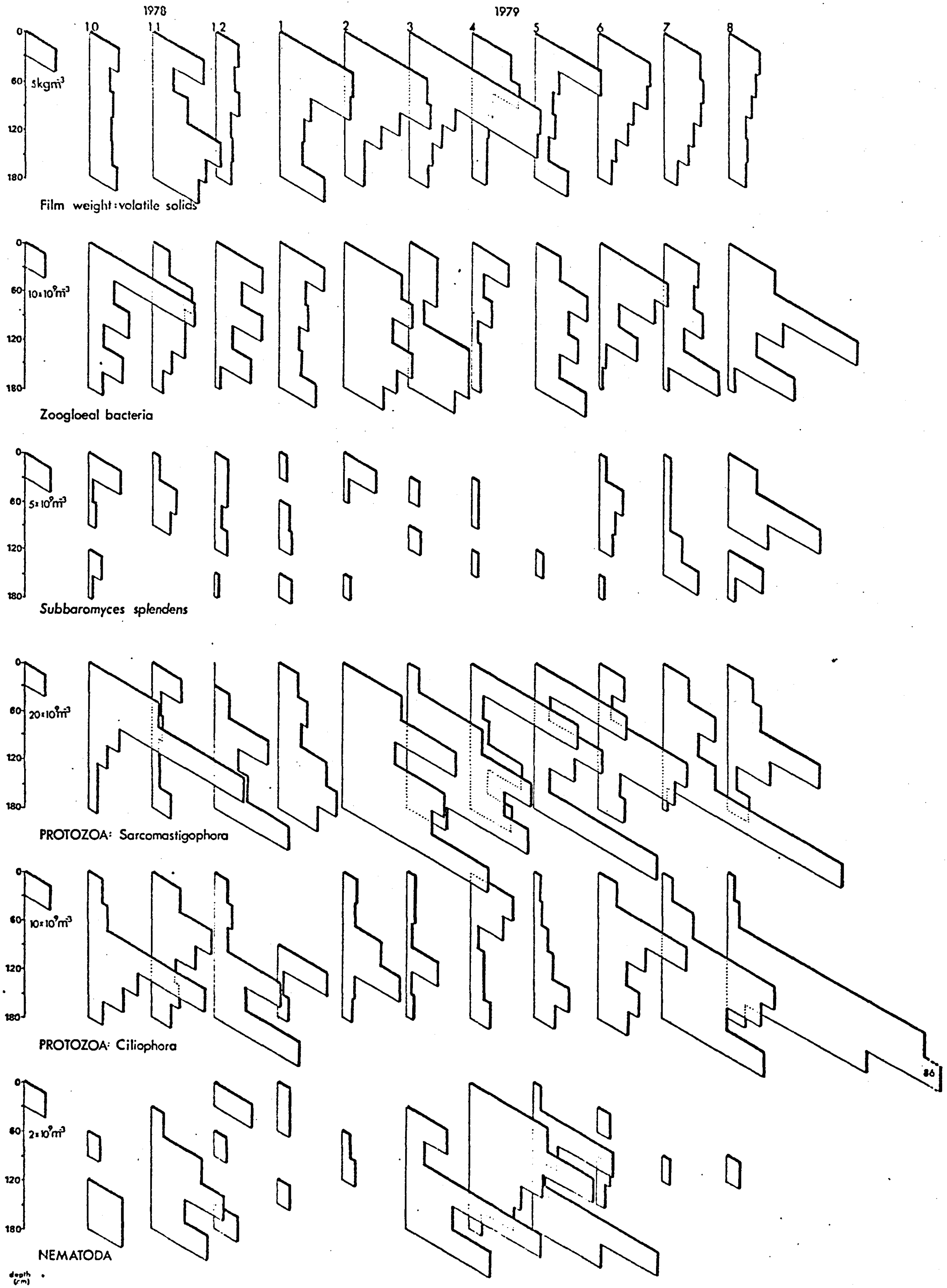


Figure: 5·5 Vertical Distribution of Film and Microfauna. High Rate Slag Filter.

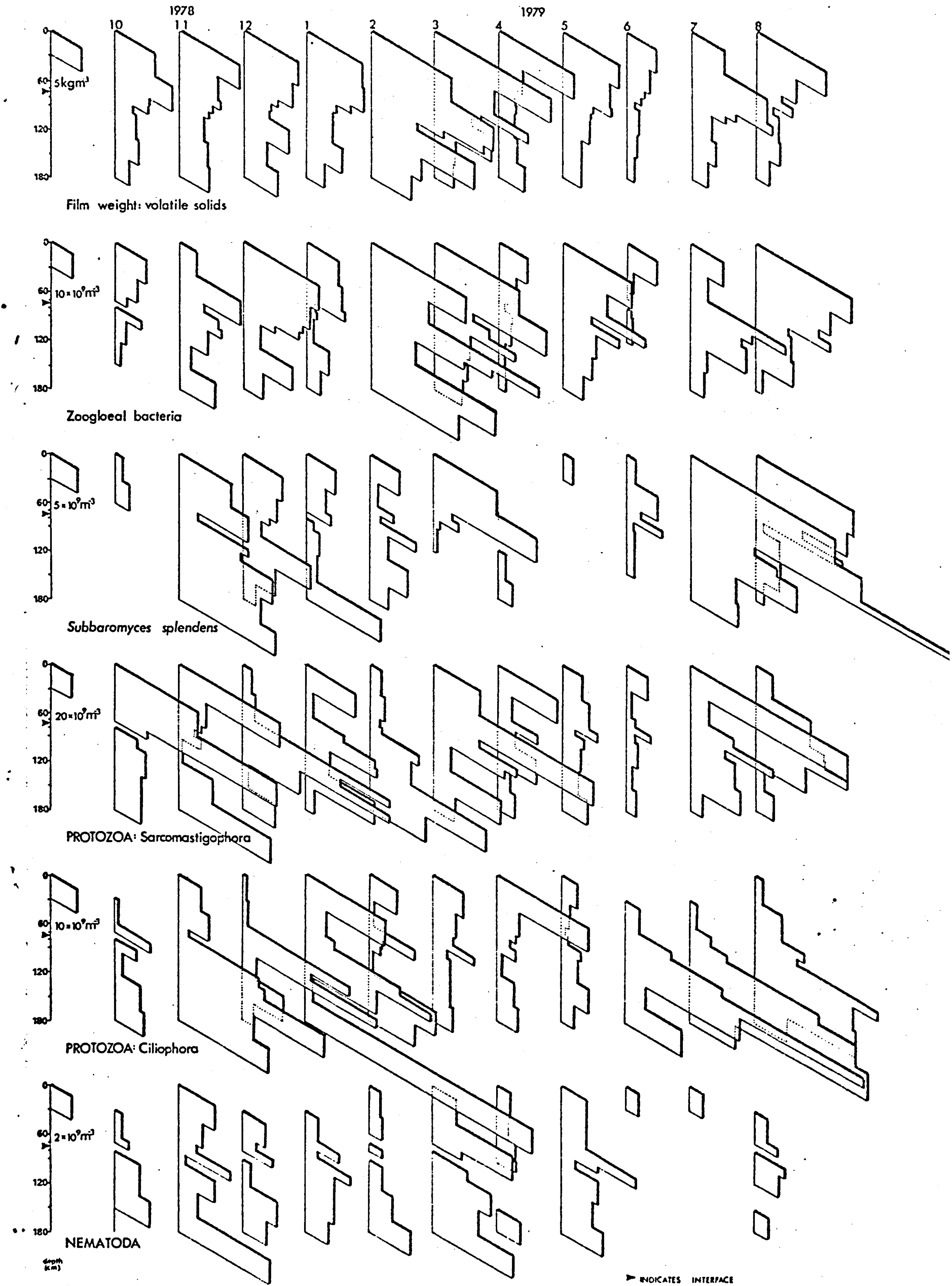


Figure:5·6 Vertical Distribution of Film and Microfauna, High Rate Mixed Filter.

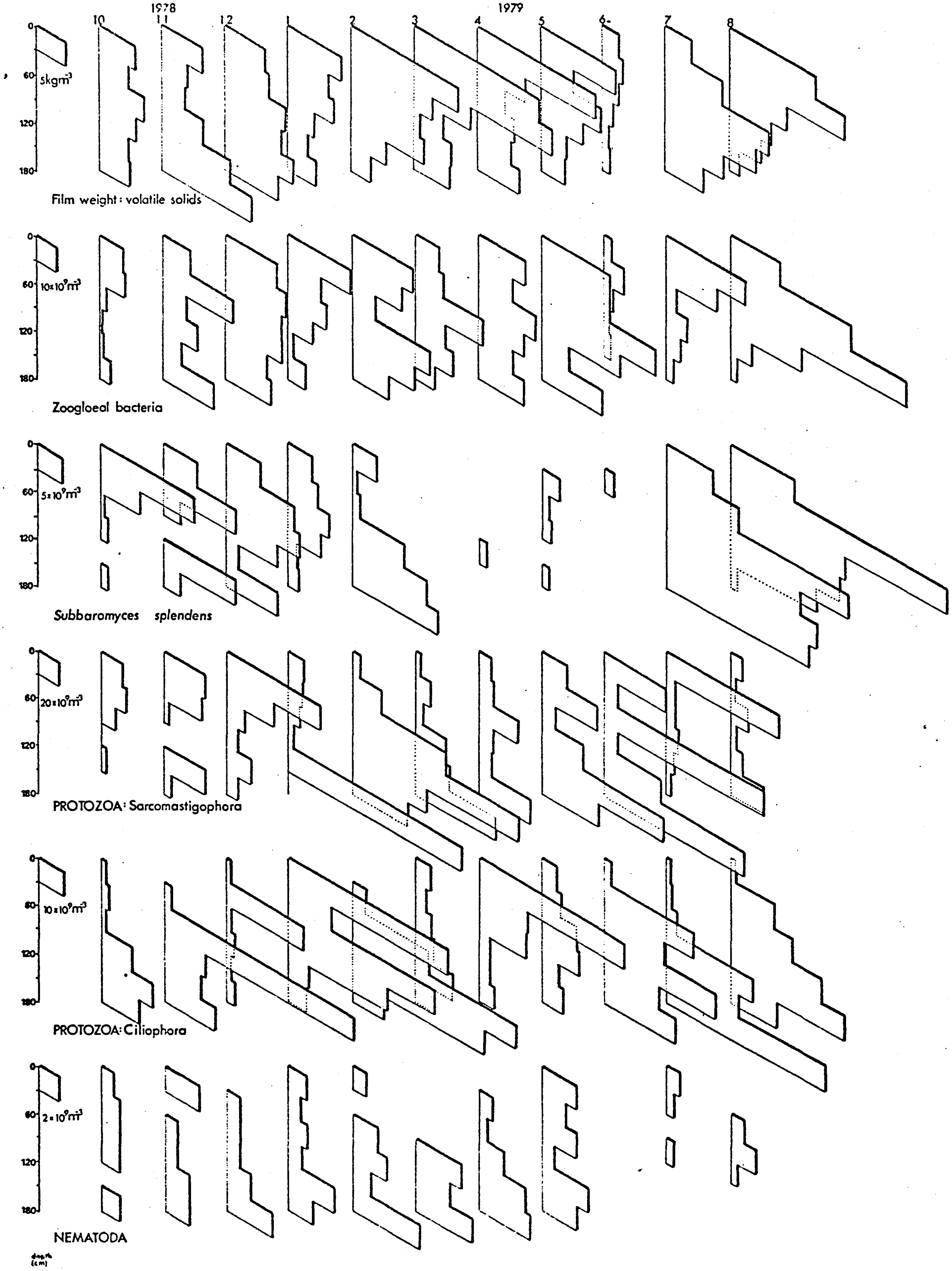


Figure: 5·7 Vertical Distribution of Film and Microfauna, High Rate Plastic Filter.

5.2.2 FILAMENTOUS BACTERIA

Three filamentous bacteria were also recorded in the filters, Sphaerotilus natans, Beggiatoa sp. and Leptothrix sp. Both the latter species were found in low numbers compared with Sphaerotilus natans. Beggiatoa sp. was found only during high rate conditions when it occurred during the spring and autumn (Tables 5.5 - 5.7). Leptothrix sp. was restricted to the colder months but occurred during both low and high rate loadings.

Sphaerotilus natans has been frequently associated with the active film in percolating filters (Cooke, 1959; Bruce et al., 1970; Wheatley, 1976) and was extremely common in the present investigation, only being absent immediately after sloughing when the film accumulation was at its lowest. Table 5.8 shows that the abundance of this particular filamentous bacterium increased substantially when the loading was increased. The mean population diversities under high rate

Table 5.8: Mean monthly abundance of Sphaerotilus natans (expressed as the total number per 3.6 x 10^{-6} litre)

	Slag Filter	Mixed Filter	Plastic Filter	No. of months sampled
Low Loading ($1.68 m^3 m^{-3} d^{-1}$)	8.50	13.17	5.08	12
High Loading ($3.37 m^3 m^{-3} d^{-1}$)	22.82	34.91	42.00	11

Table 5.5: Species diversity of the microfauna in the slag filter

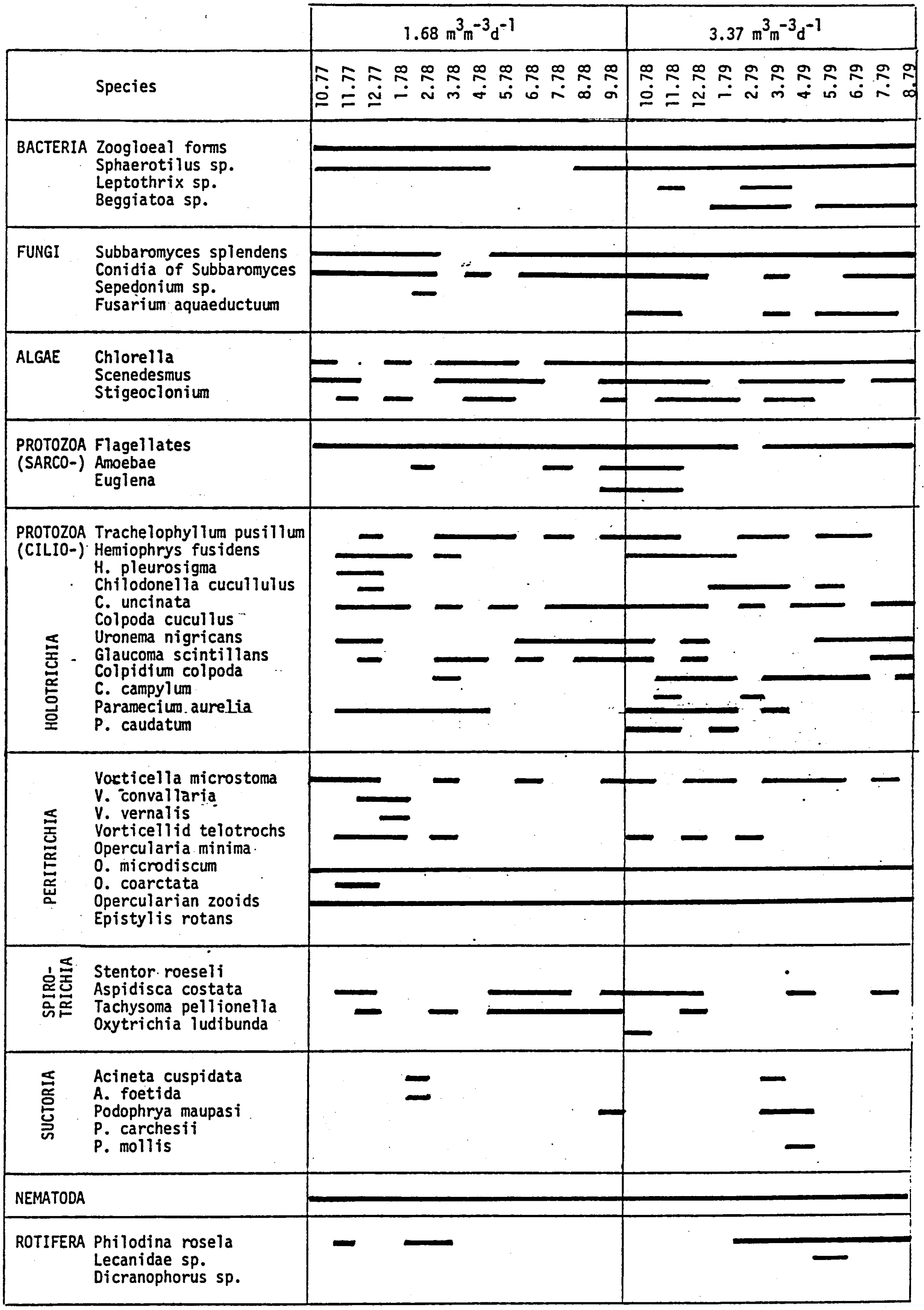
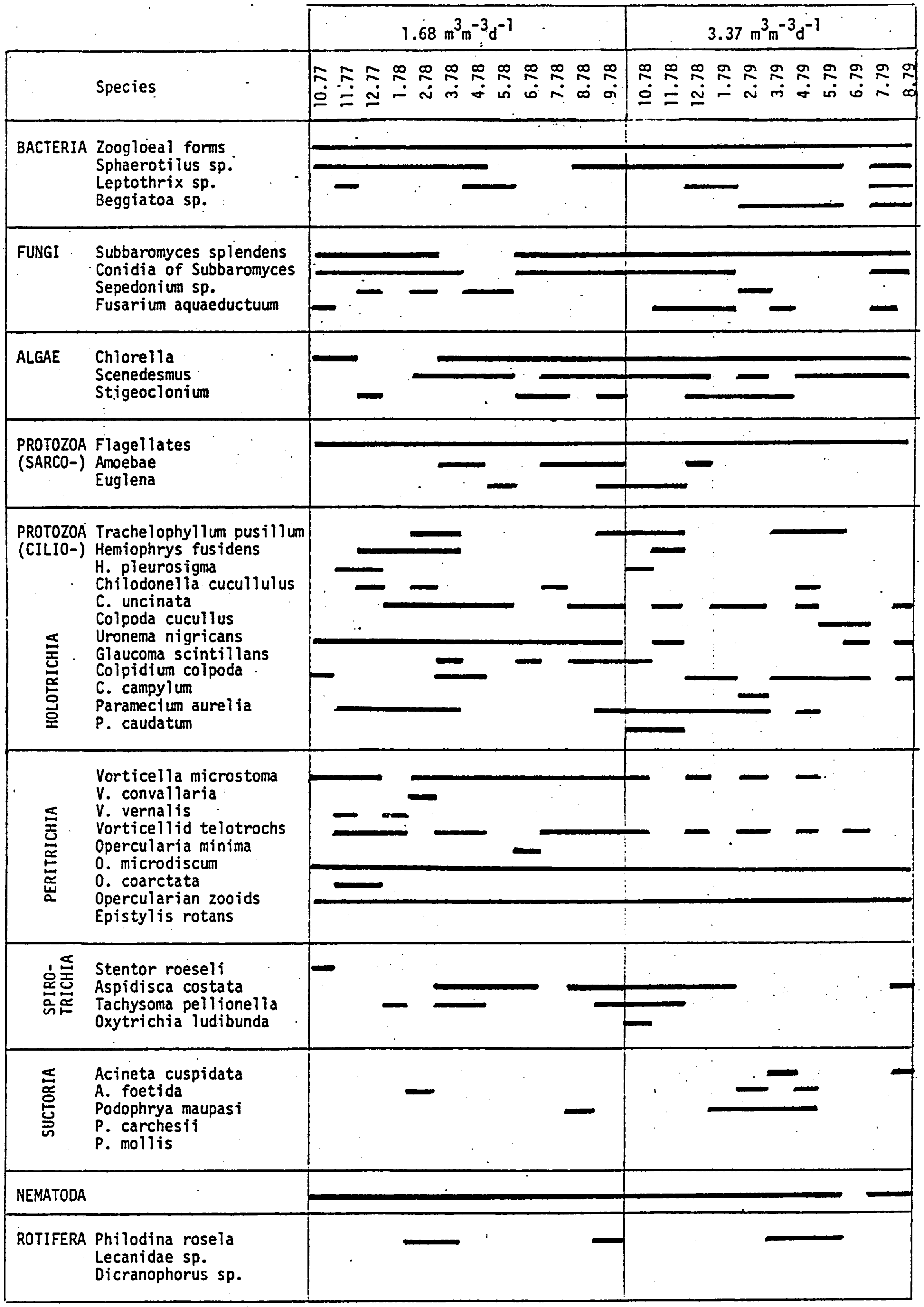


Table 5.6: Species diversity of microfauna in the mixed filter

		$1.68\ m^3m^{-3}d^{-1}$												$3.37\ m^3m^{-3}d^{-1}$										
	Species	10.77	11.77	12.77	1.78	2.78	3.78	4.78	5.78	6.78	7.78	8.78	9.78	10.78	11.78	12.78	1.79	2.79	3.79	4.79	5.79	6.79	7.79	8.79
BACTERIA	Zoogloeal forms	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Sphaerotilus sp.	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■		■	■
	Leptothrix sp.						■	■						■	■				■					
	Beggiatoa sp.																	■			■		■	■
FUNGI	Subbaromyces splendens	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Conidia of Subbaromyces	■	■	■	■		■	■	■	■	■	■	■	■	■	■			■			■	■	■
	Sepedonium sp.					■	■				■							■						
	Fusarium aquaeductuum									■	■				■	■	■		■				■	
ALGAE	Chlorella	■					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Scenedesmus						■	■	■			■		■		■				■	■	■	■	
	Stigeoclonium	■	■	■	■							■	■			■								
PROTOZOA (SARCO-)	Flagellates	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Amoebae				■				■			■	■	■		■			■					
	Euglena													■	■									
PROTOZOA (CILIO-) HOLOTRICHIA	Trachelophyllum pusillum				■		■	■		■		■	■	■	■				■	■				■
	Hemiophrys fusidens	■	■		■	■	■							■	■	■	■	■	■					
	H. pleurosigma		■											■										
	Chilodonella cucullulus						■	■			■		■				■		■					
	C. uncinata	■	■		■	■	■	■	■		■	■	■				■	■	■	■				■
	Colpoda cucullus						■																	
	Uronema nigricans	■			■	■			■	■	■	■	■			■	■					■	■	■
	Glaucoma scintillans		■				■	■	■	■	■		■	■		■	■							■
	Colpidium colpoda						■			■						■	■		■	■	■	■	■	■
	C. campylum								■									■	■					
	Paramecium aurelia	■	■	■	■	■	■	■				■		■	■		■	■	■	■		■		
	P. caudatum			■										■	■									
PERITRICHIA	Vorticella microstoma		■	■		■	■		■	■	■		■		■	■	■	■	■	■		■		■
	V. convallaria	■			■				■			■		■										
	V. vernalis								■						■									
	Vorticellid telotrochs	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■		■					
	Opercularia minima					■																		
	O. microdiscum	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	O. coarctata		■	■			■																	
	Opercularian zooids	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Epistylis rotans			■	■						■									■				
SPIROTRICHIA	Stentor roeseli		■		■																			
	Aspidisca costata	■			■	■	■	■	■	■	■	■	■	■	■	■	■					■		■
	Tachysoma pellionella				■	■	■		■	■	■		■			■								
	Oxytrichia ludibunda																							
SUCTORIA	Acineta cuspidata					■		■																
	A. foetida						■											■	■					
	Podophrya maupasi		■	■	■	■	■		■									■	■	■				
	P. carchesii		■																					
	P. mollis																			■				■
NEMATODA		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
ROTIFERA	Philodina rosela				■	■	■				■							■	■	■	■	■	■	■
	Lecanidae sp.													■								■		
	Dicranophorus sp.													■										

Table 5.7: Species diversity of microfauna in the plastic filter



conditions being related to the available surface area in each filter. The correlation analysis, summarised in Table 5.9, shows that increased *Sphaerotilus natans* abundance is strongly correlated with increased organic loading and the resulting accumulation of film and zoogloeal bacteria.

Table 5.9: Correlations between *Sphaerotilus natans* and various biological groups and environmental parameters.

	SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Low Rate	Film weight (2+)		*Paramecium aurelia*(2+)
High Rate	*Paramecium aurelia*(1+)	Sarcomastigophora(1+) *Paracyclops* sp. (3+)	Psychodid larvae(1-)
Both Loads	Ciliophora (1+) *Paracyclops* (1-) Acari-Astigmata (1-) *Colpidium colpoda* (2+)		Film weight (2+) Zoogloeal bacteria (3+) *Subbaromyces splendens* (1+) Organic load (1+) *Opercularia microdiscum* (1+)

5.2.3 FAECAL INDICATOR BACTERIA

Coliaerogens, *Escherichia coli*, faecal streptococci and *Clostridium perfringens*, are universally present in filters although they are not indigenous members of the filter community (Pike, 1975). Routine analysis was carried out every six months to check for the presence of these indicator bacteria which were always present in the influent to the pilot plant.

From colony counts at both 22°C and 37°C and three different growth media, nutrient agar, casein-peptone-starch medium and casitone-glycerol yeast-extract agar (Jones, 1970; Pike *et al.*, 1972; Staples and Fry, 1973), it was clear that large numbers of heterotrophic bacteria were present. Heterotrophic bacteria were very abundant, being found in greatest numbers in the top 900mm and then, as observed by James (1964) in his experimental filters, the numbers decreased steadily with depth. A relationship between the BOD removal and the abundance of faecal bacteria at 22°C and 37°C was recorded, but insufficient data were obtained for an assessment to be made of removal efficiencies of either faecal or other heterotrophic bacteria for the individual pilot filters, although estimates from the BOD data, which are discussed in Chapter 6, can be made.

5.2.4 NITRIFYING BACTERIA

Nitrosomonas and *Nitrobacter* are strict autotrophs oxidising ammonia and nitrite respectively. Their distribution and abundance in the film were assessed by monitoring the concentration of ammonia and oxidised nitrogen in the sewage as it passed through the pilot filters. As was found by Harkness (1966), most of the nitrification was restricted to the lower levels of the filters, between 900 to 1800mm depth in the pilot filters. Nitrifying bacteria are unable to compete with high abundances of heterotrophic bacteria (Hawkes, 1963). At the higher loadings the heterotrophs extended throughout the depth of the filter at greater population densities, restricting the nitrifying bacteria even lower in the filters, between 1500-1800mm, and often eliminating them altogether. The occurrence of nitrifying bacteria was always greater at the lower loading rates, being most abundant and therefore producing a more nitrified final effluent in the slag filter, while at the higher loading the mixed filter achieved far more nitrification of its final effluent than either of the other pilot filters. At the very high loading of 5.72 $m^3m^{-3}d^{-1}$, nitrification was virtually eliminated, with less than 10% of the ammonia being removed from the final effluent. The effect of flow-rate and retention times in relation to nitrification are discussed fully in Chapter 6.

5.3 FUNGI

The fungal ecology of percolating filters has been reviewed by Cooke (1954, 1963), Becker and Shaw (1955), and Tomlinson and Williams (1975). But although many fungi are found in percolating filters, only a few manage to take advantage of the habitat and flourish (Cooke, 1959).

The Fungi are generally considered undesirable as dominant members of the film, causing solids accumulation and eventually ponding (Hawkes, 1963). Many authors have associated heavy fungal films in filters with very large populations of fly larvae, resulting in fly problems later on. The saprophytic fungi have the same removal efficiencies as the bacteria, although the former produce a greater biomass per quantity of nutrients utilised, resulting in faster film accumulation and eventually a greater sludge production (Water Pollution Research, 1955).

Of the four species of fungi recorded from the pilot filters, *Subbaromyces splendens*, *Sepedonium* sp. and *Fusarium aquaeductum* were identified directly from the film samples. The fourth species, *Geotrichium candidum*, was identified in pure culture by Mrs. I. Williams.

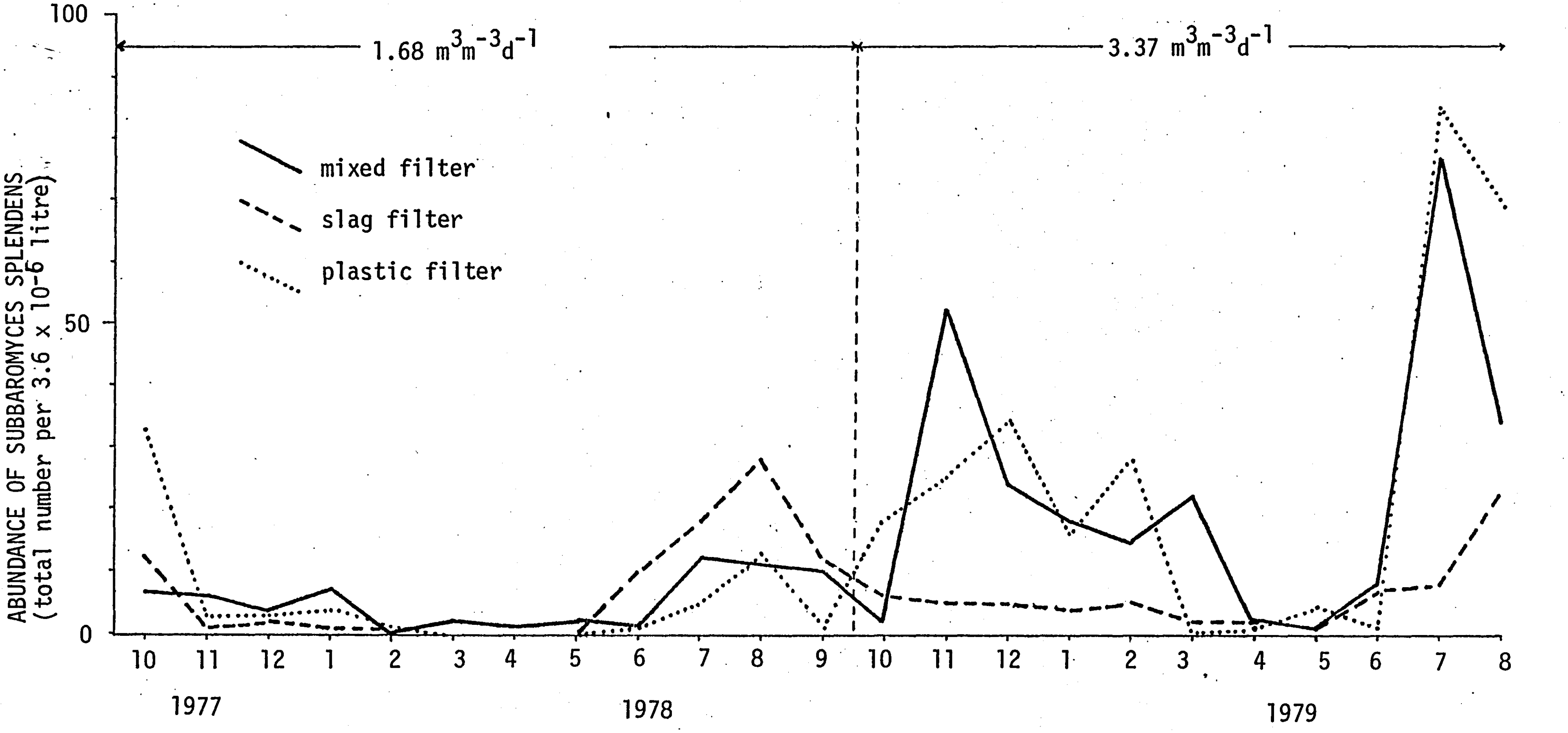
5.3.1 SUBBAROMYCES SPLENDENS

By far the most frequently observed and most abundant fungus at both loadings was *Subbaromyces splendens*. This species was originally reported by Hesseltine in 1952, and has only been recorded from percolating filters. All the fungi recorded in the percolating filters have been associated with sewages containing a high proportion of industrial waste (Hesseltine, 1953; Watson et al., 1955; Hawkes, 1957, 1965; Sladka and Ottova, 1968). Various workers at Langley Mill Sewage Treatment Works, however, found Subbaromyces sp. to be the dominant filter organism although the sewage, like that used in the present investigation, was purely domestic (Hawkes, 1965b; Hawkes and Shephard, 1972; Wheatley, 1976). Seasonal changes in abundance were similar in all the pilot filters, being highest at times of light to moderate film accumulation, and lowest abundances were recorded at times of maximum film accumulation just prior to sloughing, Figure 5.8.

The fungus was far more abundant in the mixed and plastic filters at the higher loading, and Figures 5.5 - 5.7 show that the vertical distribution of Subbaromyces sp. was more extensive in the plastic medium at this loading. Fungal films are structurally stronger than bacterial ones and are less likely to slough off easily (Tomlinson and Williams, 1975), and it is this quality which may help the Fungi, and in particular Subbaromyces splendens, to dominate in filters containing the smoother surfaced plastic medium.

Hesseltine (1953) recorded considerable growths of Subbaromyces splendens at all depths of percolating filters and in the present investigation the habit of extensive vegetative growth throughout the depth of the filters was also observed.

Figure 5.8: Seasonal abundance of Subbaromyces splendens in the pilot filters during low and high rate loadings



Maximum abundance was generally recorded in the top 300mm of the filters at the lower loading rate with the abundance declining with depth. In the mixed filter, however, there was a secondary build-up of the fungus in the interface region, but this did not restrict the passage of the sewage. *Subbaromyces splendens* was far more abundant in the mixed and plastic filters at the higher loading rate, being more widely distributed throughout the filters, with maximum abundance in the mixed filter being observed mainly in the plastic medium. Surface accumulations of the fungus were often extremely thick on the plastic medium of both the mixed and plastic filters (Plates 5.2 - 5.3) although the filters were never in any danger of ponding.

The continuous distribution system using nozzles, has been shown to favour the growth of *Subbaromyces splendens* (Shephard, 1967; Wheatley, 1976) although Hawkes and Shephard (1972) showed that the fungus could be controlled by using periodic dosing.

The abundance of *Subbaromyces splendens* is associated, as are the zoogloeal bacteria, with the accumulation of film up to moderate weights, with the fungus being limited and often eliminated at the heavier accumulations. This is reflected both in the monthly abundance (Figure 5.8), and its vertical distribution (Figures 5.2 - 5.7). Hawkes (1957, 1961, 1965) has shown that the grazing fauna is important in film control, being responsible for seasonal fluctuations in the population of fungi; although it is clear that the macrograzers do not directly restrict the growth of fungus. Only in the plastic

PLATE 5.3: Detail of the fungus Subbaromyces splendens growing over the bacterial and algal growth already on the medium, and restricting the interstices.

filter, at the higher loading especially, does the film accumulation and the abundance of Subbaromyces splendens appear closely related, with subsequent positive correlations being recorded at both loadings (Table 5.10). This is due to the high surface area available which allows the fungus to take full advantage of the increase in organic loading.

Table 5.10 Correlations between Subbaromyces splendens and various biological groups and environmental parameters

	SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Low Rate	Film weight(1-) Paracyclops(2+) Temperature(2+) Paramecium aurelia (1-)	Nematoda (1-) Paracyclops(1+) Temperature(1+)	Zoogloeal bacteria (3+)
High Rate	Ciliophora (3+) Psychodid larvae (2+) Opercularia microdiscum (3+)	Ciliophora (1+) Opercularia microdiscum (3+)	Acari-Astigmata (1-) Organic Load (1+)
Both Loadings	Film weight(2-) Nematoda (1-) Paracyclops(2+) Temperature(2+) Opercularia microdiscum (1+)	Ciliophora (1+) Organic Load (3+) Opercularia microdiscum (3+)	Film weight(1+) Zoogloeal bacteria (1+) Sphaerolitus natans (1+) Acari-astigmata (1-) Organic Load (2+)

5.3.2 CONIDIA OF SUBBAROMYCES SPLENDENS

The conidia were extremely common and could easily be counted.

Williams (1971) showed that the conidia failed to germinate at temperatures below 5°C and were still adversely affected at 15°C. This is supported by the direct relationship between the conidia abundance and the temperature recorded in the pilot filters, Table 5.12. It is not surprising that the maximum abundance of the fungus was recorded during the warmest months, when germination and growth rate were both at their maximum (Figure 5.8). The seasonal abundance of conidia (Figure 5.9) shows that maximum numbers coincided with maximum abundance of the fungus (Figure 5.8), which is also shown in the positive and significant correlation between the fungus and conidia (Table 5.12).

The mean monthly number of conidia recorded in each filter (Table 5.11) showed that the conidia were present in similar numbers in the mixed and plastic filters, at both loadings, whereas the number of conidia dropped by 86% in the slag filter with the increase in loading. This reflects the increased competition from the component species of the film for the comparatively small amount of surface area available in the slag filter at the higher loading.

Table 5.11: Mean monthly total of conidia of *Subbaromyces splendens* recorded in the pilot filters at both loadings (expressed in total number per 3.6 x 10^{-6} litre)

	Slag Filter	Mixed Filter	Plastic Filter	No. of months sampled
Low Loading ($1.68 m^3 m^{-3} d^{-1}$)	18.5	16.3	14.0	12
High Loading ($3.37 m^3 m^{-3} d^{-1}$)	2.6	15.9	14.0	11

Figure 5.9: Mean monthly production of the conidia of *Subbaromyces splendens*

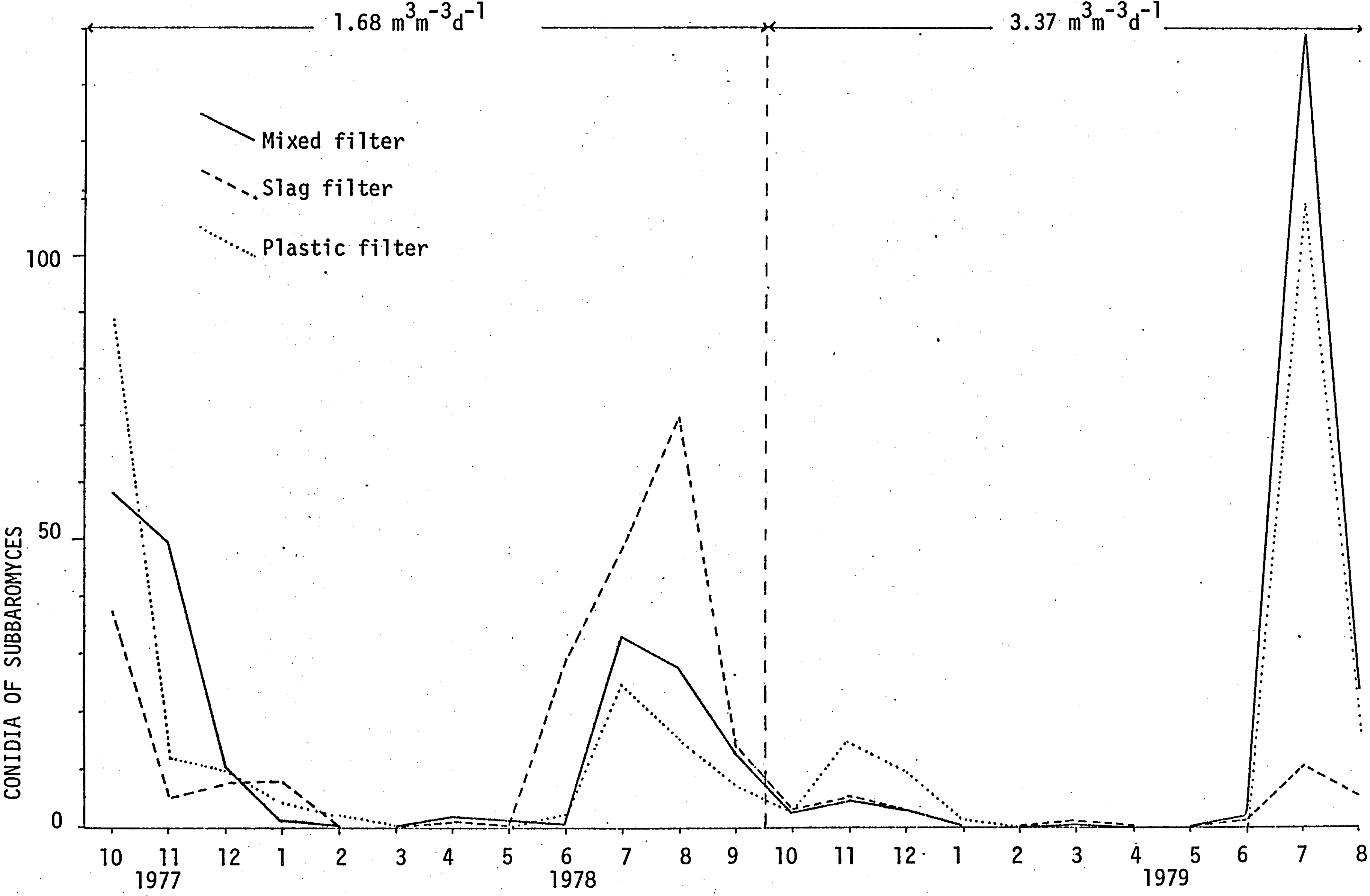


Table 5.12: Correlations between the Conidia of *Subbaromyces splendens* and various biological and environmental parameters.

	SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Low Rate	Film weight(2-) *Subbaromyces*(3+) *Paracyclops*(2+) Temperature(2+)	*Subbaromyces*(1+) *Sphaerotilus natans* (1+) Enchytraeidae(1-)	Zoogloeal bacteria (3+) *Subbaromyces* (3+)
High Rate	Temperature(1+) Organic Load (2+) Effluent BOD (1+)	*Subbaromyces*(2+) Organic Load(1+) Effluent BOD(1+)	*Subbaromyces* (2+) Organic Load (1+)
Both Loadings	Film weight(1-) *Subbaromyces* (3+) *Paracyclops*(3+) Temperature(1+)	*Subbaromyces*(2+) Temperature(1+)	*Subbaromyces* (3+) Nematoda (1-)

5.3.3 *SEPEDONIUM* SP. AND *FUSARIUM AQUAEDUCTUUM*

Sepedonium sp. and *Fusarium aquaeductuum* are commonly associated with percolating filters, were recorded in all the pilot filters. *Sepedonium* sp. was generally found during low rate conditions while *Fusarium aquaeductuum* was usually restricted to the filters during the higher loading. Both *Sepedonium* sp. and *Fusarium aquaeductuum* were found in maximum abundance in the top 300mm with their abundance decreasing with depth and never being found below 1200 and 1500mm respectively.

Fungi have been shown to prefer strong sewages (Tomlinson, 1946b; Hawkes, 1965b), and in particular the occurrence of the fungi recorded in the present investigation has been shown to be limited by sewages containing a low BOD (Tomlinson and Williams, 1975). This preference was evident in the pilot filters with a strong and positive correlation being recorded between *Subbaromyces splendens* and the organic loading (Table 5.10). This explains why at the lower loading the abundance of the Fungi and the influent BOD both decreased with increased depth in the filters. The concentration of the sewage restricted the depth at which *Sepedonium* sp. and *Fusarium aquaeductuum* in particular were found, which is most likely due to a lack of nutrients (Mills, 1945).

Seasonal variations of the more common percolating filter fungi were originally investigated by Haenseler *et al.*, (1923) and examined in detail by Holtje (1943). Similar seasonal variations in abundance were observed during the present investigation with *Sepedonium* sp. being most abundant during the spring and occasionally in late autumn, and *Fusarium aquaeductuum* being found throughout the year, being inversely related to the temperature.

Both *Sepedonium sp*. and *Subbaromyces splendens* were occasionally observed growing together in the pilot filters. Under normal operating conditions (i.e. non-continuous dosing), *Sepedonium* sp. is usually dominant because *Subbaromyces splendens* is slower growing. In the present investigation no observations were made of these two fungi competing with the latter clearly the dominant fungus. The seasonal incidence of the fungi present in the pilot filters support the laboratory observations made by Tomlinson and Williams (1975), that the fungi are separated by different temperatures with Sepedonium sp. having a lower temperature optimum than Subbaromyces splendens.

5.4 ALGAE

The algae play a relatively minor role in the purification process of the percolating filter. Their presence often results in surface ponding due to leathery filamentous growths which can adversely affect the distribution of the effluent, resulting in reduced efficiency (Hawkes, 1963).

Three species of algae, Chorella sp, Scenedesmus sp. and Stigeoclonium sp. were recorded from the pilot filters. The first two species are unicellular and the latter is filamentous. Benson-Evans and Williams (1975) included several common species of Chlorella spp. and Stigeoclonium spp. in a list of algae found in percolating filters, but did not mention Scenedesmus sp., although they are well known from oxidation ponds.

Chlorella sp. and Scenedesmus sp. were generally found during the warmer months at the lower loading (Tables 5.5 - 5.7). However, at the higher loading the two algae were found throughout the year. Both species are associated with high concentrations of nitrates (Hynes, 1970) and have been shown to be capable of utilising nitrates, ammonia or elemental nitrogen (Syrett, 1962). In the pilot filters Chlorella sp. was found in greatest abundance in the top 300mm of the filters, although small numbers were also recorded at other depths during maximum abundance of the species in May. At the higher loading Chlorella sp. was found in far greater numbers, with its vertical distribution being extended throughout the filter but with maximum abundance still in the top 300mm. The ability of this particular species to increase its population density, which was observed during April and May in the slag filter, is explained by the rapid doubling times which have been recorded as short as 15 hrs under favourable conditions (Prescott, 1969). *Scenedesmus* sp. was also most abundant in May, being located in the surface layers of all three pilot filters, although in much smaller numbers than *Chlorella* sp.

Stigeoclonium sp. is usually found in flowing waters (Prescott, 1969) and so is well suited to the filter habitat. The species found in the pilot filters was provisionally identified as *Stigeoclonium tenue* which has been reported by McLean (Benson-Evans and Williams, 1975) to utilise nitrite, nitrate or ammonium as sources of nitrogen. McLean also found that this particular species exhibited a tolerance to those concentrations of heavy metals present in sewage. *Stigeoclonium* sp. was found at all depths in each filter, usually in small numbers, although higher population densities were generally recorded in the plastic filter (Appendix II). Relatively large numbers were found in the lower depths of the filters where the oxidised nitrogen concentrations were highest.

5.5 PROTOZOA

5.5.1 SARCOMASTIGOPHORA AND CILIOPHORA

In a detailed review of the ecology of the Protozoa in wastewater treatment, Curds (1975) found that the 218 species identified in percolating filters were distributed between the various classes in the following way: 35 species of Phytomastigophora, 30 species of Zoomastigophora, 31 species of Rhizopodea, 7 species in the Actinopodea and 116 ciliate species; clearly showing that the largest proportion of protozoan species identified belonged to the Sub-Phylum Ciliophora. Because of the large diversity of ciliate species found in percolating filters it was decided that only the ciliates in the pilot filters would be identified and counted at species level. It was hoped that the variety of species of this Sub-Phylum would reflect most clearly any biotic or abiotic changes in the pilot filters. All the other species of the Sub-Phylum Sarcomastigophora (the flagellates) were grouped together and only the total numbers present recorded.

It is generally thought that in percolating filters the ciliates are numerically dominant over the flagellates (Frye and Becker, 1929; Brink, 1967; Curds and Cockburn, 1970; Curds, 1975). Although Barker (1942, 1946) occasionally found the flagellates were numerically dominant, he also generally found the ciliates to be most abundant. In the pilot filters the reverse was found to be true, the flagellates dominated the ciliates numerically for most of the year except during periods of moderate film accumulation (Table 5.13). At the lower loading the abundance of the Sarcomastigophora and Ciliophora were both related to the available surface area of the filters. Doubling the loading rate did not have the effect of doublin g the numbers of ciliates present although it did result in an overall increase in the total number of ciliates present in all three filters. The percentage increase of ciliates at the higher loading for the mixed and plastic filters were of the same order. But in the slag filter the percentage increase was higher although the mean number of cilates present was lower than in either the other filters at both loading rates.

The Sarcomastigophora population did not, however, behave in a similar way when the loading was increased. In the slag filter there was a 97% increase of the flagellate population while in the mixed filter the increase was only 13%. In the plastic filter the population of flagellates dropped overall by some 29% (Table 5.13). The reason for this is not understood. The scatter diagrams of the Sarcomastigophora population density against the 23 months of operation for each filter produced different types of plot for each filter. In the slag filter there was an overall increase in the population density with time; in the plastic filter an overall decrease was observed, while in the mixed filter there was a 'normal distribution' with the population density reaching a maximum during the middle of the experimental period.

Table 5.13: Mean monthly total of Sarcomastigophora and Ciliophora recorded in the pilot filters (expressed as total number of individuals per 3.6 x 10^{-6} litre)

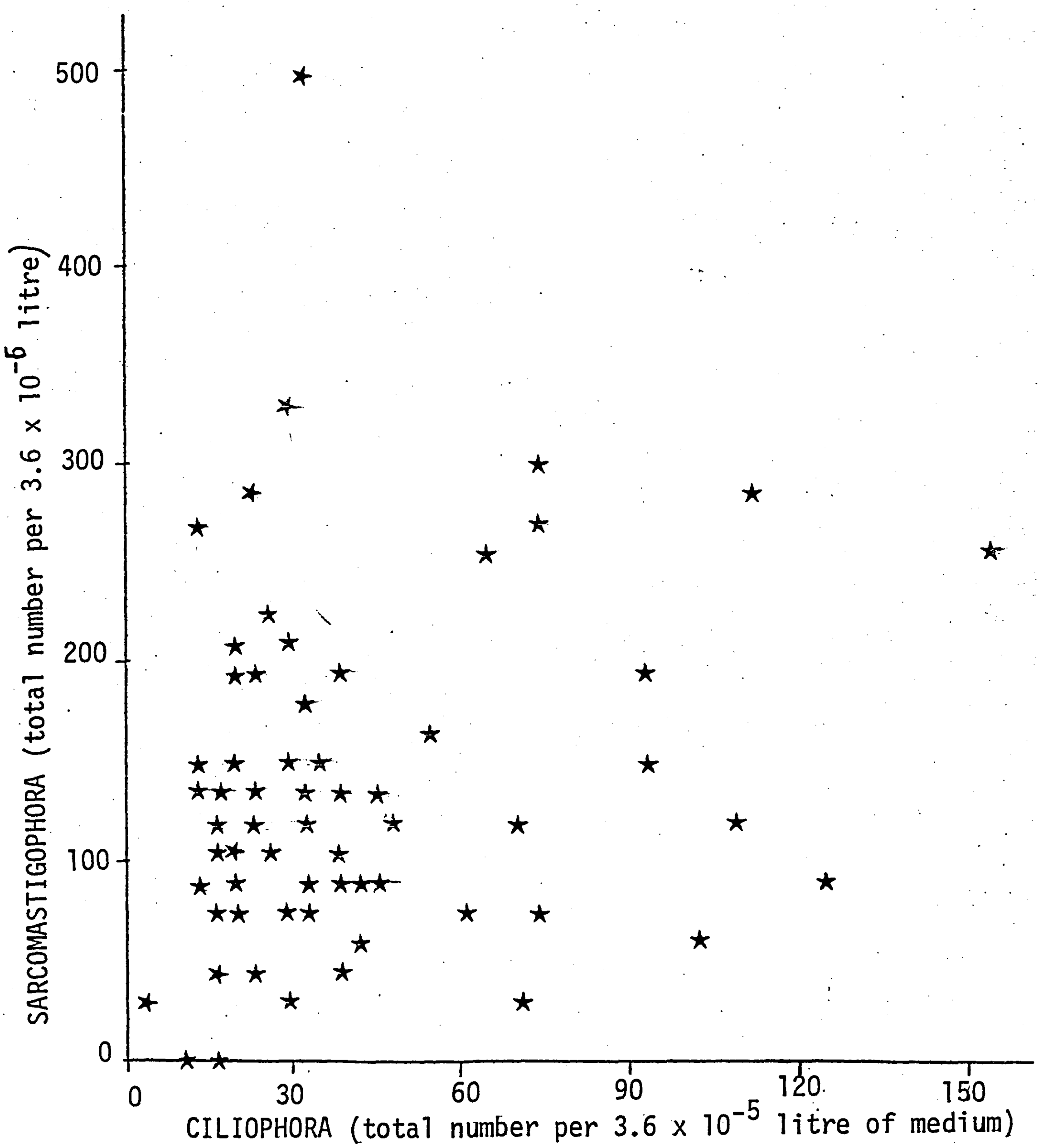
FILTER	SLAG FILTER		MIXED FILTER		PLASTIC FILTER	
LOADING	LOW	HIGH	LOW	HIGH	LOW	HIGH
Sarcomastigophora	88.3	174.1	119.8	135.8	175.0	125.0
Ciliophora	23.7	40.3	35.9	56.8	40.2	63.0
Ratio: Sarcomastigophora Ciliophora	3.73	4.33	3.34	2.39	4.35	1.99
Sarcomastigophora: % increase with load	97.0		13.4		-28.6	
Ciliophora: % increase with load	70.0		58.2		56.6	

No significant relationship was found between the Sarcomastigophora and the Ciliophora (Figure 5.10). The seasonal changes in abundance of all the major biological groups studied and the seasonal changes in the various environmental parameters measured were all plotted and compared directly to the seasonal occurrence of both the flagellates and ciliates. In the slag and mixed filters, however, similar seasonal patterns were identified between the zoogloeal bacteria and the flagellates, especially during the lower loading. Another interesting relationship emerged, being that the Sarcomastigophora in the slag and mixed filters reached maximum population density the month preceding the maximum Enchytraeidae population during the

Figure 5.10: Computed correlation between the Sarcomastigophora and Ciliophora recorded during the entire experimental period of 23 months in all the pilot filters.

Correlation coefficient r = +0.175

Degrees of freedom (n-1) = 68



period of maximum film accumulation. No such relationships were recorded for the Ciliophora, although it is not surprising that few seasonal relationships exist as the populations of Sarcomastigophora and Ciliophora are made up of numerous species each exhibiting different environmental preferences.

The correlation analysis comparing these two protozoan groups with the other faunal groups and the basic environmental parameters is summarised in Table 5.14. The main significant relationship with the Sarcomastigophora is with the Astigmata and zoogloeal bacteria. Correlations with the Ciliophora were mainly with the dominant ciliate species themselves.

The vertical distribution of both the Sarcomastigophora and the Ciliophora is shown in Figures 5.2 to 5.7. The vertical distribution of the flagellates does not appear related to any particular parameter, while the vertical distribution of the ciliates can only be related directly to the component ciliate species.

Although the flagellates were not identified before counting, the identity of the commoner species was noted. These were *Bodo caudatus*, *Peranema trichophorum* and *Amoeba radiosa*. Euglenoids were occasionally found. All the species of Sarcomastigophora found in the pilot filters are commonly found in percolating filters (Curds, 1975).

Curds (1975) lists nine of the Orders of the Ciliatea as

Table 5.14: Summary of significant correlations with the Protozoa

Sarcomastigophora	SLAG	MIXED	PLASTIC
LOW LOADING	Acari-Astigmata (1+)	Film weight (1-) *Chilodonella uncinata* (1+)	Acari-Astigmata (2+)
HIGH LOADING	Zoogloeal Bacteria (3+) *Colpidium colpoda* (1-)	*Sphaerotilus natans* (1+) Enchytraeidae (1-)	
BOTH LOADINGS	Zoogloeal Bacteria (2+) *Opercularia microdiscum* (2+) Organic Loading (1+)		Acari-Astigmata (2+)
ALL DATA FROM ALL FILTERS AT BOTH LOADINGS	Acari-Astigmata (2+), *Opercularia microdiscum* (1+)		
Ciliophora			
LOW LOADING	*Paramecium aurelia* (2+) *Chilodonella uncinata* (1+)		
HIGH LOADING	*Opercularia microdiscum* (3+) *Subbaromyces splendens* (3+) *Paracyclops* (2+) Temperature (1+)		
BOTH LOADINGS	*Opercularia microdiscum* (3+) *Sphaerotilus natans* (1+) *Psychoda* larvae (2+) Organic Loading (1+)		
ALL DATA FROM ALL FILTERS AT BOTH LOADINGS	*Opercularia microdiscum* (3+), *Colpidium colpoda* (2+), *Uronema nigricans* (3+), *Chilodonella uncinata* (2+), Organic Loading (2+), *Paracyclops* (1+), *Psychoda* larvae (2+), *Subbaromyces splendens* (1+).		

being represented in the percolating filter fauna. The percentage distribution of species between these Orders recorded by Curds and those found during the present investigation are shown in Table 5.15. The species recorded are

Table 5.15: Frequency occurrence of species in the various Orders of the Protozoa

ORDER OF PROTOZOA	SLAG		MIXED		PLASTIC		NAT'NAL SURVEY*		
	No	%	No	%	No	%	No	%	
Gymnostomatida	5	22	5	18	5	20	26	24	)
Trichostomatida	0	0	1	4	1	4	7	6	)Holotrichia
Hymenostomatida	6	26	6	21	6	24	20	18	)
Peritrichia	5	22	7	25	6	24	21	19	Peritrichia
Heterotrichida	0	0	1	4	1	4	8	7	)
Oligotrichia	0	0	0	0	0	0	1	1	)Spirotrichia
Odontostomatida	0	0	0	0	0	0	1	1	)
Hypotrichia	3	13	2	7	3	12	20	18	)
Suctorida	4	17	6	21	3	12	5	5	Suctoria
TOTAL DIVERSITY	23		28		25		109		

* after Curds (1975)

distributed in a similar way between the various Orders except that the Order Suctorida has a larger percentage of the total species recorded while fewer species were recorded from the Order Hypotrichia. No species from the Orders Oligotrichia and Odontostomatida were found in the present investigation, species from these two Orders being rarely found in filters.

The number of protozoan species within the three pilot filters was similar ranging from 23 in the slag to 28 in the mixed filter, with a mean value for all three of 25.3 (Table 5.15). The greater number of species in the mixed filter is primarily due to the greater variety of suctorian species which inhabited this filter. The same twelve holotrich species were found in all three filters, with the exception that *Colpoda cucullus* was not found in the slag filter. The mixed filter alone had a more diverse peritrich and suctorian fauna. Of the 29 different ciliate species identified all but *Oxytricha ludibunda* were found in the mixed filter. *Epistylis rotans*, *Podophyra carchesii* and *Sphaerophrya magna* were all restricted to the mixed filter. *Podophrya mollis* was not found in the plastic filter and three species, *Opercularia minima*, *Stentor roeseli* and *Colpoda cucullus* were not recorded from the slag filter.

As only one species was not recorded in the mixed filter, the mixed medium had an overall greater diversity of ciliate species. However, just how important species found in low numbers are to the overall energy of the system is unknown, and indeed most of the extra species found in the mixed filter were only present in small numbers and were generally sessile or small in size. The presence of a greater variety of species however can only be advantageous because any change in the characteristics of the influent sewage may alter the balance of the ciliate community and therefore alter the dominance and relative importance of the species present. Table 5.16 shows that an increase in loading reduced the mean diversity of ciliates. This reduction was 19% in the

Table 5.16: Mean monthly diversity of ciliate species

	SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Low Loading			
mean	6.9	10.1	7.8
standard deviation	3.52	1.83	2.53
High Loading			
mean	6.7	8.2	6.3
standard deviation	2.45	3.25	2.97

plastic and mixed filters but only 3% in the slag filter. Therefore although fewer species occurred in the slag filter, the increased loading had less effect on the species present. This may be due to the higher voidage of the plastic medium allowing a greater loss of ciliates with the increase in hydraulic load. The slag filter was overloaded throughout the 23 month experimental period and so the reduced protozoan fauna was unaltered by futher increases in organic load.

A number of workers have reported that the number of ciliate species increased with depth in filters (Johnson, 1914; Barker, 1949; Baines _et al._, 1953; Curds _et al._, 1970; Wheatley, 1976). Hussey (1975) found that the ciliate diversity was negatively associated with the film weight. Many of the above workers suggested that the ciliates are unable to compete effectively with the other organisms normally associated with the film in the low dissolved oxygen conditions prevalent at the filter surface. Therefore the greatest diversity and largest abundance of ciliates occur in the lower depths of filters where there is an increasingly smaller concentration of organic matter in the partly treated sewage. From the present investigation it appears that at the lower loading the ciliates were widely distributed throughout the depth of the pilot filters, and, although certain species were limited to specific regions, that generally there was no increase either in diversity of species or abundance with depth. At the higher loading maximum species diversity and abundance of Protozoa occurred in the lower half of the filters. The increased abundance of certain species in the lower depths of the filters at this loading such as Opercularia microdiscum (Figures 5.16 to 5.18) was not due to the lower organic content of the influent sewage at that depth as suggested previously, as this species is tolerant of both organic load and film accumulation. It is more probable that in the pilot filters the increased occurrence of protozoans at the lower depth was a consequence of the increased hydraulic loading. In conventional filters there would be a greater tendency for the protozoan fauna to be forced deeper into the filters by using the normal instantaneous and heavy system of sewage application.

It can be clearly seen (Tables 5.5 to 5.7) that some species were restricted to either low or high loading rate conditions. Vorticella convallaria, Vorticella vernalis (not reported previously in percolating filters), Opercularia minima, Opercularia coarctata and Stentor roeseli were only recorded at the lower loading along with *Sphaerophrya magna*, although there was only one record of this particular species. *Tachysoma pellionella*, was far more successful during the lower loading, being rarely found in the high rate filters. Only *Podophrya mollis* and *Oxytrichia ludibunda* were completely restricted to high rate conditions although three holotrichs, *Colpidium colpoda*, *Colpidium campylum* and *Paramecium caudatum*, were all far more abundant at this loading.

5.5.2 COMPONENT CILIATE SPECIES

Several workers have divided the protozoan species present in activated sludge systems into two groups, those indigenous species which are well adapted to living in the system all the year round and those species only found occasionally (Brown, 1965; Schoefield, 1971). *Opercularia microdiscum* was the only ciliate to be present in all three filters at both loadings. But frequently occurring species also included *Chilodonella uncinata*, *Paramecium aurelia* and *Vorticella microstoma*, while *Colpidium colpoda* was frequently recorded during the higher loading period.

Of the 29 ciliate species recorded, 15 species (not including vorticellid telotrichs) were found to be present in such numbers as to represent at least 10% of the total ciliate population at some time during the experimental period (Table 5.17). These species were divided into three separate groups, according to their role within the filter.

GROUP I : "Dominant species", comprising of 10% of the total ciliate population in all three filters at least once at both loadings, and which were numerically dominant in at least one of the pilot filters.

GROUP II : "Sub-dominant species", comprising of 10% of the total ciliate population in any filter at either loading at least once and were numerically sub-dominant species. (Often species in this group were restricted to a particular loading or medium type.)

GROUP III : "Non-dominant species", comprising of 10% of the total ciliate population in any filter at either loading at least once, but were never numerically dominant or sub-dominant.

The relative abundance of a particular organism in a habitat is used to indicate its importance in the ecological structure of that habitat. In assessing the important species during the present investigation, both the frequency and abundance data were studied. In order to understand how the ecology of the filter changed from month to month the five Group I dominant ciliates (Table 5.17) were studied in detail. Each of these species was present in large enough numbers to play an important role in the energy flow in the pilot filters. There were four holotrichs, *Paramecium aurelia*, *Uronema nigricans*, *Glaucoma scintillans* and *Colpidium colpoda*, and one peritrich, *Opercularia microdiscum*. They all feed on bacteria (Barker, 1946; McKinney and Gram, 1956; Curds and Vandyke, 1966; Curds, Cockburn and Vandyke, 1968) and are commonly found in percolating filters (Learner, 1975). All the Group I holotrichs belong to the Order Hymenostomatida.

The total number of months, at each loading, in which these species occurred as the dominant species is summarised in Table 5.18. *Opercularia microdiscum* was the most frequently occurring dominant species overall. At the low loading *Opercularia microdiscum*, *Uronema nigricans* and *Paramecium aurelia* were most frequently recorded, while at the higher loading rate only *Opercularia microdiscum* was commonly recorded (Figures 5.11 and 5.12).

Table 5.17: Component Ciliate species found in the pilot filters divided into relative dominance groups

GROUP I (dominant sp.)	GROUP II (sub-dominant)	GROUP III (other component sp)
Paramecium aurelia *Opercularia microdiscum* *Uronema nigricans* *Glaucoma scintillans* *Colpidium colpoda*	*Chilodonella uncinata* *Vorticella microstoma* *Aspidisca costata* *Tachysoma pellionella* *Trachelophyllum pusillum* *Colpidium campylum* *Podophrya maupasi* *Verticella vernalis* (Vorticellid telotriochs)	*Chilodonella cucullus* *Epistylis rotans*

Figure 5.11: Dominant ciliate protozoan species in pilot filters at various film accumulations

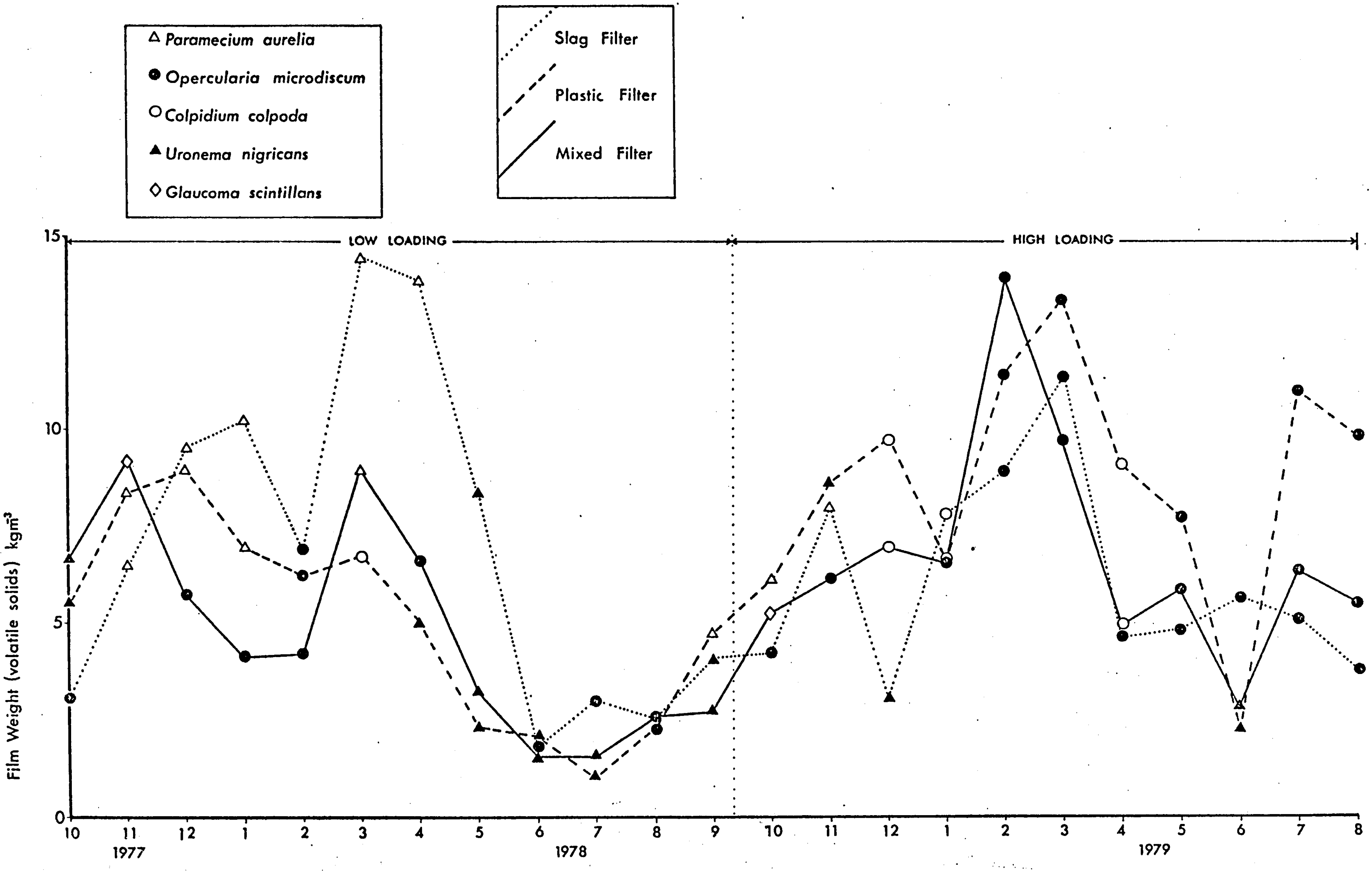


Figure 5.12: Occurrence of dominant ciliate protozoa at various film accumulations throughout the entire experimental period of 23 months, in all the pilot filters. Boxed areas enclose the mean film accumulations at which each species was recorded in each filter; the total range at which each species was recorded is also indicated.

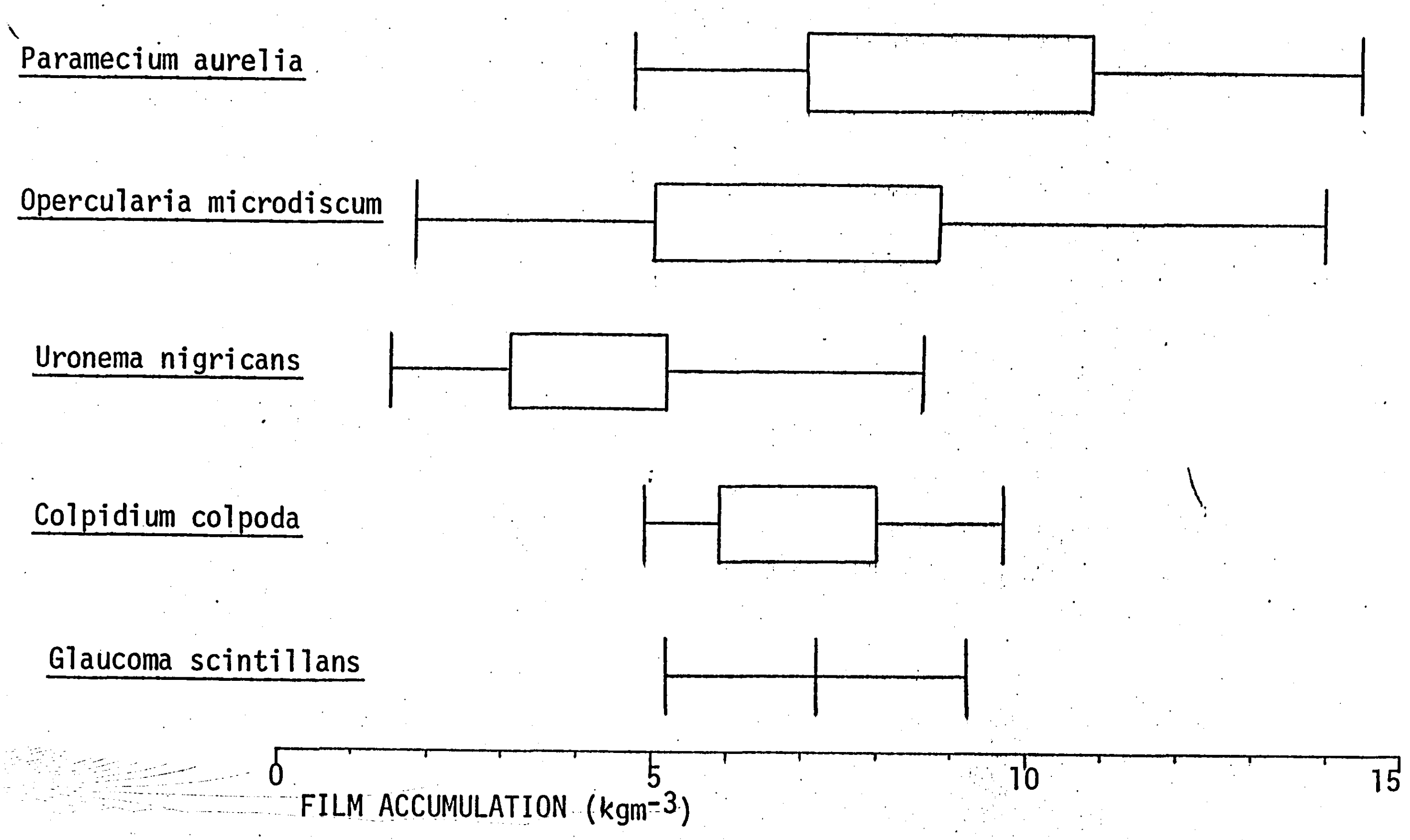


Table 5.18: Monthly frequency occurrence of dominant species

LOADING	LOW LOADING			HIGH LOADING			TOTAL		TOTAL DOMINANCE
FILTER	SLAG	MIXED	PLASTIC	SLAG	MIXED	PLASTIC	LOW LOADING	HIGH LOADING	
Uronema nigricans	2	5	5	1	1	2	12	4	16
Paramecium aurelia	5	1	4	1		1	10	2	12
Opercularia microdiscum	5	5	2	8	7	5	12	20	32
Colpidium colpoda			1	1	2	3	1	6	7
Glaucoma scintillans		1			1		1	1	2

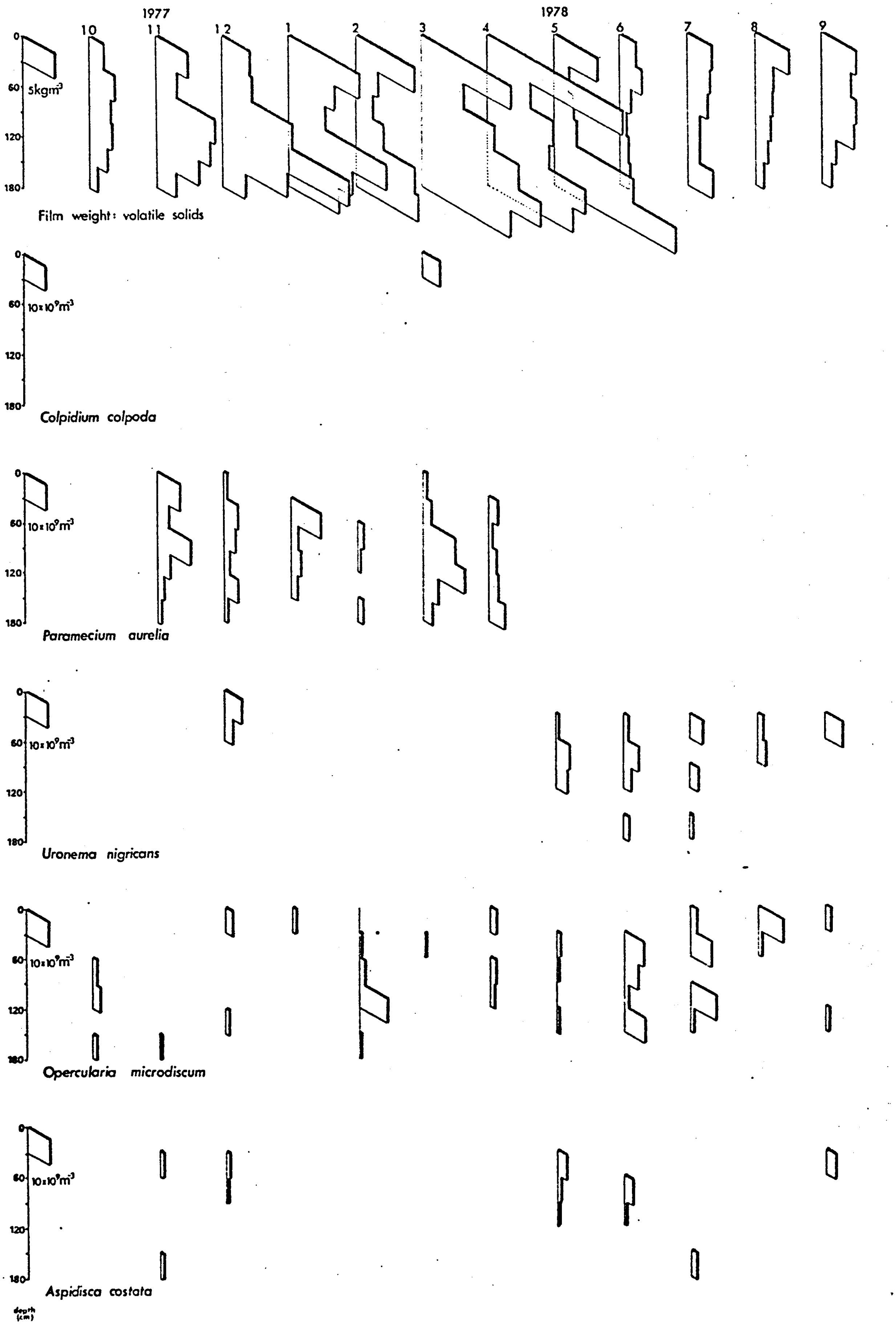
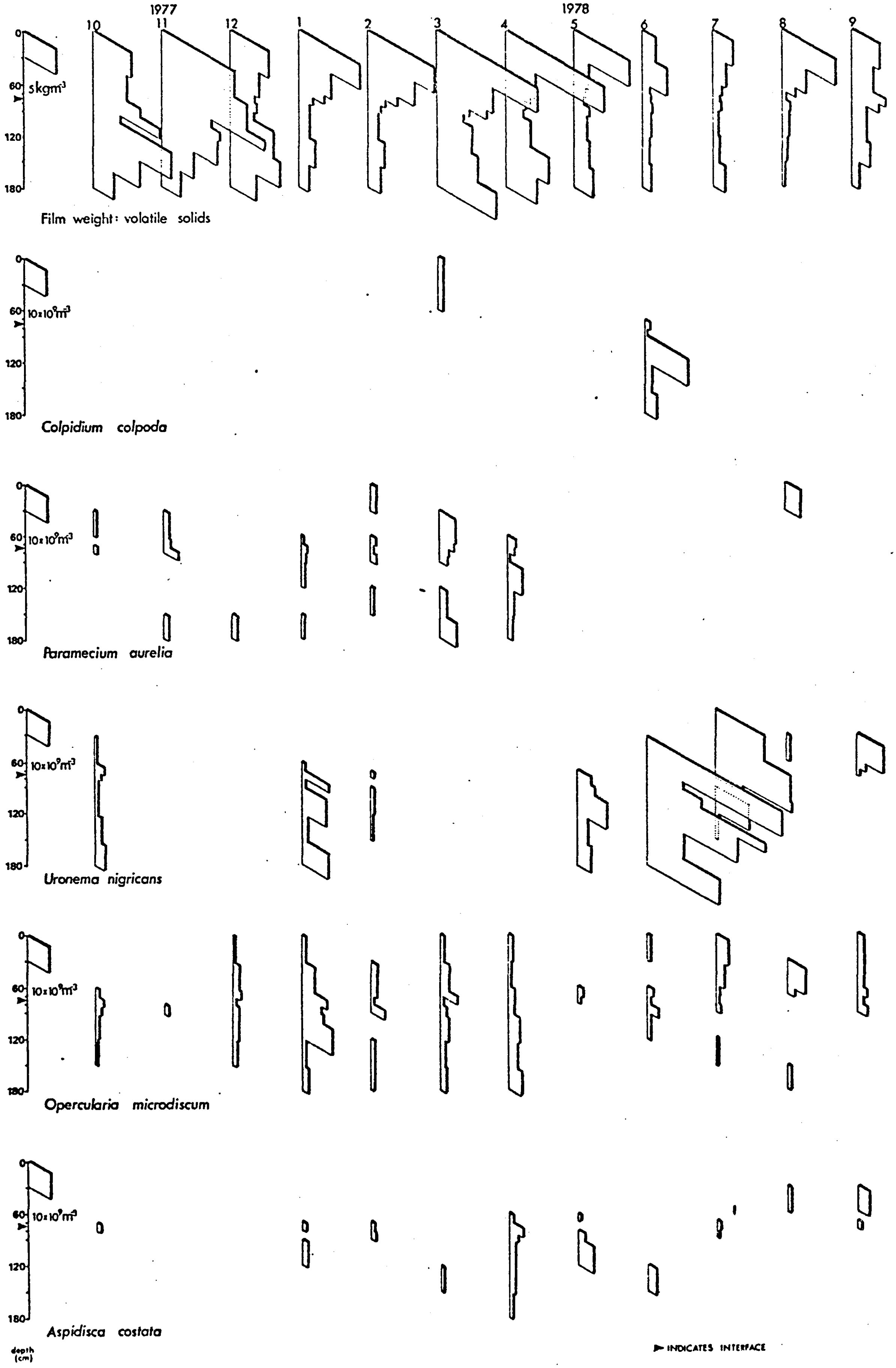


Figure: 5·13 Vertical Distribution of Film and Ciliated Protozoa. Low Rate Slag Filter.



Film weight: volatile solids

Colpidium colpoda

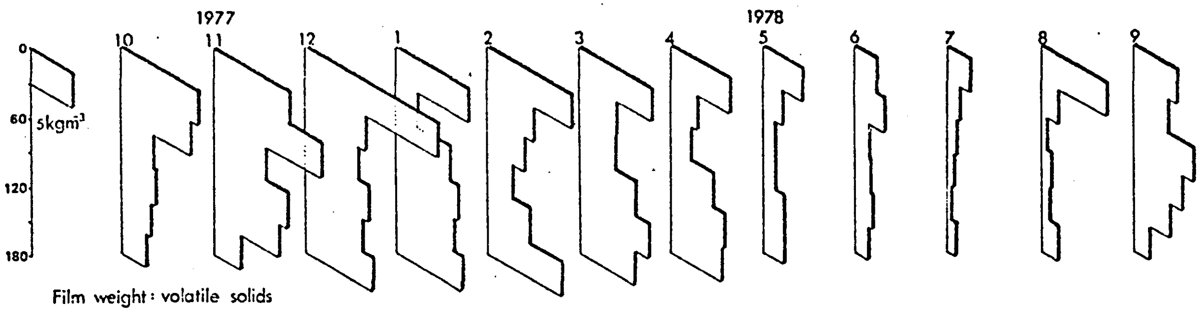
Paramecium aurelia

Uronema nigricans

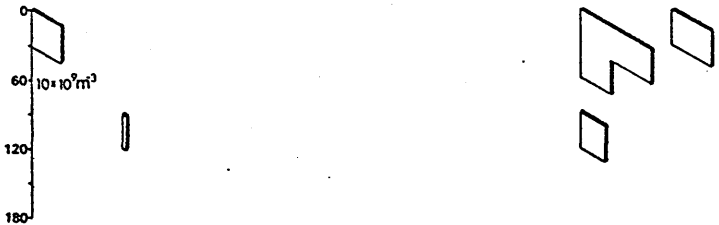
Opercularia microdiscum

Aspidisca costata

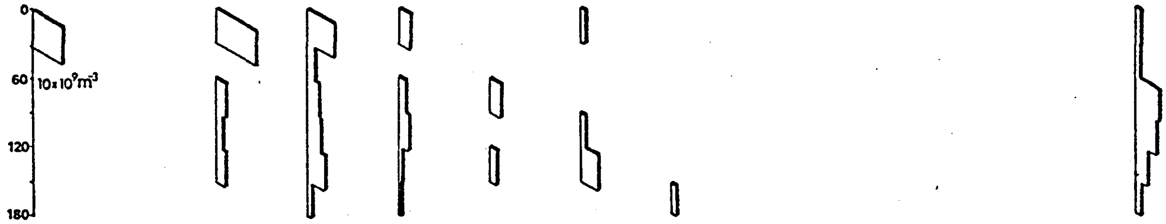
Figure: 5·14 Vertical Distribution of Film and Ciliated Protozoa, Low Rate Mixed Filter.



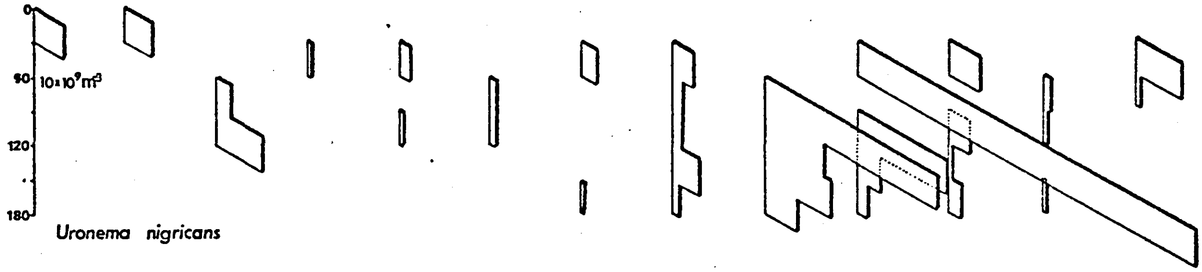
Film weight: volatile solids



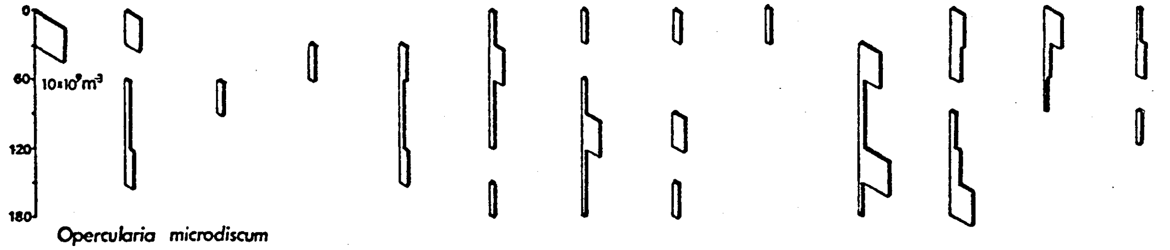
Colpidium colpoda



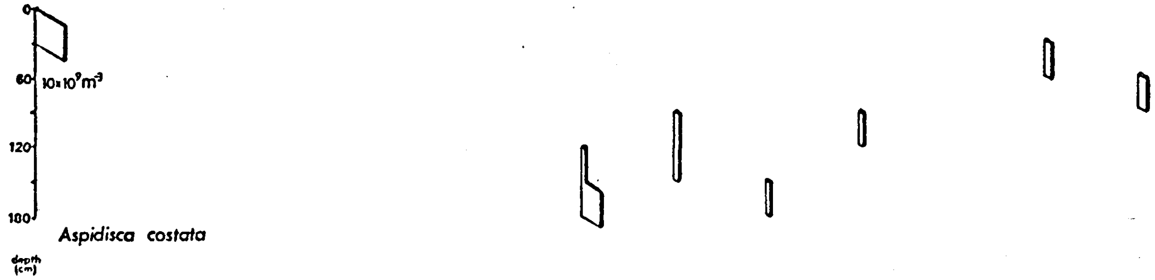
Paramecium aurelia



Uronema nigricans

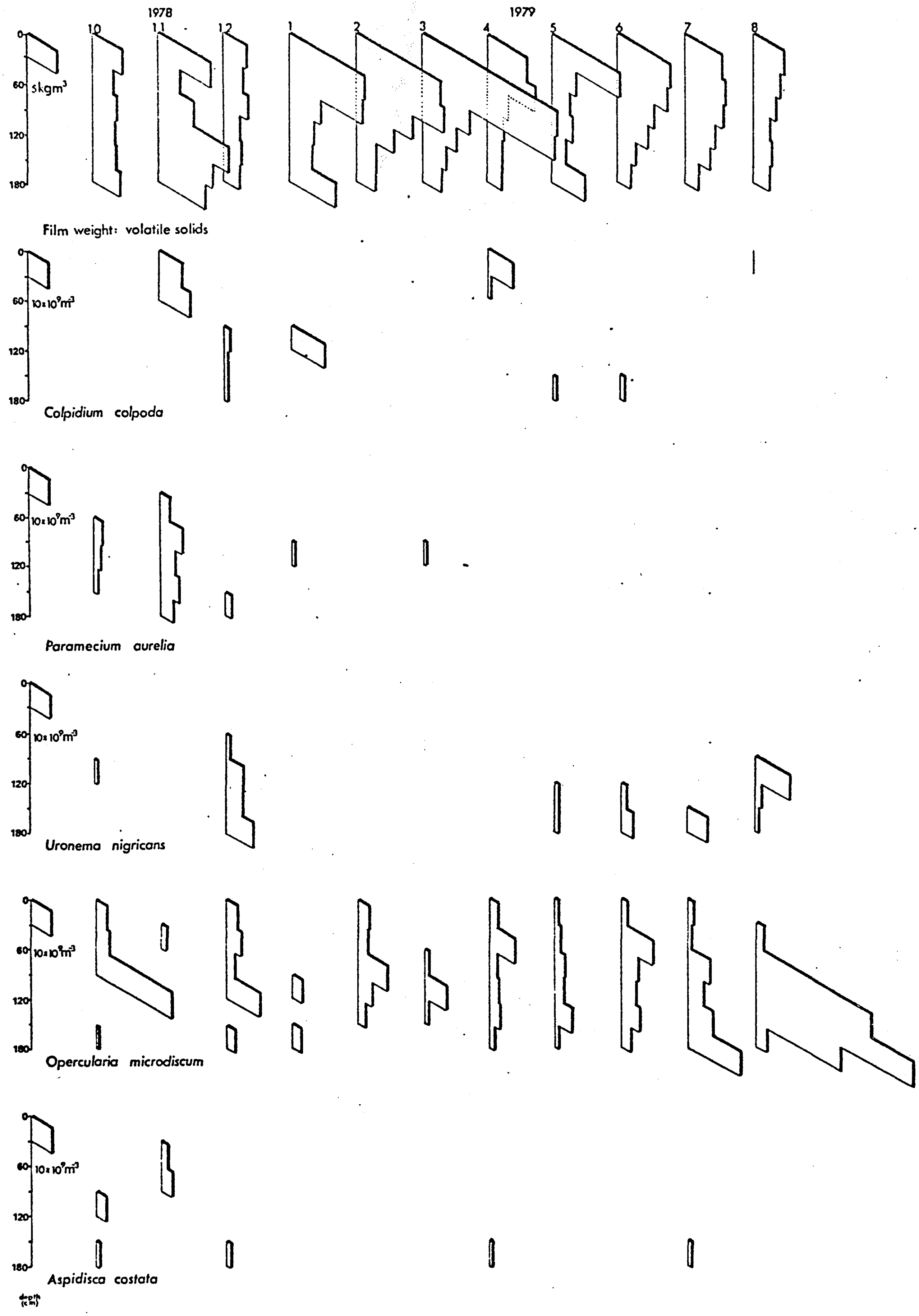


Opercularia microdiscum



Aspidisca costata

Figure: 5·15 Vertical Distribution of Film and Ciliated Protozoa; Low Rate Plastic Filter.



Film weight: volatile solids

Colpidium colpoda

Paramecium aurelia

Uronema nigricans

Opercularia microdiscum

Aspidisca costata

Figure: 5·16 Vertical Distribution of Film and Ciliated Protozoa. High Rate Slag Filter.

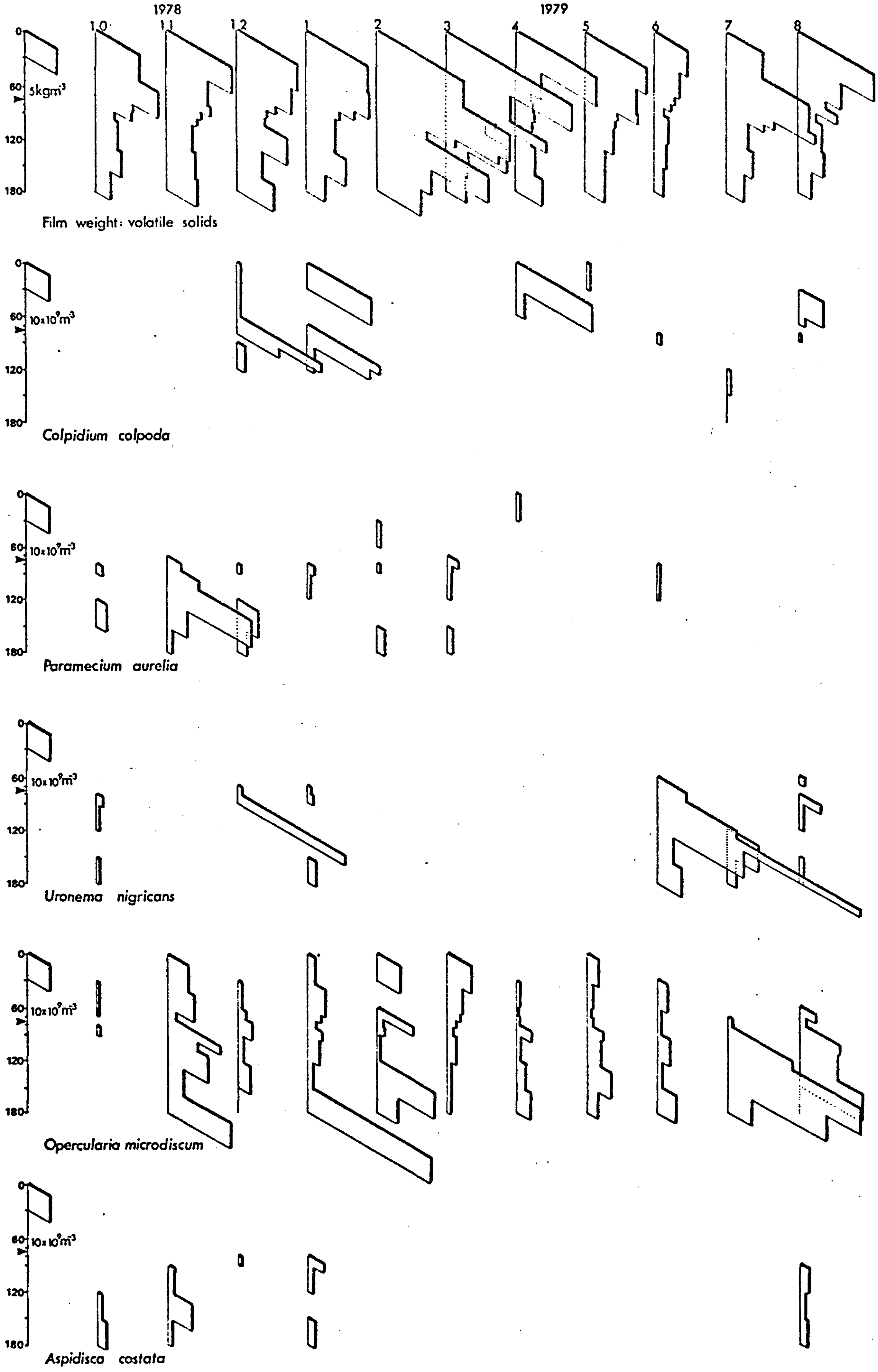


Figure: 5·17 Vertical Distribution of Film and Ciliated Protozoa, High Rate Mixed Filter.

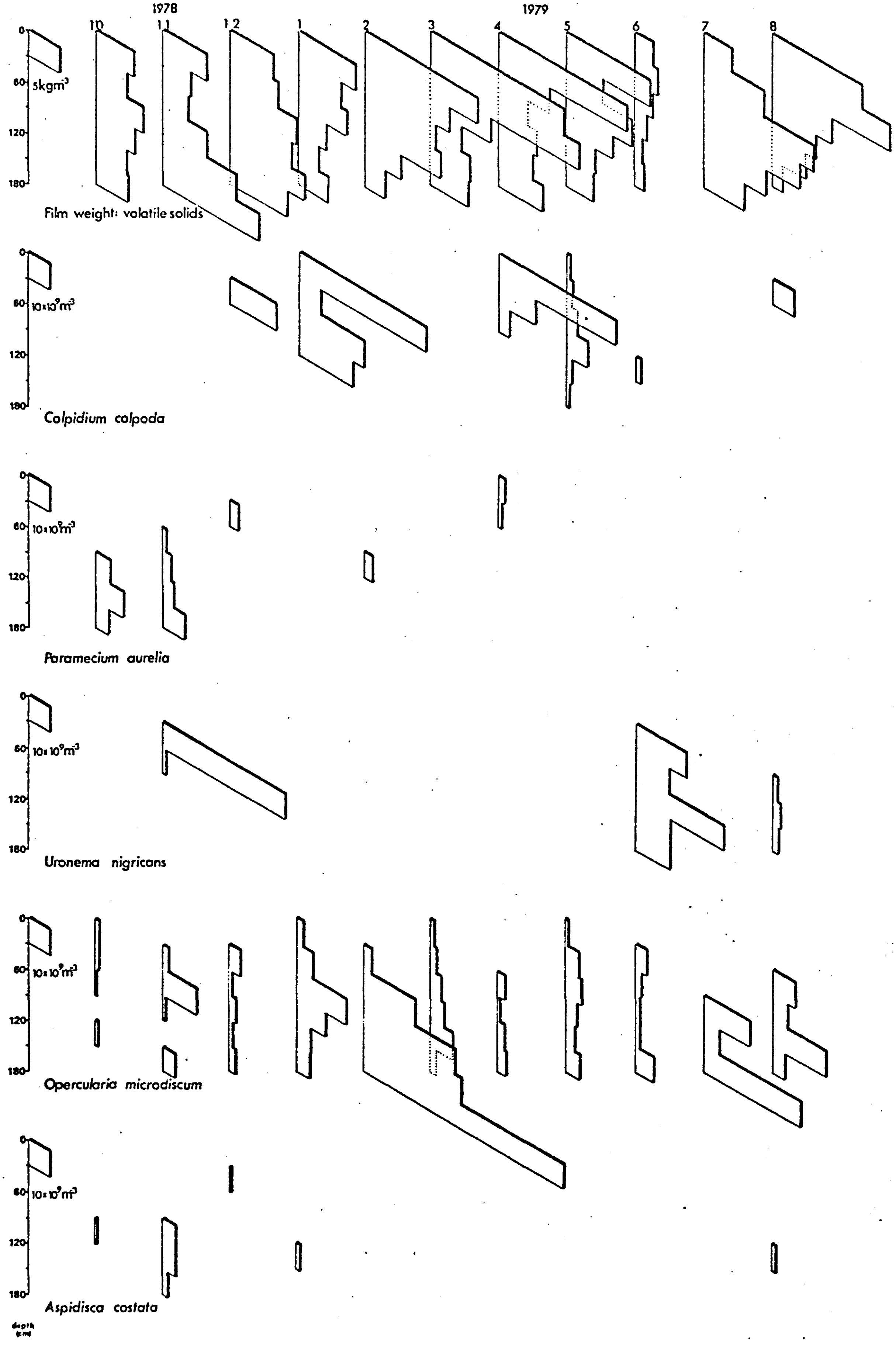


Figure: 5·18 Vertical Distribution of Film and Ciliated Protozoa, High Rate Plastic Filter.

5.5.2.1 Paramecium aurelia

Paramecium aurelia is a large holotrich between 120 - 150 µm in length which is some 50 - 100 µm smaller than Paramecium caudatum, which was associated with it in the pilot filters. Seasonal abundance of Paramecium aurelia (Figure 5.19) shows that there was a similar distribution in all three filters and that up to December 1978, some three months after the increase in loading, the peaks of Paramecium aurelia abundance corresponded with the maximum accumulation of film, being positively correlated at the 1% significance level (Figure 5.20). This species was more abundant in the winter months being rarely found from May to August. Seasonal fluctuations in abundance are reflected by the vertical distribution graphs (Figures 5.13 to 5.18) which show the species was found throughout the depth of the slag and plastic filters at the lower loading, but was restricted to the lower half of the filters at the commencement of the higher loading, the species being eventually washed out. Subsequent populations were restricted to the surface in small numbers, resulting in an overall reduction in the mean population density with the increase in loading, Table 5.19. Occasionally, Paramecium aurelia comprised of between 70 to 80% of the total ciliate population, when dominant, in both the slag and plastic filters, Table 5.20. It was found that the population density was also regulated by temperature (Figure 5.21), maximum abundance being recorded between 7 - 8^{o}C.

Paramecium aurelia was only recorded at low population densities during the latter nine months of the higher loading

Figure 5.19: Seasonal abundance of Paramecium aurelia in the pilot filters during low and high rate loadings.

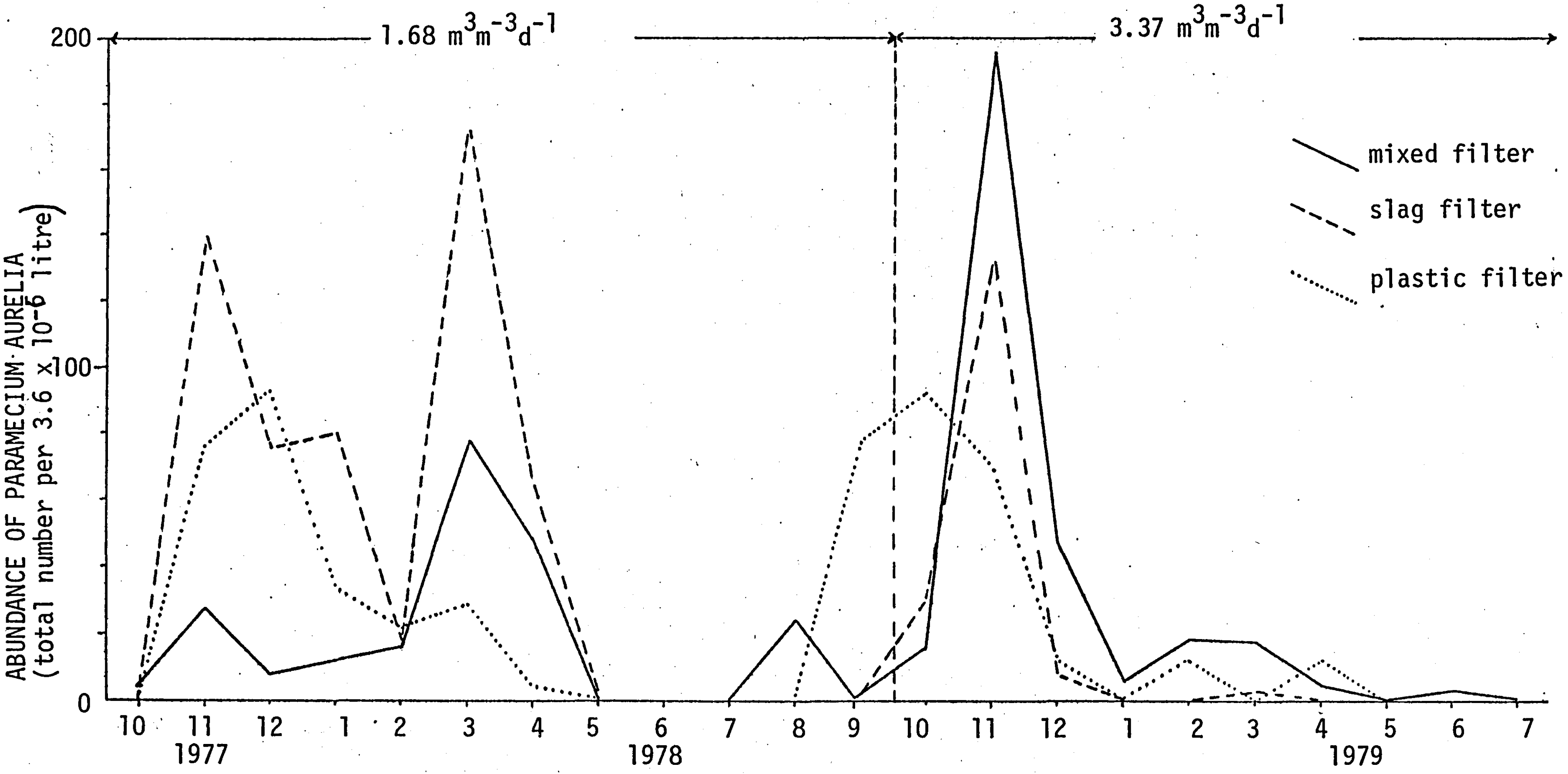


Figure 5.20: Computed distribution of Paramecium aurelia with film accumulation, recorded during the entire experimental period of 23 months in all the pilot filters.

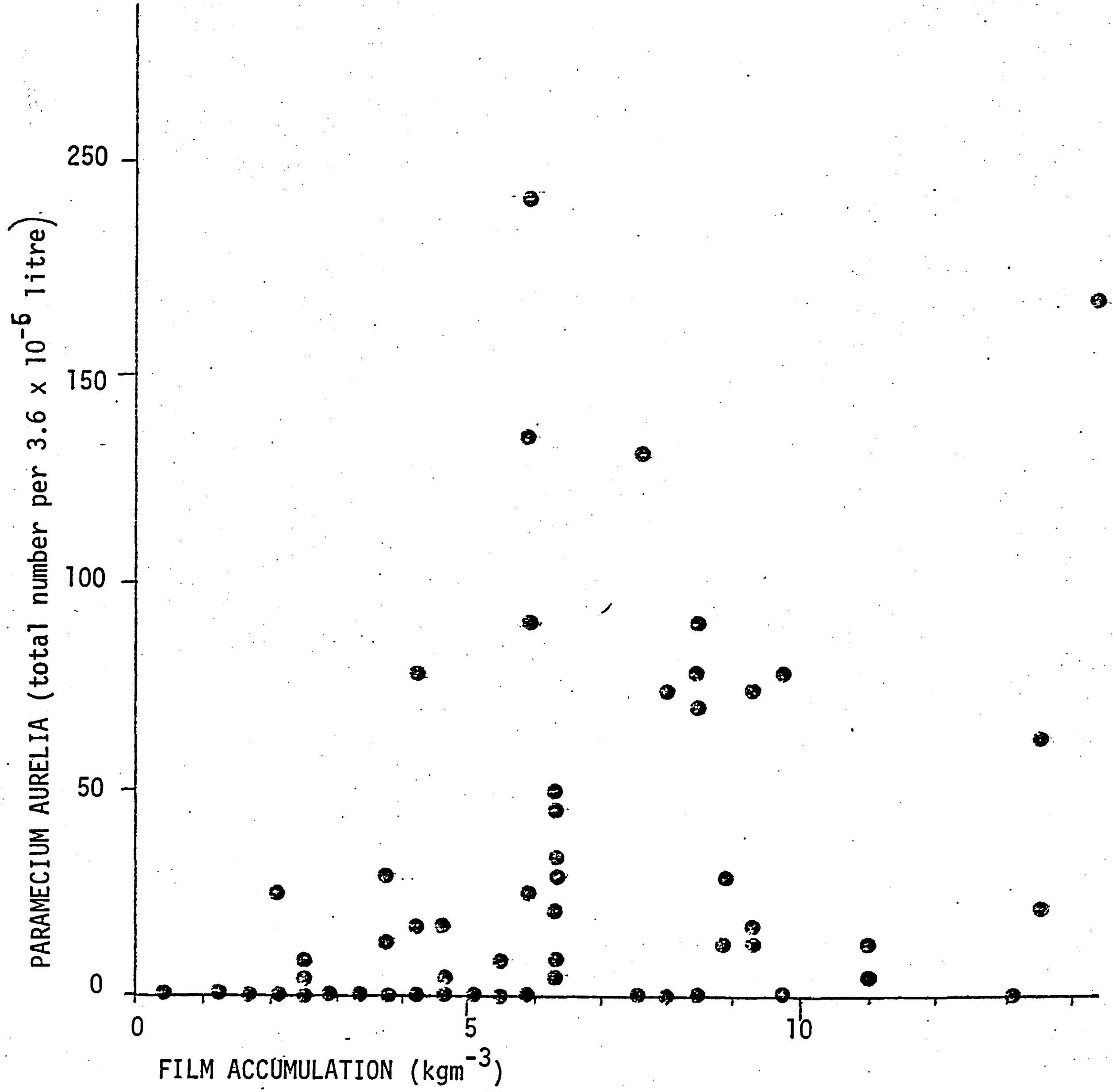


Figure 5.21: Computed distribution of *Paramecium aurelia* with temperature recorded during the entire experimental period of 23 months in all the pilot filters.

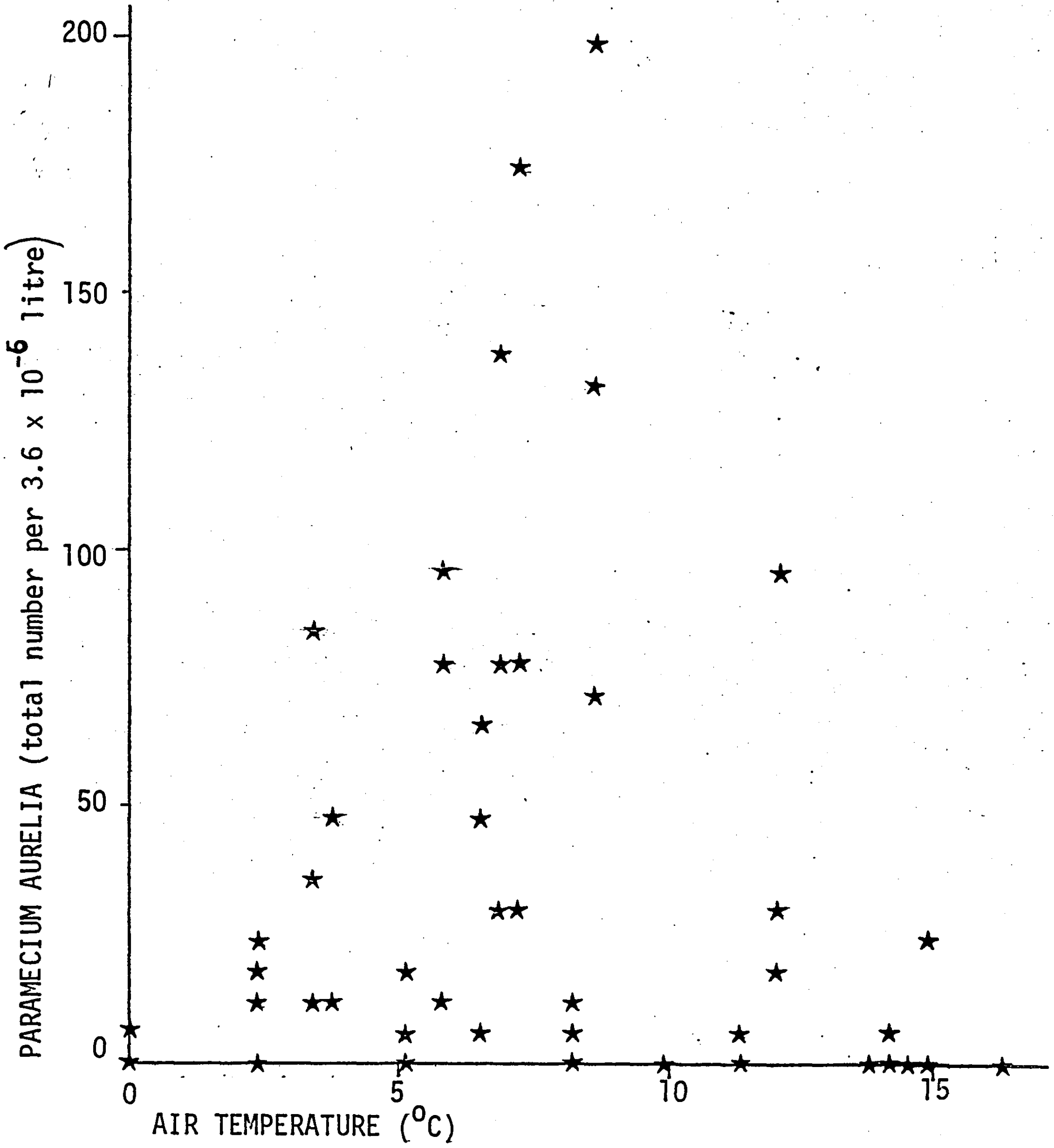


Table 5.19: Mean monthly abundance and range of component species of the pilot filters at different loadings

	SLAG FILTER		MIXED FILTER		PLASTIC FILTER	
	MEAN	RANGE	MEAN	RANGE	MEAN	RANGE
LOW LOADING						
Paramecium aurelia	45.8	172	18.1	78	27.9	93
Opercularia microdiscum	30.4	64	34.2	112	27.5	66
Colpidium colpoda	2.3	28	9.3	97	16.7	152
Uronema nigricans	18.3	52	104.8	656	113.8	564
Chilodonella uncinata	7.1	36	6.8	37	13.1	40
Glaucoma scintillans	7.9	36	6.4	40	8.3	42
HIGH LOADING						
Paramecium aurelia	15.6	132	27.9	196	18.0	92
Opercularia microdiscum	140.0	628	168.6	533	167.5	754
Colpidium colpoda	19.5	88	41.7	189	87.7	460
Uronema nigricans	22.2	104	47.7	359	57.8	400
Chilodonella uncinata	9.3	32	11.9	73	5.5	24
Glaucoma scintillans	9.5	50	11.2	92	3.5	38

period. Its lack of success was due, partly, to an inability to cope with the increased loading and also to competition from either *Opercularia microdiscum* or *Colpidium colpoda*, both of which appear to be highly successful at the higher loading.

5.5.2.2. *Uronema nigricans*

Another holotrich, which, like *Paramecium aurelia*, was more successful during the period of lower loading was *Uronema nigricans*. This is also a very active species, but is smaller than *Paramecium aurelia*, being only 20 - 35 μm in length. Negatively correlated to *Paramecium aurelia*, *Uronema* sp. was found in greatest numbers during the summer when *Paramecium aurelia* was absent from the pilot filters, and also in smaller numbers during the early winter (Figure 5.22).
The abundance of *Uronema nigricans* was reduced during periods of heavy film accumulation being closely associated with light film conditions, being negatively correlated with the film at the 1% significance level ($P < 0.01$).

The preference of *Uronema nigricans* for light weights of film (< 5 kg m^{-3}) affected its vertical distribution within the filters (Figures 5.13 - 5.18) and it can be seen how *Paramecium aurelia* and *Uronema nigricans* are rarely found together. *Uronema nigricans* was usually restricted to the lower half of the filters at the higher loading, and in the mixed filter maximum abundance was recorded at the top of the slag portion near the interface region. The species was found in greatest abundance in both the plastic and

Figure 5.22: Seasonal abundance of <u>Uronema</u> <u>nigricans</u> in the pilot filters during low and high rate loadings.

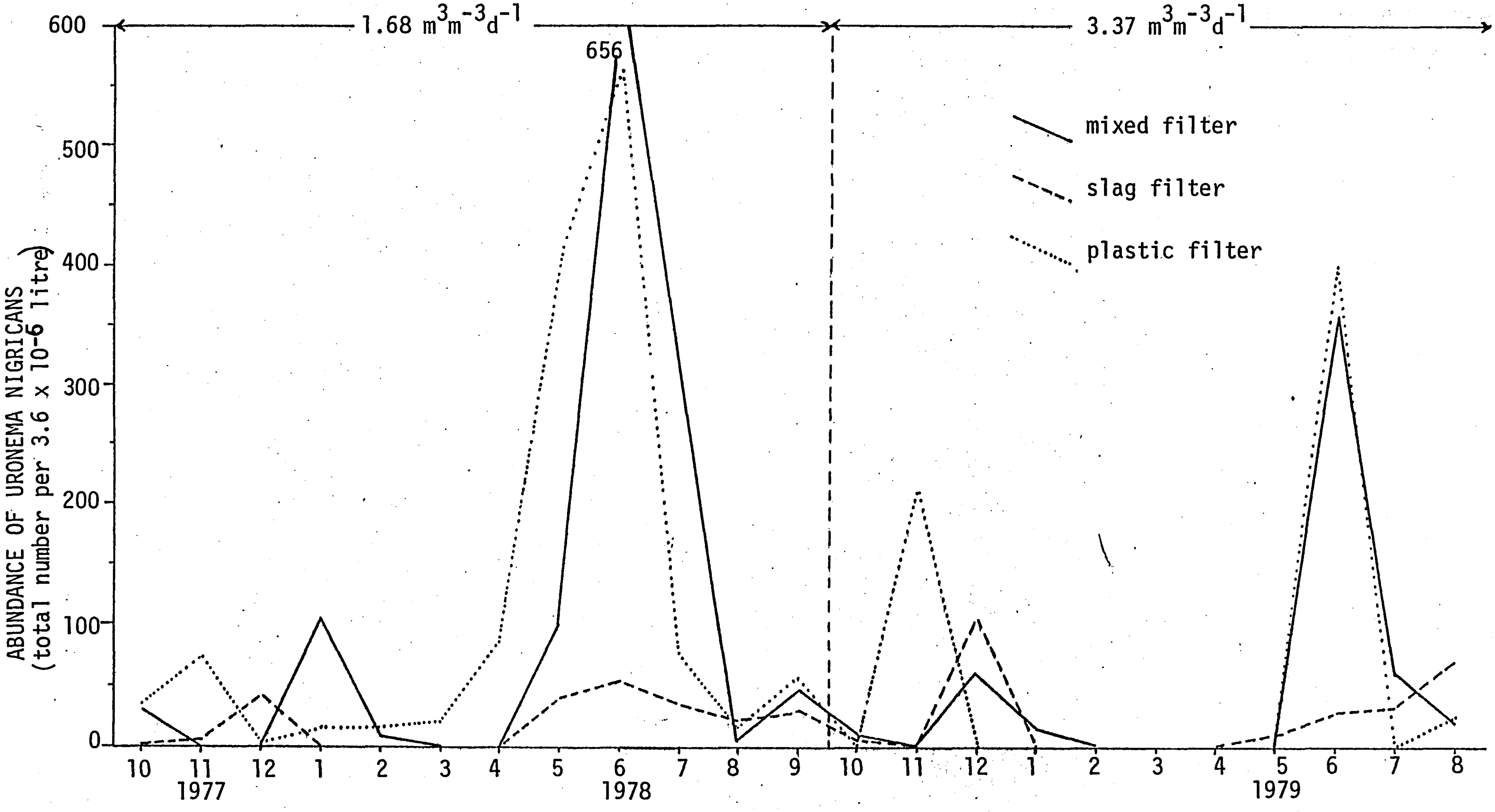


Table 5.20: Maximum percentage of the total ciliate population comprised by individual component species in each filter during both loadings.

PERCENTAGE OF TOTAL POPULATION	SLAG FILTER	MIXED FILTER	PLASTIC FILTER
>90	Opercularia microdiscum	Opercularia microdiscum	Opercularia microdiscum
80-89		Uronema nigricans	Uronema nigricans
70-79	Paramecium aurelia		Paramecium aurelia
60-69			Colpidium colpoda
50-59	Uronema nigricans Colpidium colpoda	Colpidium colpoda	
40-49		Paramecium aurelia Glaucoma scintillans	
30-39			
20-29	Glaucoma scintillans		Glaucoma scintillans Chilodonella uncinata
10-19			
0-9			

mixed filters, although it was far less common in the slag filter (Table 5.19). This may well be due to the lower voidage and the relatively high accumulation of film within the voids normally found in the slag medium. The higher loading reduced overall population density as was shown previously in Figure 5.22, and suppressed the normal summer peaks in population density.

Uronema nigricans was positively correlated with temperature, maximum population densities being recorded between 10-14°C. Other significant correlations were recorded at the 0.1% significance level with the ciliates and psychodid larvae, with effluent BOD with a significance of 1% and negatively correlated with *Sphaerotilus natans* at the 10% significance level. These relationships can all be explained by this species being abundant during low film conditions in the summer, which is when *Sphaerotilus natans* is at its lowest abundance and when psychodid larvae are at maximum population density. As such large numbers of individuals are involved compared with the numbers of *Paramecium aurelia* recorded, it was to be expected that a strong correlation would exist between the total ciliate population and the numbers of *Uronema nigricans* recorded. Whether *Uronema* sp. plays a vital role in the improvement of effluent quality either by flocculation or predation, or whether this is due to other factors is not clear; and so the significance of the positive correlation with effluent BOD quality is not completely understood. Although Curds *et al.*, (1968) showed that the major role of the Protozoa in the activated sludge process was to clarify the effluent by flocculation of suspended matter and predation of bacteria present in the influent sewage.

5.5.2.3 Opercularia microdiscum

Unlike all the other dominant ciliate protozoans found, Opercularia microdiscum is a sessile organism attached to the substrate by a non-contractile stalk and feeding passively (Plate 5.4). It is unable to search for food and unlike the holotrichs it is unable to move away from any adverse environmental changes, predators or the activities of the invertebrate grazing fauna except in its telotroch phase. The population density of the opercularian remained relatively small during the lower loading period, but when the loading was increased then the mean population density increased five fold (Table 5.19), occasionally making up between 90 - 100% of the total ciliate population in all three filters (Table 5.20). The distribution graph, Figure 5.23, shows that at neither loading was Opercularia microdiscum able to compete successfully with Uronema nigricans during periods of light film accumulation. Opercularia microdiscum was however found in greatest abundance during January and February and again during July and August when the film accumulation was heavy. Correlation analysis showed positive and significant associations existed between the peritrich and the zoogloeal bacteria and Subbaromyces splendens at the 0.1% significance level, with the psychodid larvae (which is closely associated with film accumulation) at the 1% significance level and at the 10% level with Sphaerotilus natans. Interestingly all the sedentary ciliates attached themselves to a variety of substrates, including zoogloeal bacteria, fungal hyphae, insect debris and the larger filaments of bacteria. When the interactions between

PLATE 5.4: Dominant ciliate protozoan Opercularia microdiscum (X500)

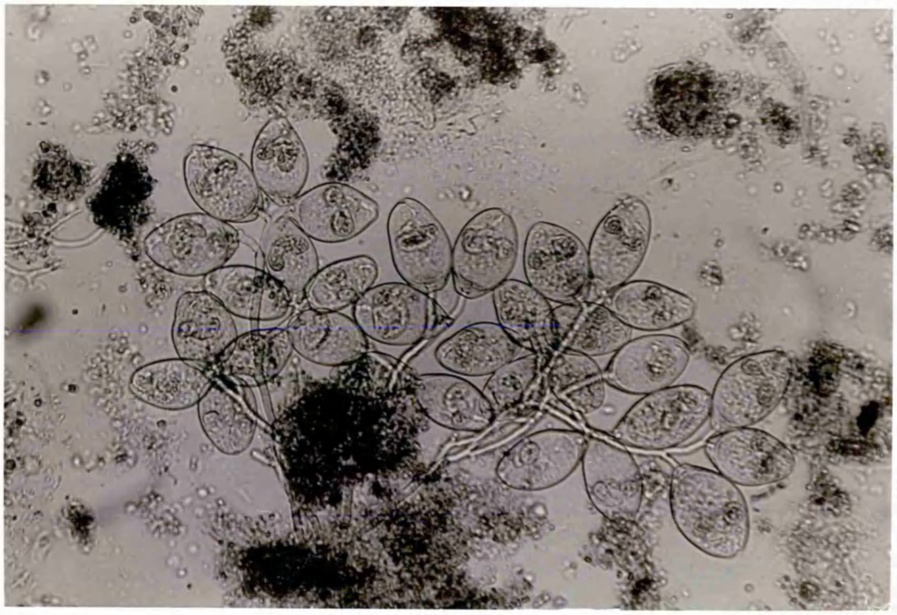


PLATE 5.5: Colonies of Opercularia microdiscum attached to the hyphae of the fungus Subbaromyces splendens (X500)

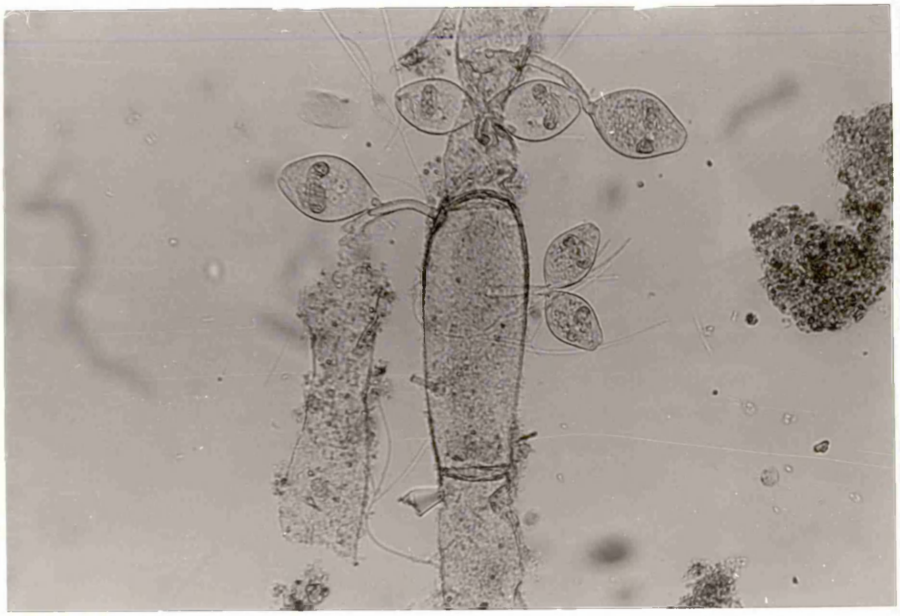
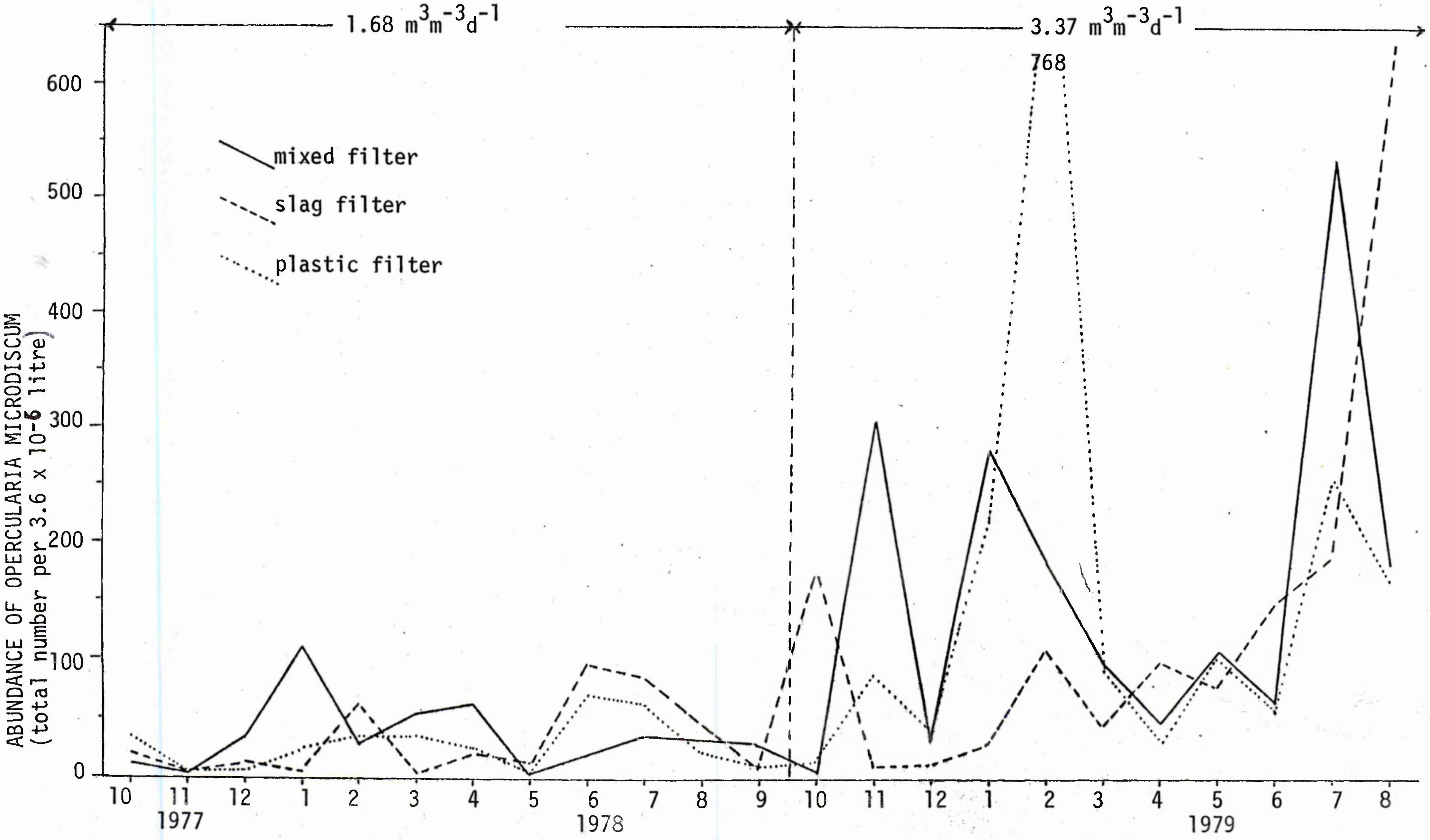


Figure 5.23: Seasonal abundance of Opercularia microdiscum in the pilot filters during low and high rate loadings.



the various species were studied further, it became apparent that *Opercularia microdiscum* was restricted by competition for food and space at the lower loading and limited only by lack of suitable surfaces for attachment at the higher rate of loading. For example in March during the higher loading period, the film became unstable and sloughed, reducing the population density of the peritrich and removing most of the suitable substrate required for attachment. At this stage the free-swimming holotrich *Colpidium colpoda* became the most abundant ciliate temporarily, due to the decreased competition from *Opercularia microdiscum*. Temperature appears to be unimportant to this species so long as there is enough suitable material for attachment. It appeared that with reduced competition from *Paramecium aurelia* at heavy film accumulations it is able to extend its dominance from the areas of moderate film build-up during the lower loading, to heavy film accumulations at the higher loading rates.

In all the filters *Opercularia microdiscum* was found throughout the depth of the filters during the low loading except at depths of heavy film accumulation or high abundance of *Paramecium aurelia*. With the increase in the loading rate however, the population increased mainly in the lower half of the pilot filters although still avoiding those areas of heaviest film accumulation (Figures 5.13 - 5.18). In all the filters, especially in the plastic filter, there was a clear association between the depth at which *Subbaromyces splendens* was found and the population density of *Opercularia microdiscum*, especially during the winter and spring, the species using the tough mycelium of the fungus for attachment.

This species has previously been associated with low concentrations (Plate 5.5) of organic matter (Barritt, 1940; Barker, 1946; Tomlinson and Snaddon, 1966). More recent work has suggested that *Opercularia microdiscum* has a more general distribution (Curds, 1969; Curds and Cockburn, 1970; Hussey, 1975). Learner (1975) also noted the importance of this species in waste water treatment and found it to be the dominant organism in the majority of the filters examined. The results of the present investigation are in agreement with those of Learner, who recorded a positive correlation of the organic and hydraulic loading with *Opercularia microdiscum*, noting that greatest abundance was recorded in filters receiving loads in excess of 0.25 kg BOD $m^{-3}d^{-1}$. Some years earlier, Bruce and Merkens (1970) had found large numbers of *Opercularia microdiscum*, but no other ciliate species, in experimental filters receiving an organic load of 2.0 kg BOD $m^{-3}d^{-1}$, and a hydraulic loading of 6 $m^3m^{-3}d^{-1}$.

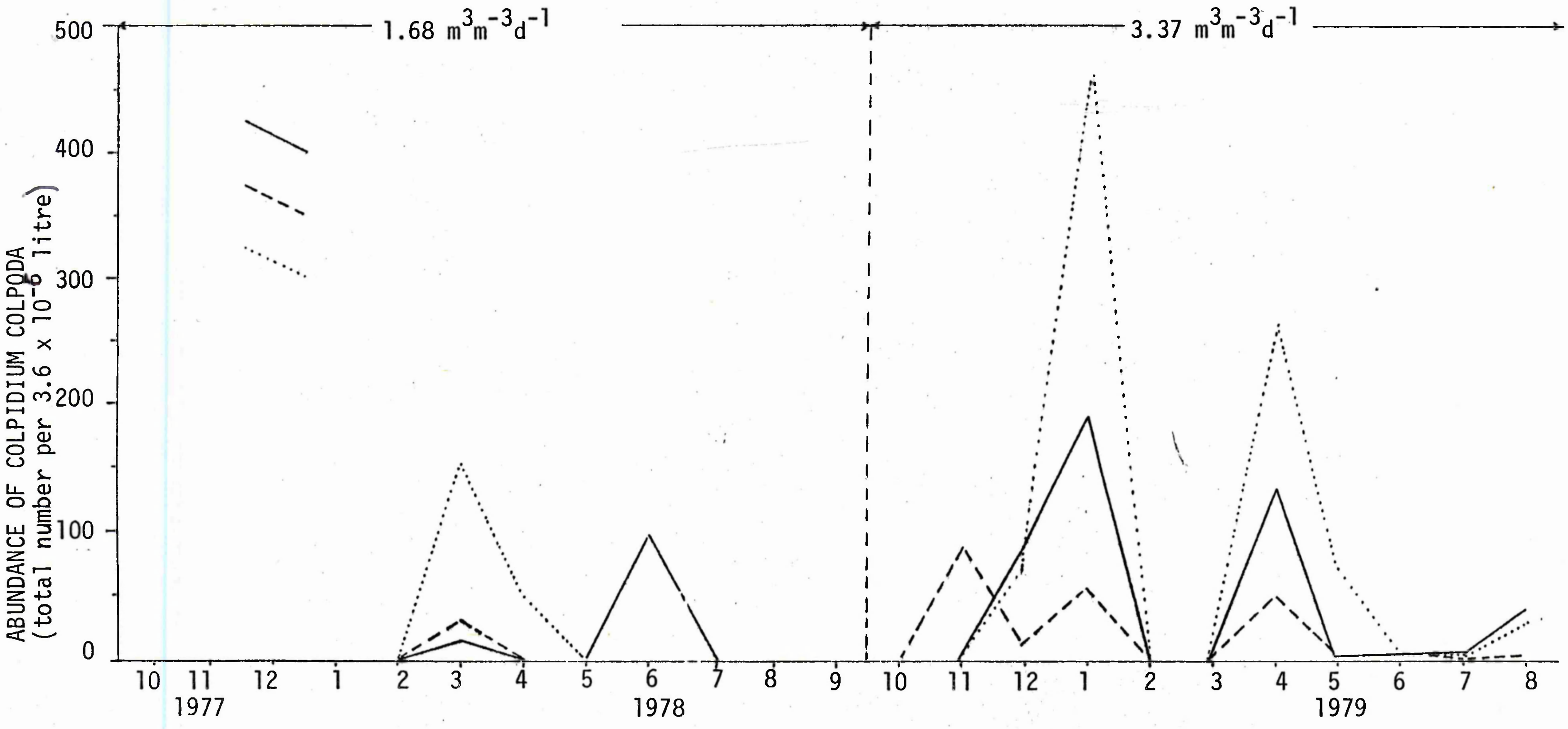
A clear association with organic loading has also been observed in another opercularian, *Opercularia coarctata*, which proved to be the commonest ciliate present in two experimental high rate filters using Flocor RC filter medium, loaded at 0.24 kg BOD $m^{-3}d^{-1}$($1.2\ m^3m^{-3}d^{-1}$) and 0.55 kg BOD $m^{-3}d^{-1}$($2.4\ m^3m^{-3}d^{-1}$)(Wheatley, 1976). From the survey conducted by Learner (1975) it would appear that such increases in population at the higher organic loading, as reported by Wheatley, would normally be associated with *Opercularia microdiscum* rather than *Opercularia coarctata*.

Curds (1973, 1975) divided the waste water protozoan fauna into three groups according to their habitat. Those which swim freely in the liquid phase and so are prone to be washed out, those which crawl over the surface of the film and are occasionally washed out, while thirdly, those which are attached directly to the film or some other material and which are only removed during sloughing. Obviously the habitat preference of those species found in percolating filters is important in survival terms and so dictate which species are to be successful. Bungay and Bungay (1968) found that a peritrich such as Opercularia microdiscum is always present even after sloughing in quite large numbers, and therefore potentially able to build up the population rapidly. Though in any given situation, in the competition between species for food, the organism which is fastest to grow and reproduce under the prevailing conditions will become dominant (Moser, 1958).

5.5.2.4 Colpidium colpoda

The abundance of Colpidium colpoda declined when the population density of Paramecium aurelia increased. Similar in shape and behaviour, this holotrich is only slightly smaller than Paramecium aurelia, ranging from 100 to 130 μm. Equally as active, Colpidium colpoda was normally found during the same periods as Paramecium aurelia. Abundance was greatest at the higher loading possibly due to reduced competition from Paramecium aurelia, reaching maximum densities during January and April. In February and March, when the film accumulation was at its maximum the holotrich was replaced by a large population of Opercularia microdiscum (Figure 5.24). Colpidium colpoda was most successful during the moderate film accumulations,

Figure 5.24: Seasonal abundance of Colpidium colpoda in the pilot filters during low and high rate loadings.



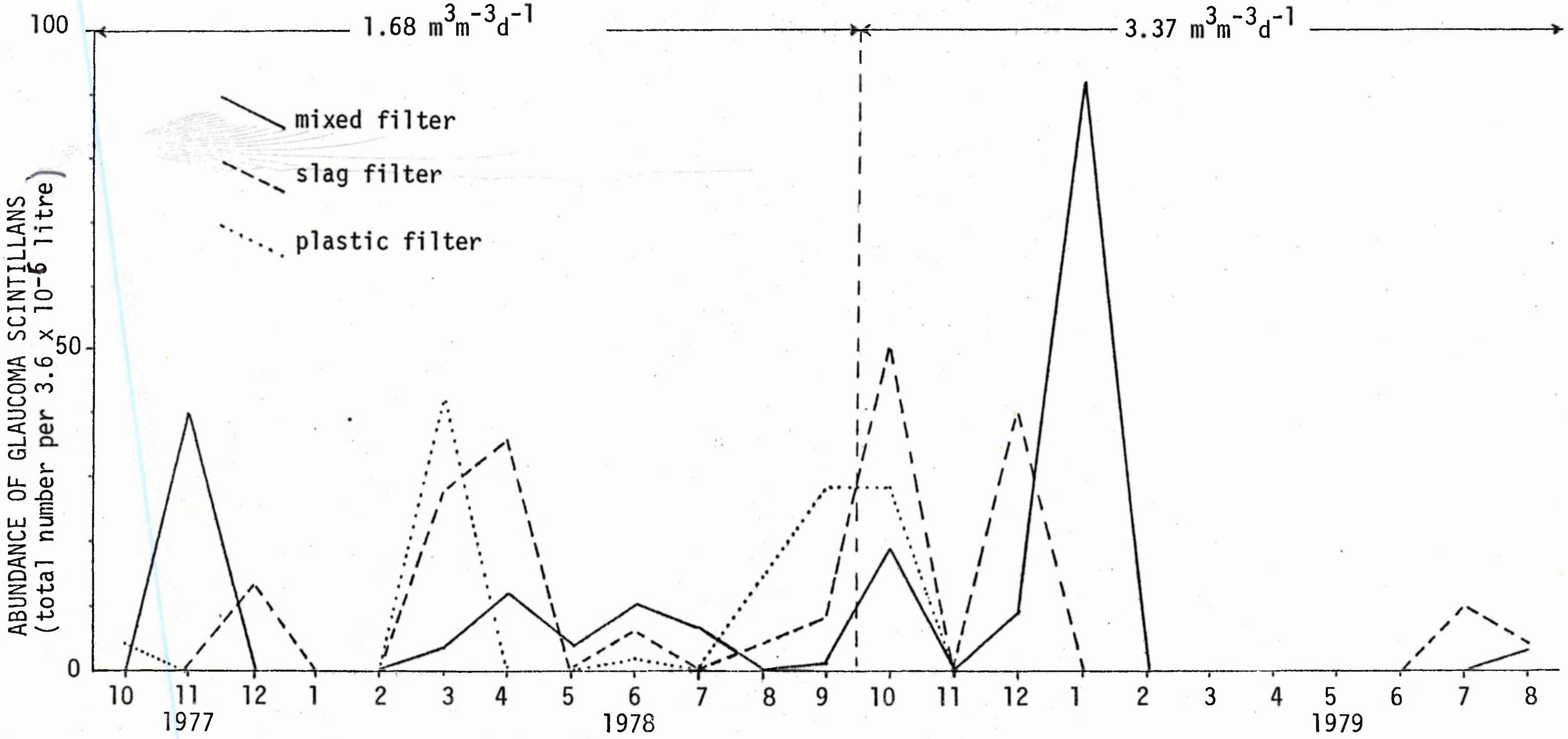
reaching maximum abundance between 4 to 9 kg m^{-3} of film, which is well illustrated by the vertical distribution graphs (Figures 5.16 to 5.18). The action of the invertebrate grazers was clearly observed to reduce the weight of the accumulated film, allowing Colpidium colpoda to temporarily increase in abundance before disappearing as the film accumulation was reduced even further.

At the higher loading the sequence of species from heavy to light film accumulation can be seen quite clearly, from Opercularia microdiscum to Colpidium colpoda and then to Uronema nigricans at the lightest film weights, each peak in the population density clearly separated from the next. Colpidium colpoda and Opercularia microdiscum are both high rate species and compete directly, so that when one species is found in large numbers the other is found in small numbers. It does seem, however, that Opercularia microdiscum is more successful than Colpidium colpoda when there are enough suitable surfaces for attachment.

5.5.2.5 Glaucoma scintillans

This species is a free-swimming holotrich between 35 and 50µm in length. It is generally found in low numbers (Table 5.19), being more abundant in the slag and mixed filter at the higher loading (Figure 5.25). There is a clear interaction between Glaucoma sp. and Uronema sp., the former being more successful at the moderate film weights (5 to 9 kg m^3) while Uronema sp. was most abundant during periods of low film accumulation (<5 kg m^3). Glaucoma sp. was effectively absent from the plastic filter throughout the higher loading, never being

Figure 5.25: Seasonal abundance of Glaucoma scintillans in the pilot filters during low and high rate loadings

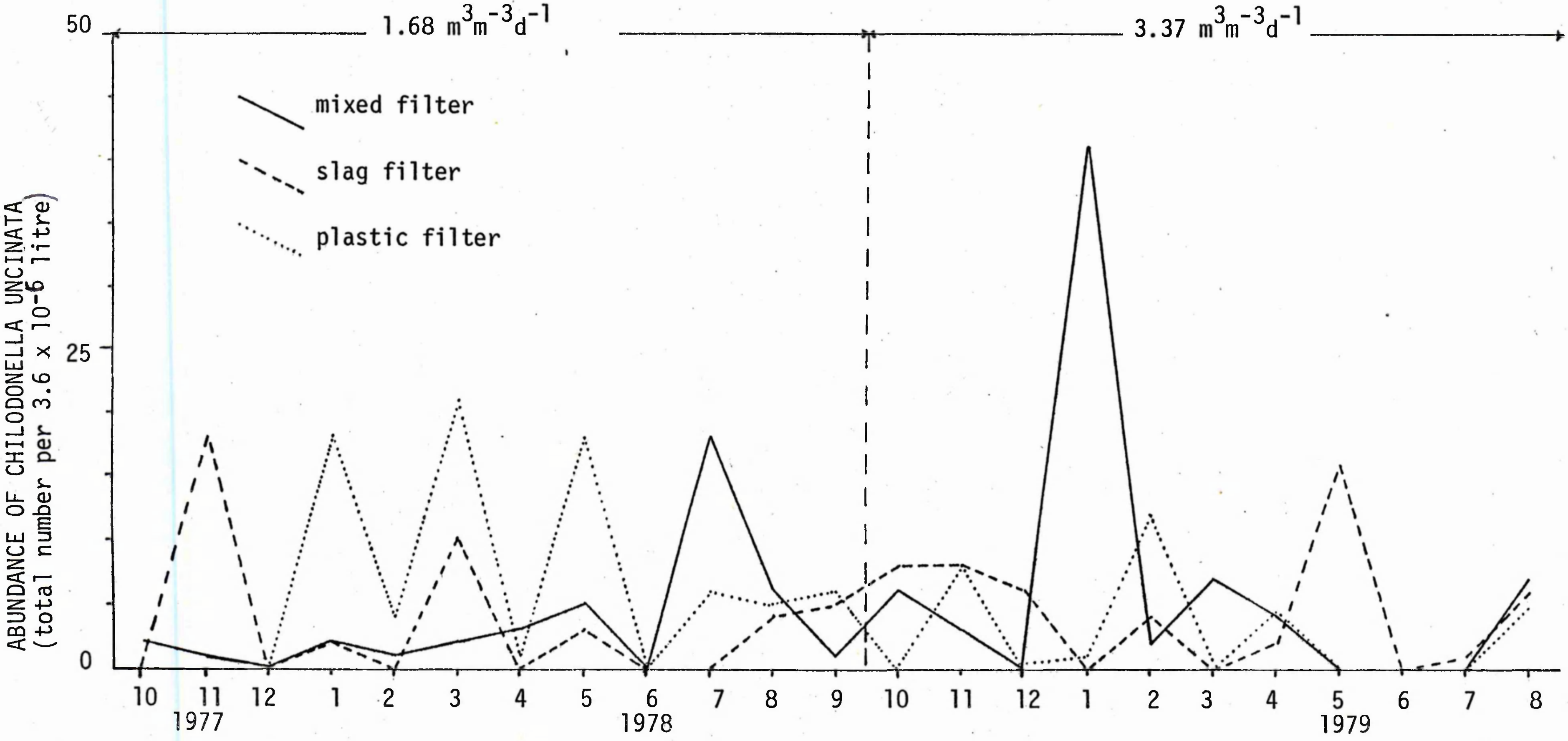


recorded at times of heavy film accumulation in any of the filters. The interactions between these two similar holotrichs appears to be solely dependent on the film accumulation as there was no obvious relationship between *Glaucoma* sp. and temperature or any other measured environmental parameter. *Glaucoma scintillans* is correlated significantly and positively with one other species only, this being *Chilodonella uncinata* ($P < 0.01$). Although no computed relationship could be found between *Colpidium colpoda* and *Glaucoma* sp., the two species were often recorded together. The extremely low abundance of *Glaucoma scintillans* in the plastic filter during the higher loading could, for example, be due to the extremely high population densities of *Colpidium colpoda* over the same period. The results show *Glaucoma* sp. is competing directly against the other holotrichs and in particular *Colpidium colpoda* and also *Uronema nigricans*. The seasonal abundance of *Chilodonella uncinata* is shown in Figure 5.26.

5.5.3 COMMUNITY STRUCTURE

Numerous authors have reported on the vertical distribution of various ciliate species within percolating filters (Johnson, 1914; Lackey, 1924, 1925; Frye and Becker, 1929; Cutler *et al.*, 1932; Holtje, 1943; Barker, 1946; and more recently Ingram and Edwards, 1960). Generally they found that particular species tended to predominate at certain depths, stratification being dependent on any one parameter or a mixture of environmental and biological interactions. Liebmann (1951) suggested that it was mainly due to nutrition while Liebmann (1949) put forward the saprobity theory. Liebmann (1949) suggested that

Figure 5.26: Seasonal abundance of Chilodonella uncinata in the pilot filters during low and high rate loadings.



Vorticella microstoma, Glaucoma scintillans and Colpidium colpoda were restricted to the surface (polysaprobic) while Paramecium caudatum, Chilodonella uncinata, Uronema nigricans, Opercularia coartata and Podphyra fixa were all typical of middle regions of the filter (α-mesosaprobic). Aspidisca costata was recorded in the lower regions of the filter and was associated with the lowest levels of organic matter (β-mesosaprobic).

In the present study Opercularia microdiscum, Paramecium aurelia were found at all depths at the lower loading, while Colpidium colpoda was found in the upper regions where the organic load was strongest. Aspidisca costata was limited to the lower half of the pilot filters, and was continuously washed out of the filters in large numbers. At the higher loading rate however, the dominant species were more definitely restricted to particular depths. The results were in general agreement with those of Liebmann (1949) with Colpidium colpoda found in the top and middle regions of the pilot filters, Opercularia microdiscum in the middle and lower regions, while Aspidisca costata and Uronema nigricans were restricted to the lower portion of the filters. It was interesting to find that the Suctoria, which are mainly predators on other protozoan species, were found in the middle and lower areas of the filters where they would have maximum opportunity to come into contact with suitable prey. From the present investigation it is apparent that no individual reason can account for the stratification of the various protozoan species, but that it is the result of a number of environmental (e.g. organic load, temperature, hydraulic flow, food availability, available surface area) and biological parameters (e.g. competition, predation, type of film) which change continuously altering the distribution of the protozoans within the film.

Changes in community structure during the year were examined by Barker (1942) who recorded the changes in the fauna of filters over twelve months. Generally he found the protozoan population to be more constant and abundant in spring and summer, and more erratic and with a lower population density during the colder autumn and winter months. Although he found certain species throughout the year, several species were only observed seasonally. For example _Chilodonella_ sp. was found in the winter while _Uronema_ sp. was most prominent in the summer. _Podophyra_ spp were found in maximum numbers in the spring and autumn. The results from the pilot filters showed that all the dominant species exhibited seasonal variations, although perhaps this is due to other experimental factors such as film accumulation, and interspecific competition rather than just temperature. The apparent seasonal incidence of certain species made by Barker (1942) was also found in the pilot filters, with _Uronema_ sp. restricted to the summer months while the Suctoria and _Podophyra_ spp. in particular were found in the late winter, spring and autumn.

In conclusion the different characteristics of the media in the mixed filter does provide a wider variety of habitats, increasing the diversity of ciliate species compared to the single medium filters. The community structure within the mixed filter was more stable with less variability in the population densities of individual ciliate species. It was also noticeable that this particular filter retained individual ciliate species for longer periods than either the slag or plastic filters.

5.6 ROTIFERA

The role of the Rotifera in wastewater treatment processes has been reviewed by Doohan (1975). Unfortunately most of the research carried out on this group has been in connection with the activated sludge process (Curds and Vandyke, 1966; McKinney, 1967; Calaway, 1968; Sydenham, 1971) and so relatively little is known concerning the rotifers found in the percolating filter environment.

In the present study three species were found, Philodina roseola of the Order Bdelloidea and two species from the Order Monogononta, Lecanes sp. and Dicranophorus sp., all of which are commonly found in percolating filters (Donner, 1966). Philodina roseola was the most common rotifer, being most abundant at the higher loading in the slag and mixed filters, where it reached maximum population densities during the summer. In the plastic filter, this species was only found in low numbers during the spring at both rates of loading.

Lecane sp. was never recorded in the plastic filter, but was present in the other filters during the higher loading period only. Dicroanophorous sp. was also found during the higher loading period and was restricted to the mixed filter. All three species were limited to the lower half of the filters, with the largest populations being recorded from the slag filter during the summer months.

From field experiments, Doohan (1975) supposed that it was food availability which exerted the greatest influences on the reproduction rate of the Rotifera, rather than other environmental parameters such as temperature. In the present investigation the reduced abundance of bacteria and suspended material in the lower sections of the filters during the warmer months was reflected by a decrease in protozoan abundance in the same region of the filters. The resultant increase in the Rotifera, and the extension of their distribution area upwards was most likely due to a) their greater mobility, for example Lecane sp which has a specialised foot for crawling over the medium; and b) their stronger ciliary currents which concentrated the diminished number of suspended bacteria and particles found in the lower half of the filters, more efficiently than the protozoan species. This was especially evident when the Rotifera were far more successful in the same region of the filters than the sessile peritrich Opercularia microdiscum which had replaced the larger more active protozoan holotrichs at the higher loading.

5.7 NEMATODA

Little is known regarding the role of the Nematoda in wastewater purification processes, but being present in such large numbers in percolating filters they are important members of the filter ecosystem. The Nematoda is a widely distributed group being found in a variety of aquatic and terrestrial habitats, and the filter environment appears to be an ideal habitat for such a diverse group. Indeed large populations of nematodes have been recorded in percolating filters (Peters, 1930; Lloyd, 1945; Calaway, 1963). In the present investigation the nematodes were not identified to species level, but were expressed as total numbers of Nematoda present. The nematode fauna of the percolating filter is very similar to the other polysaprobic freshwater habitats, being dominated by bacterial feeders and the less abundant predators feeding on other nematodes and rotifers (Schiemer, 1975).

The summary of the mean monthly number of nematodes per litre of medium (Table 5.21), shows that the nematodes were most abundant in the slag filter and to a lesser extent in the mixed filter, than in the plastic filter. Weninger (1964), recorded maximum population densities of 180 individuals per millilitre while Scherb (1968) found the maximum level of 240 individuals per millilitre in a bench scale activated sludge plant. Schiemer (1975) suggested that experiments carried out by Pillai and Taylor (1968) showed the maximum population in conventional low rate filters could be in the order of 1000 individuals per millilitre, which corresponds closely with the present results where a maximum population of 940 individuals per millilitre was recorded in the slag filter at the low loading period during February (Table 5.21).

The seasonal variation in abundance coincided with the film accumulation with maximum population densities of nematodes being recorded during the early spring and minimum population densities immediately after sloughing was completed. Weninger (1971) and Murad and Bazer (1970) recorded that the population density was inversely related to temperature, resulting in maximum populations between 7 and 10°C, although Chaudhain _et_ _al_., (1965) recorded maximum population densities between 17 - 18°C. From the correlation analysis (Table 5.22) the nematode population was strongly and negatively correlated with temperature with maximum numbers being recorded at 8°C. Unlike Weninger (1964), who recorded that the number of nematodes decreased with depth up to the centre of his experimental filter, the Nematoda in the pilot filters were found at all depths, reaching maximum numbers in the lowest 900 mm of the filters. During the high loading period the distribution of nematodes was restricted even lower, although in the mixed filter the maximum number of nematodes occurred at the lower half of both the slag and plastic media sections.

From the vertical distribution graphs (Figures 5.2-5.7) an association between the film accumulation and the nematode population can be identified, the minimum accumulation of film coinciding with the minimum nematode population density, although no significant correlation with the film weight was found. Hawkes and Shephard (1972) regarded the Nematoda as

Table 5.21: Mean monthly number of Nematoda recorded in the pilot filters (Expressed as total number x 10^6 individuals per litre)

LOADING	DURATION (months)	SLAG FILTER			MIXED FILTER			PLASTIC FILTER		
		MEAN	MAXIMUM		MEAN	MAXIMUM		MEAN	MAXIMUM	
			TOTAL	MONTH		TOTAL	MONTH		TOTAL	MONTH
LOW LOADING	12	2.21	9.4	Feb	1.94	6.6	Apr	1.67	3.3	Feb
HIGH LOADING	11	2.22	6.1	Apr	1.87	4.9	Mar	1.60	3.0	May
BOTH LOADINGS	23	2.22			1.91			1.64		
Maximum number per millilitre	23	940			660			330		

Table 5.22: Correlations with the Nematoda and various biological groups and environmental parameters

	SLAG	MIXED	PLASTIC
LOW RATE	Temperature(2-) Organic Load (1-)	Zoogloeal Bacteria (1+) *Subbaromyces splendens*(1-) *Paramecium aurelia* (2+)	Enchytraeidae (2+) Temperature (1-)
HIGH RATE	Enchytraeidae (2+) Psychodid larvae (2-)		Psychodid larvae (2-) Acari-Astigmata (2+) Temperature (1-) Organic Load (1-) Effluent BOD (1-)
ALL LOADINGS	*Subbaromyces splendens*(1-) Enchytraeidae (1+) Psychodid larvae (1-) Temperature (1-) Effluent BOD (1-)	Temperature (1-) Effluent BOD (1-) *Paramecium aurelia* (1+)	Enchytraeidae (2+) Psychodid larvae (1-) Temperature (3-) Effluent BOD (1-) *Uronema nigricans* (1-)

important micrograzers, associated with the increase in film accumulation. A very significant and positive correlation was recorded in both the slag and plastic filters between nematode and Enchytraeidae abundance. The latter group is one of the dominant macrograzers which like the Nematoda is found in greatest abundance at temperatures of 7°C (Solbé, Ripley and Tomlinson, 1974), and is also related to the film accumulation. The high reproductive potential of the nematodes (Schiemer, 1975) is similar to that of the astigmatid mites and the enchytraeids, all three groups being able to respond rapidly to increases in the available food.

As mentioned previously the Nematoda are associated with heavy film accumulations and so it is not surprising that a strong negative correlation between the nematode population and the effluent BOD should exist. The negative association with the organic load as well suggests that the nematodes are affected by high flow rates which wash out the individual organisms, and may also account for the lower population levels recorded in the plastic medium (Table 5.21). Weninger (1965, 1971) found the Nematoda to be strongly associated with Sphaerotilus natans, but such an association was not apparent in the present investigation, although the filamentous bacteria were positively related to the film weight.

5.8 ANNELIDA

The Enchytraeidae and the Lumbricidae are two extremely common families both being frequently recorded in percolating filters. Both laboratory and field based studies, have been undertaken on the ecology and biology of these two groups, which has been excellently reviewed by Solbé (1975).

5.8.1 ENCHYTRAEIDAE

Enchytraeids were recorded throughout the experimental period in all the filters, often being recorded in very large numbers. One species, *Lumbricillus rivalis*, made up 95% - 100% of the total enchytraeids present. One other species was also occasionally recorded in an immature state, and this was provisionally identified as *Enchytraeus buchholzi*.

Under low rate conditions similar mean population levels were recorded in all three filters (Table 5.23) with the maximum monthly mean being found in the plastic filter, which had the greatest potential surface area.

The increase in the loading rate had interesting effects on the population densities. In the slag and mixed filters the population density doubled, appearing related to the increase in organic loading, while the population in the plastic filter dropped by 40 percent. The maximum population density was recorded in the mixed filter, during the high loading regime, at 10,640 individuals per litre of medium.

Table 5.23: Monthly mean population density of Enchytraeidae (expressed as total number per litre of medium)

LOADING	DURATION OF LOADING IN MONTHS	SLAG FILTER			MIXED FILTER			PLASTIC FILTER		
		MEAN	MAXIMUM		MEAN	MAXIMUM		MEAN	MAXIMUM	
			TOTAL	MONTH		TOTAL	MONTH		TOTAL	MONTH
LOW LOADING	12	1122	2232	Jan	1083	2949	Feb	1114	3869	Feb
HIGH LOADING	11	2006	8985	Apr	2264	10640	May	666	2592	May
BOTH LOADINGS	23	1545			1648			900		

The low number of enchytraeids recorded in the plastic filter during the higher loading was probably due to several factors. Primarily due to the washout from the smooth surfaced medium, which, unlike the slag medium has no pores or rough surfaces to aid attachment, and secondly due to the high population of Psychoda sp. found in the filter at the the higher loading rate, competing for the same food and space. Reynoldson (1941) reported that the Enchytraeidae were restricted by higher rates of flow (2.02 - 2.24 $m^3m^{-3}d^{-1}$) and that large numbers were lost in the effluent especially during sloughing (Reynoldson, 1948). Bruce and Merkens (1970) found that L. rivalis was absent from their highrate plastic and mineral filters treating sewage at 6 $m^3m^{-3}d^{-1}$. Enchytraeidae have been found to dominate the grazing fauna under reduced competition from the fly larvae, created by higher hydraulic loadings (Tomlinson and Hall, 1950; Hawkes, 1955, 1961), and at lower temperatures (i.e. <10°C) (Solbé et al., 1974). Hawkes (1955) in his experiments on dosing frequencies found the L. rivalis could withstand certain hydraulic flows because it possessed strong, curved setae and that as the cocoons were firmly attached to the medium they could withstand even higher flow rates.

Previous workers have found L. rivalis principally in the upper portions of percolating filters near the surface (Reynoldson, 1947; Solbé et al., 1967; Williams et al., 1969). In the present investigation L. rivalis was recorded throughout the depth of the filters at the lower loading rate, reaching maximum abundance in the central and lower areas of the filters. In the mixed filter this species was found

Table 5.24: Correlations between the Enchytraeidae and various biological groups and environmental parameters

	SLAG	MIXED	PLASTIC
LOW RATE			Nematoda (2+) Temperature(2-)
HIGH RATE	Nematoda (2+)	Sarcomastigophora (1-)	
BOTH LOADINGS	Nematoda (2+)		Nematoda (2+)

in greatest abundance in the lower portion, i.e. the slag medium, of the filter. Maximum abundance of L. rivalis was recorded in the lower half of all the filters at the higher loading. Hawkes (1955) and Solbé et al. (1967) both recorded maximum numbers of the Enchytraeidae during February with minimum numbers in August, which corresponds with the results obtained in the present study. Figures 5.27 - 5.32 show that the vertical distribution of the Enchytraeidae was probably restricted by the presence of the psychodid larvae at both loadings, which predominated in the upper regions of the pilot filters under low rate conditions and throughout the filter at the higher loading. The Enchytraeidae were not directly associated with film accumulation (Table 5.24) but reached maximum population density, the month preceding the maximum number of psychodid larvae were recorded; both reaching maximum abundance in response to the heavy film accumulation. The increased competition from the psychodid larvae caused a dramatic decline in the number of enchytraeids present. Correlation analysis (Table 5.24) showed the Enchytraeidae were only associated with nematode abundance, this being a strong and positive correlation. Both L.rivalis and the Nematoda are capable of increasing their populations rapidly, nematodes because of their short life cycles and the enchytraeids because of (a) the large number of cocoons present in the filter at specific periods, and (b) the high population growth rate (Learner, 1972). This allows the Nematoda and the Enchytraeidae to respond quickly to changes in the film accumulation and also to changes in community structure.

Cocoons of L.rivalis were also identified and counted during the biological analysis carried out each month (Table 5.25). The result reflect the adult population densities at the lower loading, both the number of cocoons and adult abundance being similar in all the pilot filters. At the increased loading the number of adults doubled in the slag and mixed filters resulting in increased numbers of cocoons. The number of cocoons increased by factors of 2.7 in the slag, 1.9 in the mixed and 1.1 in the plastic filters, the difference possibly reflecting the reduction of voidage caused by the accumulation of film and so the potential retention of the cocoons. The cocoons were generally found in maximum numbers in the centre of the slag and plastic filters and in the interface region of the mixed filter.

Table 5.25: Monthly mean number of cocoons of Lumbricillus rivalis (expressed as total number per litre of medium)

LOADING	DURATION OF LOADING IN MONTHS	SLAG FILTER			MIXED FILTER			PLASTIC FILTER		
		MEAN	MAXIMUM		MEAN	MAXIMUM		MEAN	MAXIMUM	
			TOTAL	MONTH		TOTAL	MONTH		TOTAL	MONTH
LOW LOADING	12	899	2213	Feb	1083	3627	Apr	1033	2347	Apr
HIGH LOADING	11	2390	8933	Apr	2002	7520	Apr	1181	2880	Mar
BOTH LOADINGS	23	1612			1522			1104		

Table 5.26: Correlations with the cocoons of *L.rivalis* and various biological groups and environmental parameters.

	SLAG	MIXED	PLASTIC
LOW RATE		Nematoda (2+) Acari-astigmata (1+)	*Subbaromyces splendens* (1-) Sarcomastigophora (1+) Nematoda (1+) Acari-astigmata (2+)
HIGH RATE	Enchytraeidae (3+) Nematoda (2+)	Effluent BOD (1+)	Psychodid larvae (1-) Acari-astigmata (1+) Nematoda (2+) Temperature(2-) Organic Load (3-) Effluent BOD (3-)
BOTH LOADINGS	Enchytraeidae (3+) Nematoda (2+)		Nematoda (2+) Acari-astigmata (1+) Temperature(1-) Effluent BOD (1-)

The number of cocoons recorded was controlled by the film accumulation. More were retained as the film increased, either by adhesion to the film or some other suitable substrate, and by being mechanically filtered out of the sewage by the film and humus. At times of low film accumulation there was a corresponding low abundance of cocoons recovered which were mainly adhering to the actual surface of the medium. Like Reynoldson (1941), there was an increase in the number of adult Enchytraeidae and cocoons during the sloughing period. Reynoldson (1947) and Solbé *et al.* (1967) both found that the abundance of cocoons followed a seasonal pattern, reaching maximum numbers in the spring and autumn. In the pilot filters the seasonal abundance of cocoons followed a similar pattern to that of the adult enchytraeids (Table 5.26) reaching maximum numbers during February to April and minimum numbers during the summer months after sloughing.

Both the adult enchytraeids and the cocoons are both eaten by a number of predatory dipteran larvae. Lloyd (1945) reported L.rivalis and its cocoons as being eaten by fly larvae including Hydrobaenus minimus, Metriocnemus hygropetricus and Psychoda severini, all of which were recorded in the pilot filters. The protozoan Glaucoma sp. was reported by Reynoldson (1939b) as occasionally attacking the cocoons of L.rivalis. Glaucoma scintillans was frequently recorded in the pilot filters and was associated with thin film conditions (Section 5.5) and may result to this unusual behaviour at times of food shortage.

5.8.2 LUMBRICIDAE

Only two members of the Lumbricidae were found in the pilot filters. These were Dendrobaena subrubicunda and Eiseniella tetraedra, both of which frequently occur in percolating filters (Learner, 1975). Considerable information has been gathered relating to these species (Tomlinson, 1946; Hawkes, 1963; Solbé et al, 1967; Solbé, 1971), and this has been reviewed in detail by Solbé (1975). The species were present in small numbers at both loadings. Both species were found in greatest abundance between 900 - 1500 mm at the lower loading in all the filters, although they were not recorded during the period of lowest film accumulation during June and July. At the higher loading, Dendrobaena subrubicunda was only recorded in the mixed and slag filters during the first month of operation at the new loading. Eiseniella tetraedra however was recovered from the lower half of all the filters until April when the species disappeared from the filters. At both loadings the lumbricid worms were found throughout the plastic filter. Eiseniella tetraedra is an amphibious species while Dendrobaena subrubicunda is terrestrial in nature being commonly found in compost heaps (Gerard, 1964). Therefore it is not surprising that Eiseniella tetraedra was more successful at the higher hydraulic loading than the other species. Lumbricids were shown to be more numerous in smaller media by Terry (1951), who recorded that in the larger medium the worms were rarely found near the surface due to the high flushing action of the sewage. Solbé (1971), examining the depth distribution of lumbricids, reported that Dendrobaena subrubicunda was found to increase towards the base of the filters while Eiseniella tetraedra was found in the middle regions of the filters. The present investigation indicates that the distribution of the lumbricids is related to the hydraulic flow and the size of the interstices.

5.9 INSECTA

The members of the various Orders of the Insecta are principally associated with percolating filters, rarely being found in other kinds or at other stages of wastewater treatment. Many species lists have been compiled (Lloyd, 1945; Tomlinson, 1946; Terry, 1951; Hawkes, 1963; Solbé *et al*, 1967) but it was comparatively recently that the first comprehensive survey into the fauna of percolating filters was undertaken by Learner (1975) and a comprehensive species list prepared, containing 186 species of insects belonging to 38 families.

5.9.1 COLLEMBOLA

Sixteen species of springtails have been recorded from percolating filters, the most important species being *Hypogastrura viatica*, formally referred to as *Achorutes subviaticus* (Lawrence, 1970). More recently Learner (1975) recorded seven species of which only *Hypogastrura viatica*, *Anurida tullbergi* and *Proisotoma* sp. were found in numbers greater than 100 individuals per litre of medium.

Only one species was recorded in the pilot filters, *Isotoma olivacea-violacea*. Frequently recorded in the plastic filter at both loadings, it was only recorded once in the other two pilot filters. The species was found in the plastic filter from November to May at the lower loading, with maximum population densities during November and December, seasonal incidence being reduced to three months at the higher loading rate being recorded from October to December. During periods of maximum abundance, the species extended throughout the depth of the filter becoming more restricted to the lower half during the warmer months and also when the loading was increased. Clearly *Isotoma olivacea-violacea* preferred the lower loading and moderate accumulations of film, maximum populations being recorded when the mean film weight was between 6 and 7 kg m^{-3}. Although an active grazer, no correlation was found between *Isotoma* sp. and any of the constituents of the film such as zoogloeal bacteria or *Subbaromyces splendens*.

Hypogastrura viatica is extremely sensitive to increased rates of filtration (Hawkes and Jenkins, 1955, 1958; Wheatley, 1976); Tomlinson and Hall (1950) recorded that the maximum abundance of the springtail occurred at 1.5 $m^3m^{-3}d^{-1}$ but none was found at loads in excess of 3.0 $m^3m^{-3}d^{-1}$. The greater success of *Isotoma* sp. in the plastic medium used in the present investigation is due to a preference for drier areas such as inter-jet zones in conventional filters (Hawkes, 1959) and it has been shown previously (Section 2.4.2) that each module of Flocor RC filter medium has a dry area suitable for such organisms as *Isotoma* sp.

5.9.2 COLEOPTERA

Only members of the Hydrophilidae and the Staphylinidae are commonly found in percolating filters. In the present investigation only two species were recorded, Cercyon ustulatus and an unidentified species of the Staphylinidae. Both species were only recorded occasionally as adults in very small numbers. In his survey, Learner (1975) found adult Cercyon ustulatus in 6% of the filters examined, but never recorded the larvae. Learner only examined medium from the filter surface, and Hawkes (1963) recorded that the Coleoptera were normally found in the lower regions. In the present investigation, Cercyon ustulatus was found in the top 900 mm of the pilot filters at both loadings during the spring and autumn, when the maximum numbers of adults outside the filters were recorded (Table 5.32). It would appear that this species did not reproduce within the filter, but was attracted by the decaying organic matter, as was the staphylinid species recorded.

The Staphylinidae species was restricted to the surface of the pilot filters except in June when the species was recorded lower down towards the centre of the filters. Maximum population densities occurred during May to June being more abundant in the mixed and plastic filters during the lower loading. At the higher loading it was only found in the plastic filter where it was recorded throughout the year with maximum population densities occurring during the summer. Learner (1975b) noted that although adult staphylinids were frequently recorded in percolating filters, the larvae were rarely found, and suggested that the conditions found in filters were probably not suitable for these insects to breed.

5.9.3 DIPTERA

5.9.3.1 Psychodidae

Both *Psychoda alternata* and *Psychoda severini* were recorded in the pilot filters. Only the adults were identified to species level while the larvae of both species were counted together.

Lloyd (1943) showed that *Psychoda severini* was parthenogentic and like *P.alternata*, was able to carry out its life cycle within the filter. *Psychoda severini* was able to reproduce at temperatures below 10°C and so is far more abundant than *P.alternata* during the winter and spring, while the latter species is dominant in the summer and early autumn (Tables 5.27 to 5.29).

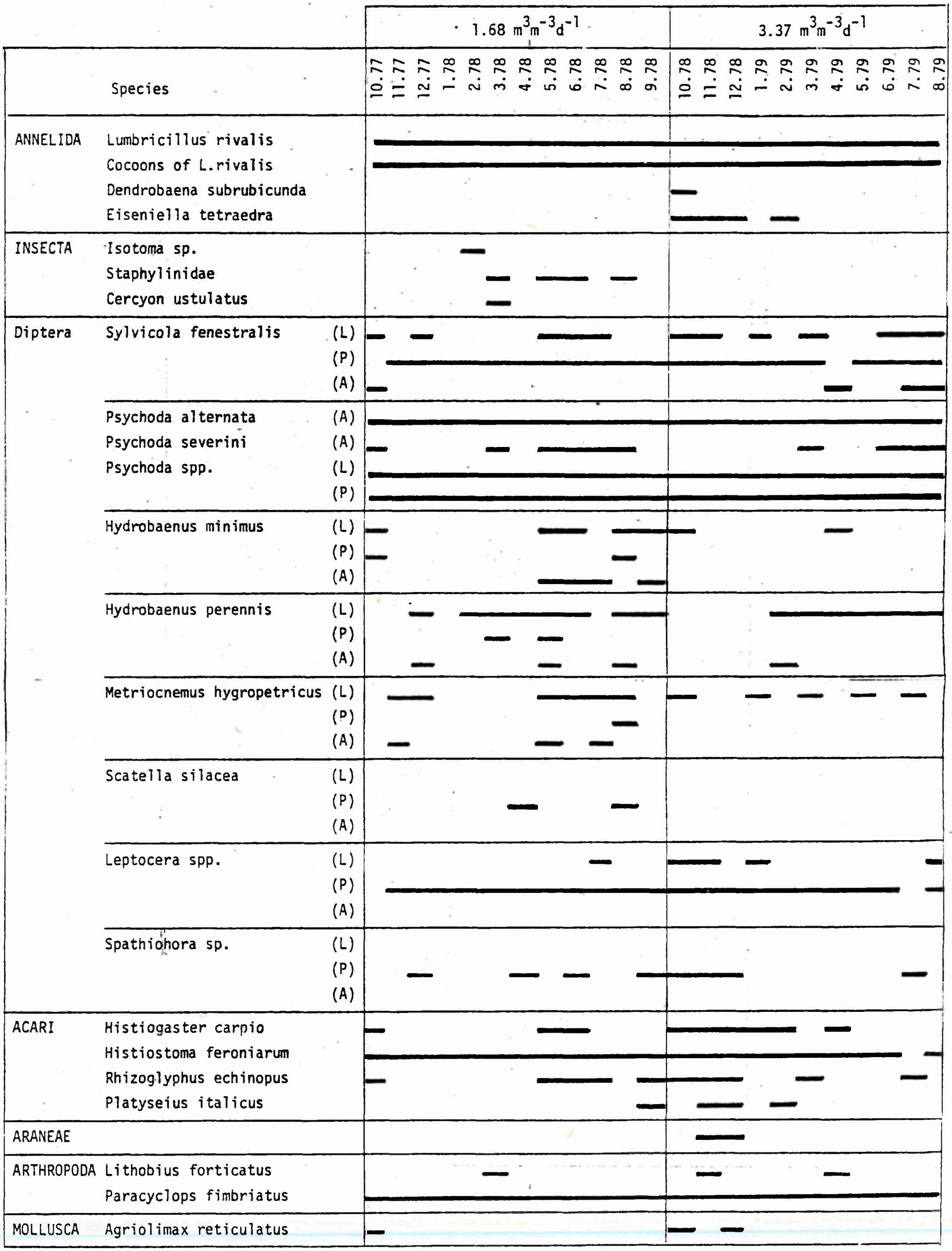
The psychodid larvae were the first macroinvertebrates to colonise the filters and were found in all three filters throughout the experimental period of 23 months. Maximum abundance of the larvae occurred during the summer months, normally in June or July each year with minimum populations generally recorded during either early spring or late autumn. The slag and mixed filters supported similar larval population densities at the low loading (Table 5.30), whereas the plastic filter contained twice as many larvae. In the mixed and plastic filters there was a considerable increase in the larvae population following the increased loading rate. This also occurred, but to a lesser extent, in the slag filter. The smaller population recorded in the slag medium may be due to the reduced voidage restricting the natural

Table 5.27: Species diversity of macrofauna in the slag filter

			$1.68\ m^3m^{-3}d^{-1}$												$3.37\ m^3m^{-3}d^{-1}$										
	Species		10.77	11.77	12.77	1.78	2.78	3.78	4.78	5.78	6.78	7.78	8.78	9.78	10.78	11.78	12.78	1.79	2.79	3.79	4.79	5.79	6.79	7.79	8.79
ANNELIDA	Lumbricillus rivalis			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Cocoons of L.rivalis			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Dendrobaena subrubicunda													●	●										
	Eiseniella tetraedra												●		●	●	●								
INSECTA	Isotoma sp.			●																					
	Staphylinidae									●															
	Cercyon ustulatus															●									
Diptera	Sylvicola fenestralis	(L)		●	●					●	●	●	●	●	●	●	●	●				●	●	●	●
		(P)		●	●		●	●			●	●	●	●	●	●	●	●		●	●			●	●
		(A)									●		●									●		●	
	Psychoda alternata	(A)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Psychoda severini	(A)		●						●	●	●	●						●	●			●	●	
	Psychoda spp.	(L)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		(P)	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Hydrobaenus minimus	(L)								●	●		●		●										
		(P)																							
		(A)								●	●														
	Hydrobaenus perennis	(L)			●	●	●	●	●	●	●	●	●			●			●		●	●	●	●	●
		(P)																					●		
		(A)			●					●								●							
	Metriocnemus hygropetricus	(L)	●	●	●	●	●			●	●	●	●	●								●	●	●	
		(P)		●												●									
		(A)		●	●							●										●			
	Scatella silacea	(L)																							
		(P)									●	●	●	●			●					●			
		(A)																							
	Leptocera spp.	(L)										●					●								●
		(P)					●									●		●							
		(A)																							
	Spathiophora sp.	(L)																							
		(P)		●		●		●	●			●	●	●		●									
		(A)																							
ACARI	Histiogaster carpio											●	●	●	●	●					●				
	Histiostoma feroniarum		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	
	Rhizoglyphus echinopus									●			●		●	●									
	Platyseius italicus														●	●	●	●							
ARANEAE														●											
ARTHROPODA	Lithobius forticatus							●														●			
	Paracyclops fimbriatus		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
MOLLUSCA	Agriolimax reticulatus																								

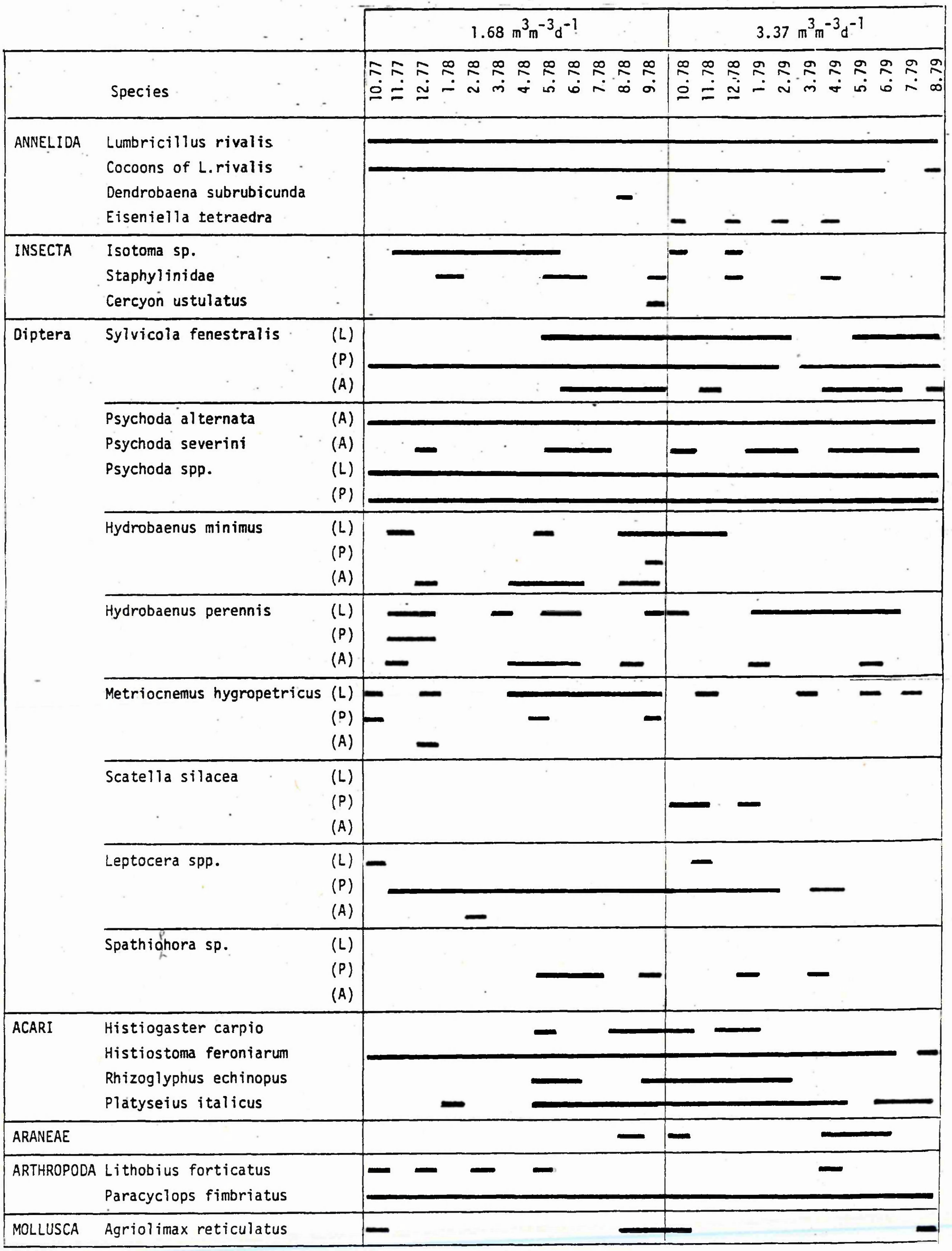
Key: (L) larvae
(P) pupae
(A) adult

Table 5.28: Species diversity of macrofauna in the mixed filter



Key: (L) larvae
(P) pupae
(A) adult

Table 5.29: Species diversity of macrofauna in the plastic filter



Key:
(L) larvae
(P) pupae
(A) adult

Table 5.30: Monthly mean abundance of *Psychoda* larvae (expressed as total number per litre of medium)

LOADING	DURATION (months)	SLAG FILTER			MIXED FILTER			PLASTIC FILTER		
		MEAN	MAXIMUM		MEAN	MAXIMUM		MEAN	MAXIMUM	
			TOTAL	MONTH		TOTAL	MONTH		TOTAL	MONTH
Low Loading	12	1281	5346	Jun	1493	5210	Dec	2553	9065	Jun
High Loading	11	3802	10177	Aug	6603	33226	Jun	6497	25097	Jun
Both Loadings	23	2486			3937			4439		

life cycle of the insects due to increased film accumulation, which is discussed fully later in this section. The maximum monthly mean number of Psychoda larvae recorded in any filter was 33,226 per litre of medium during June 1979, in the high rate mixed filter, illustrating just how large the population density of this species could rise over a comparatively short period. Psychoda was an important member of the grazing fauna being the second most abundant grazer recorded in the filters, the most common being the astigmatid mites.

The maximum population densities for the larvae coincided with the period of thinnest film accumulation, and vice versa. The abundance of psychodid larvae was found to be positively correlated with temperature (Table 5.31). Learner (1975b) clearly illustrated that the reproductive potential (life cycle) of the commonest psychodid, P.alternata, was controlled by the temperature and that it has the most rapid development rate at temperatures in excess of 10^{o}C of any of the Insecta found in the percolating filter environment. Obviously there is a 'lag phase' between maximum food availability and the resultant increase in the number of grazers. In the case of Psychoda alternata this phase was of one to two months duration depending on the temperature within the filters (Solbé and Tozer, 1971). This could explain why no correlation existed between the quantity of film and the abundance of psychodid larvae. A similar delay before the grazing fauna responded to the increase in film accumulation was also recorded by Wheatley (1976), but he concluded that the macroinvertebrates were not responsible for seasonal fluctuations in the film, although the grazing activities of the Enchytraeidae and Psychoda larvae were clearly responsible for the control of the film.

Tomlinson and Stride (1945) recorded that the number of psychodid flies emerging from a percolating filter increased with increased organic loading but only up to a maximum of 0.34 kg BOD $m^{-3}d^{-1}$. In the plastic filter there was a positive correlation at both loadings between Psychoda spp. and Uronema nigricans, a holotrich protozoan which was found to be restricted to low film conditions (Section 5.5.2.2), this association also being recorded in the other filters at both loadings. Interestingly the abundance of Psychoda spp. was very strongly and positively correlated with Opercularia microdiscum in the slag filter, this protozoan being generally recorded where moderate to heavy accumulations of film occurred. A number of other significant correlations are summarised in Table 5.31.

Many authors have recorded that both psychodid larvae and the Enchytraeidae prefer a thick film (Lloyd, 1945; Terry, 1951; Hawkes, 1957) and therefore it was expected that the maximum accumulation of larvae would occur where there was greatest film accumulation within the filters. However, this did not appear to be the case (Figures 5.27 to 5.32). At the lower loading the larvae were found mainly in the top 900 mm and when the film was at its minimum accumulation after sloughing, maximum abundance of Psychoda spp was recorded, with the larvae distributed throughout the depth of the filters. In June the light weight of the film reduced the Psychoda population due to lack of food. By the following month the

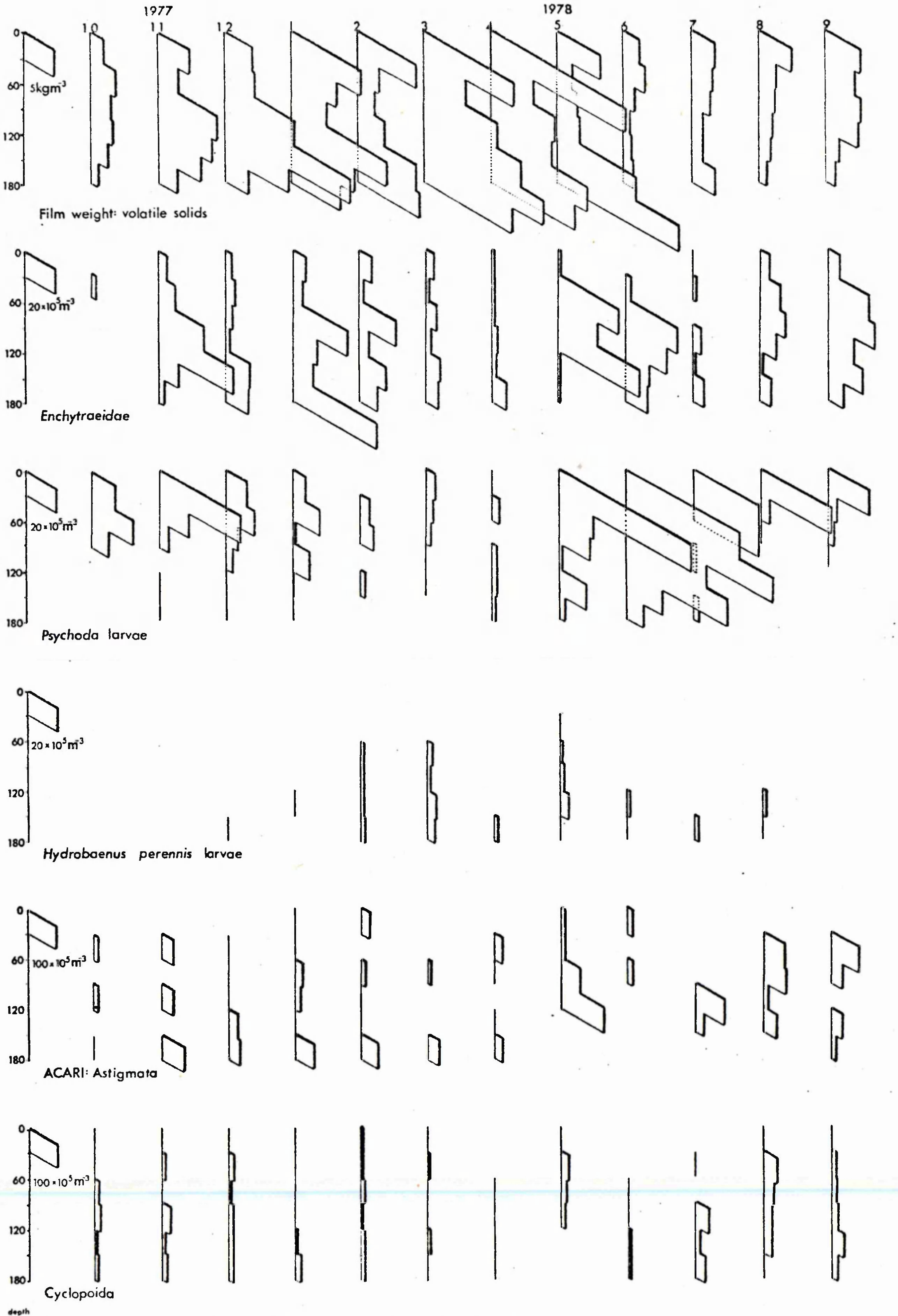


Figure: 5·27 Vertical Distribution of Film and Macrofauna. Low Rate Slag Filter.

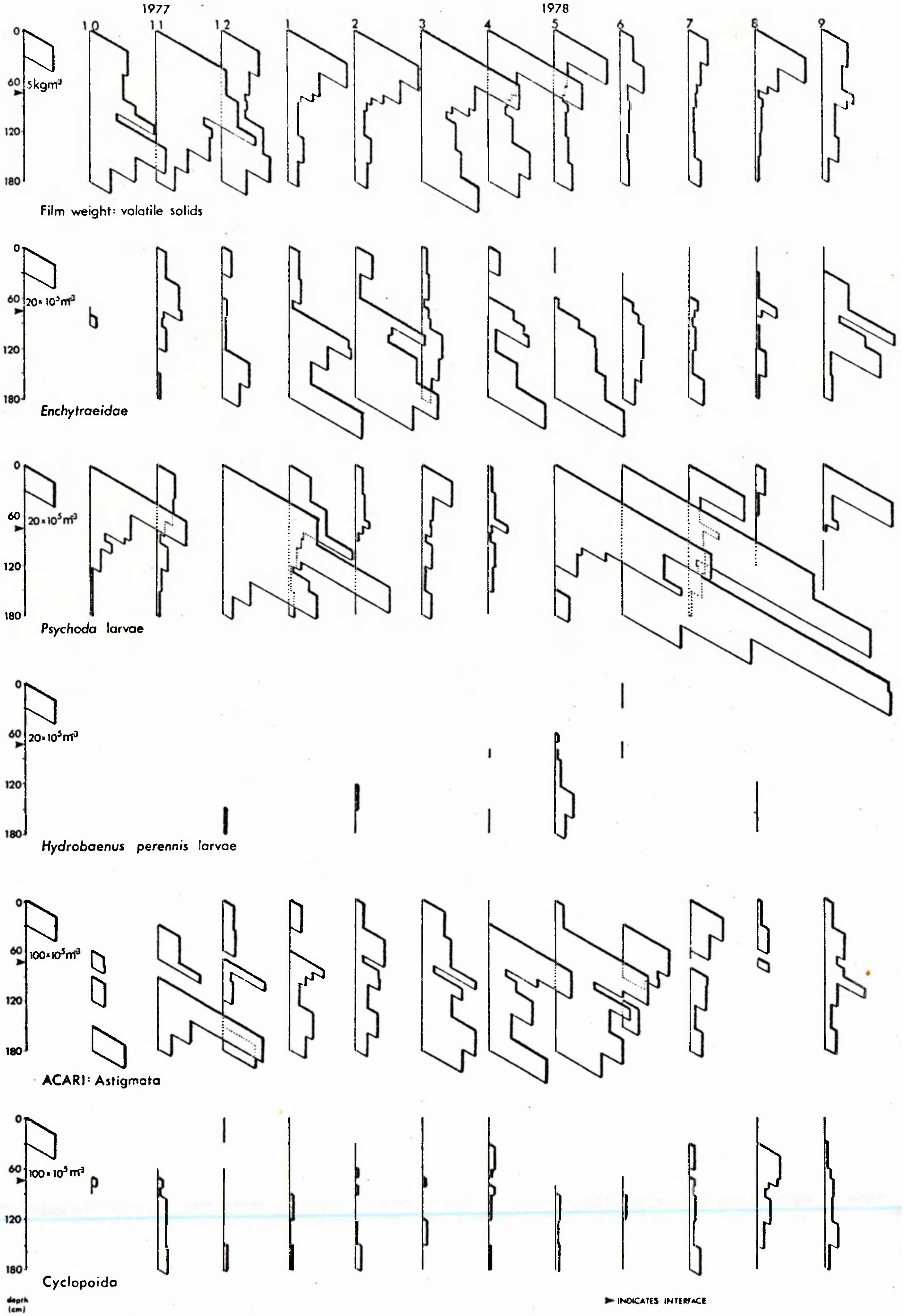
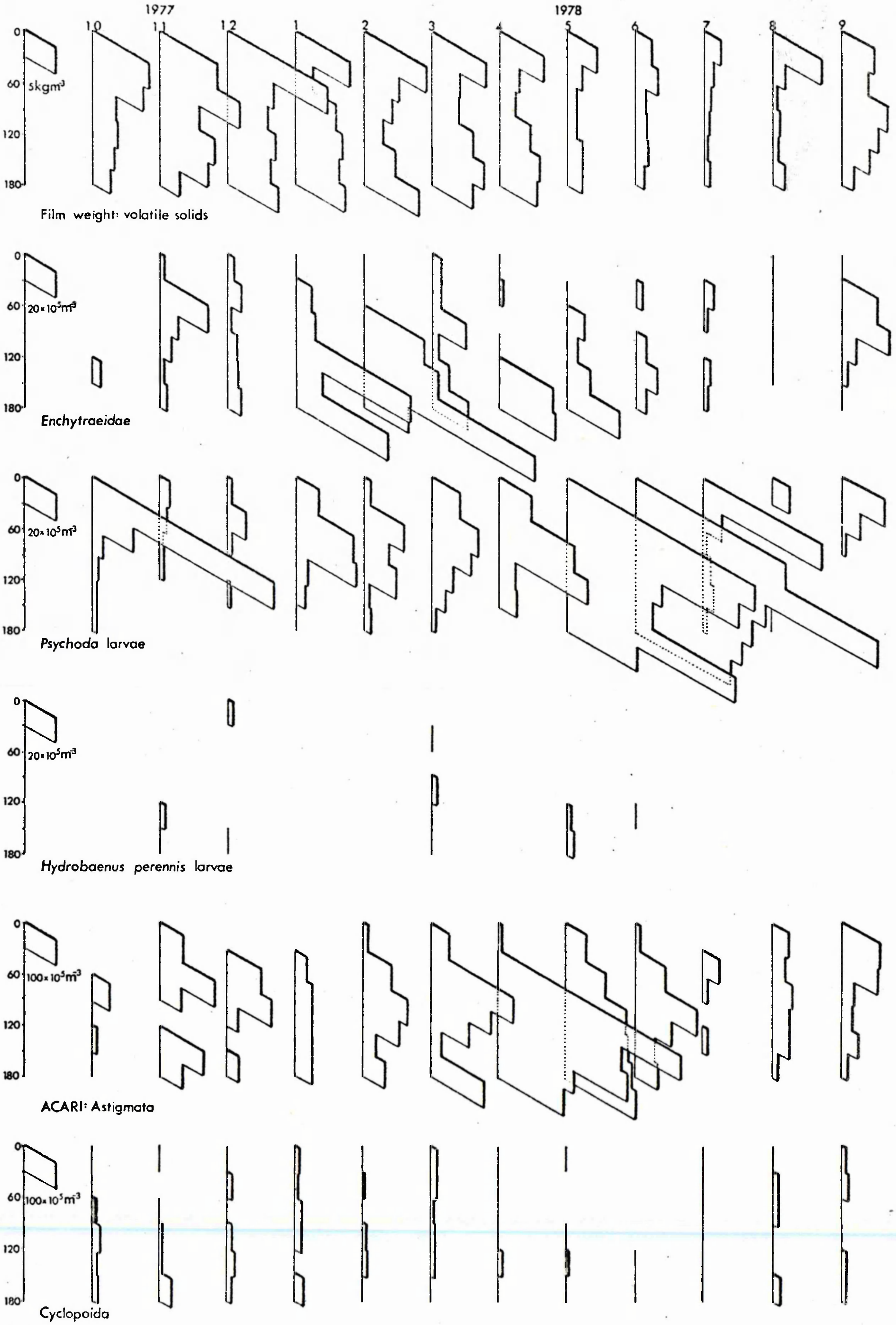


Figure: 5·28 Vertical Distribution of Film and Macrofauna. Low Rate Mixed Filter.



Film weight: volatile solids

Enchytraeidae

Psychoda larvae

Hydrobaenus perennis larvae

ACARI: Astigmata

Cyclopoida

Figure: 5·29 Vertical Distribution of Film and Macrofauna. Low Rate Plastic Filter.

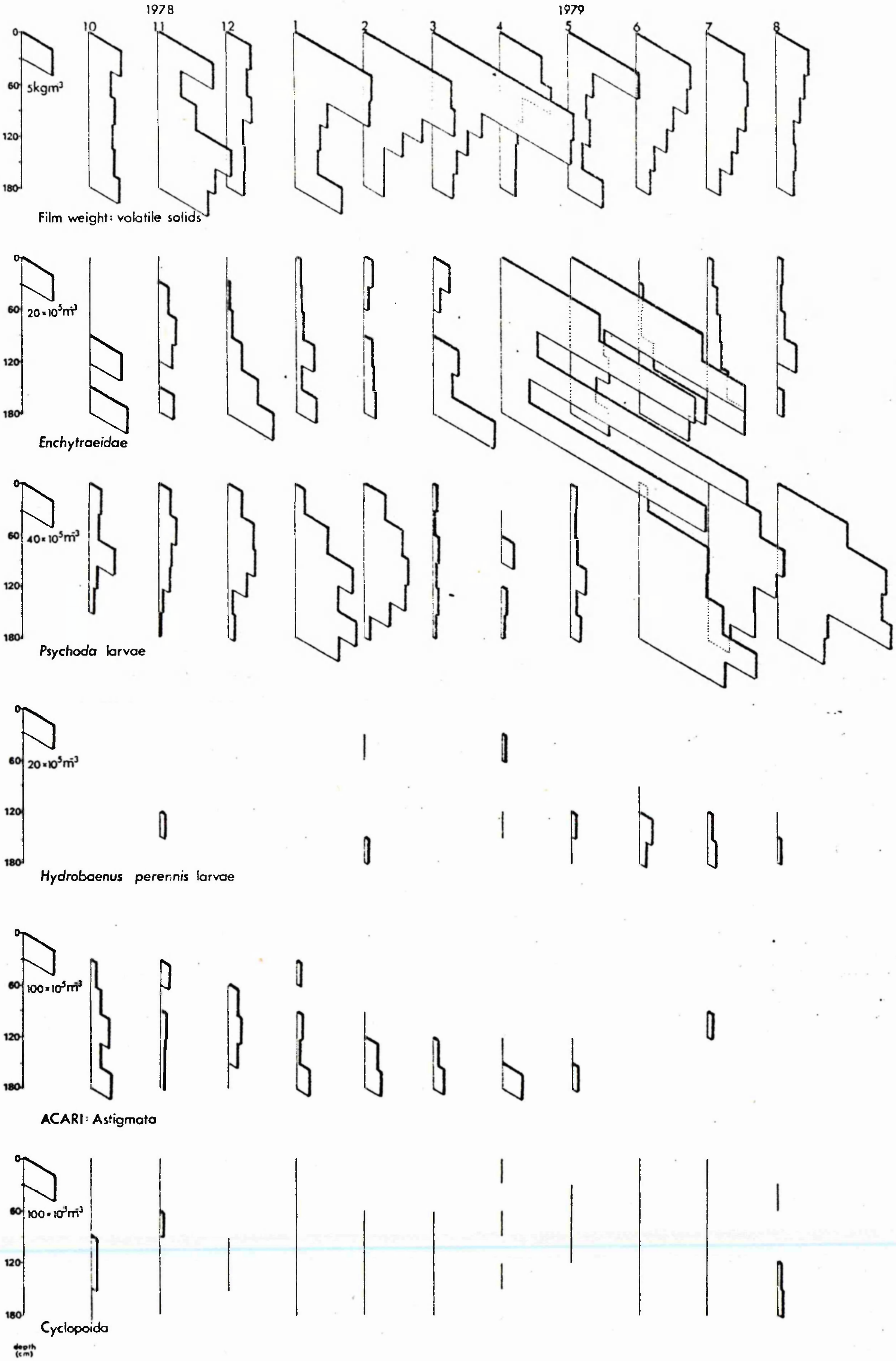


Figure: 5·30 Vertical Distribution of Film and Macrofauna, High Rate Slag Filter.

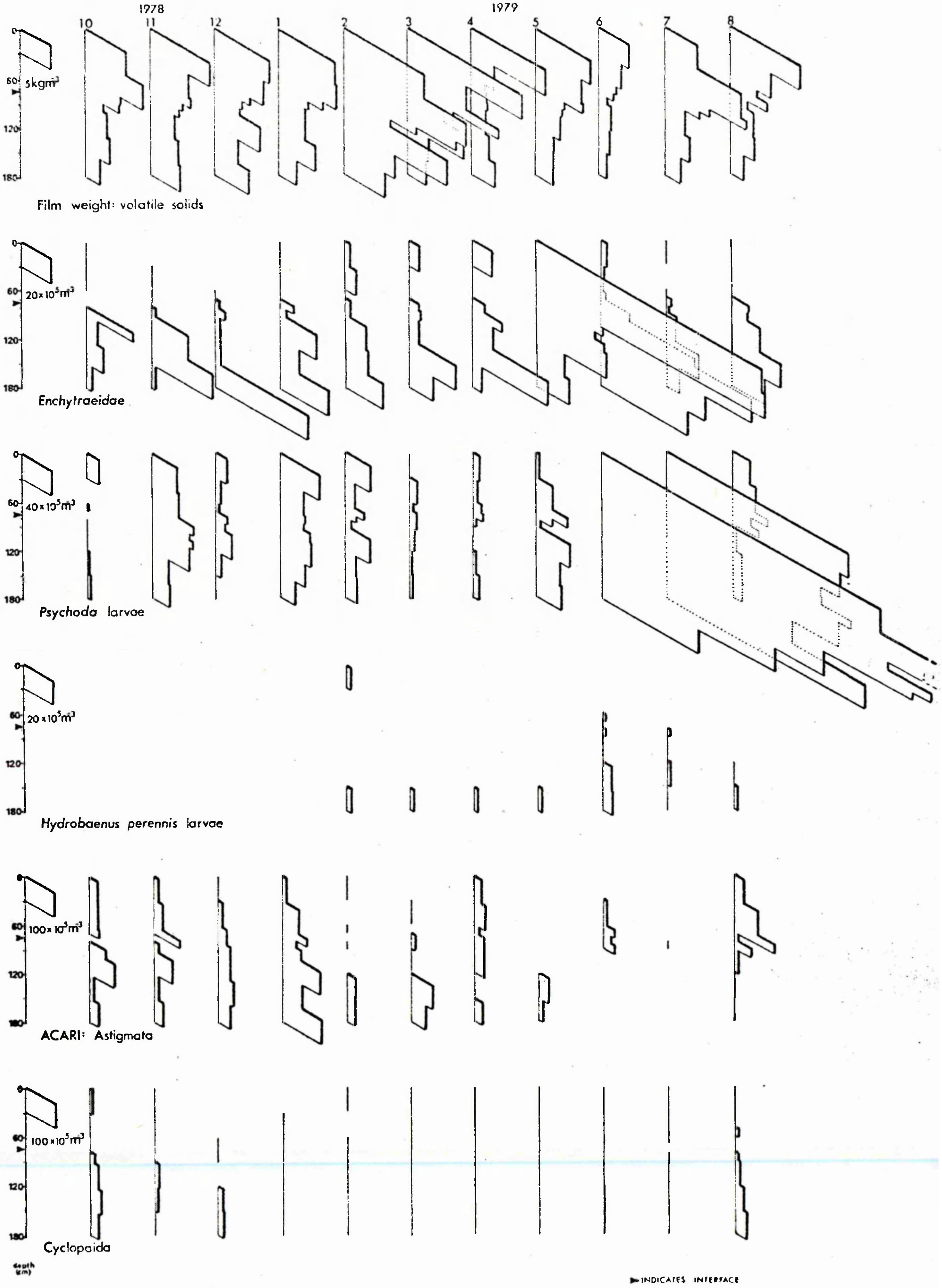
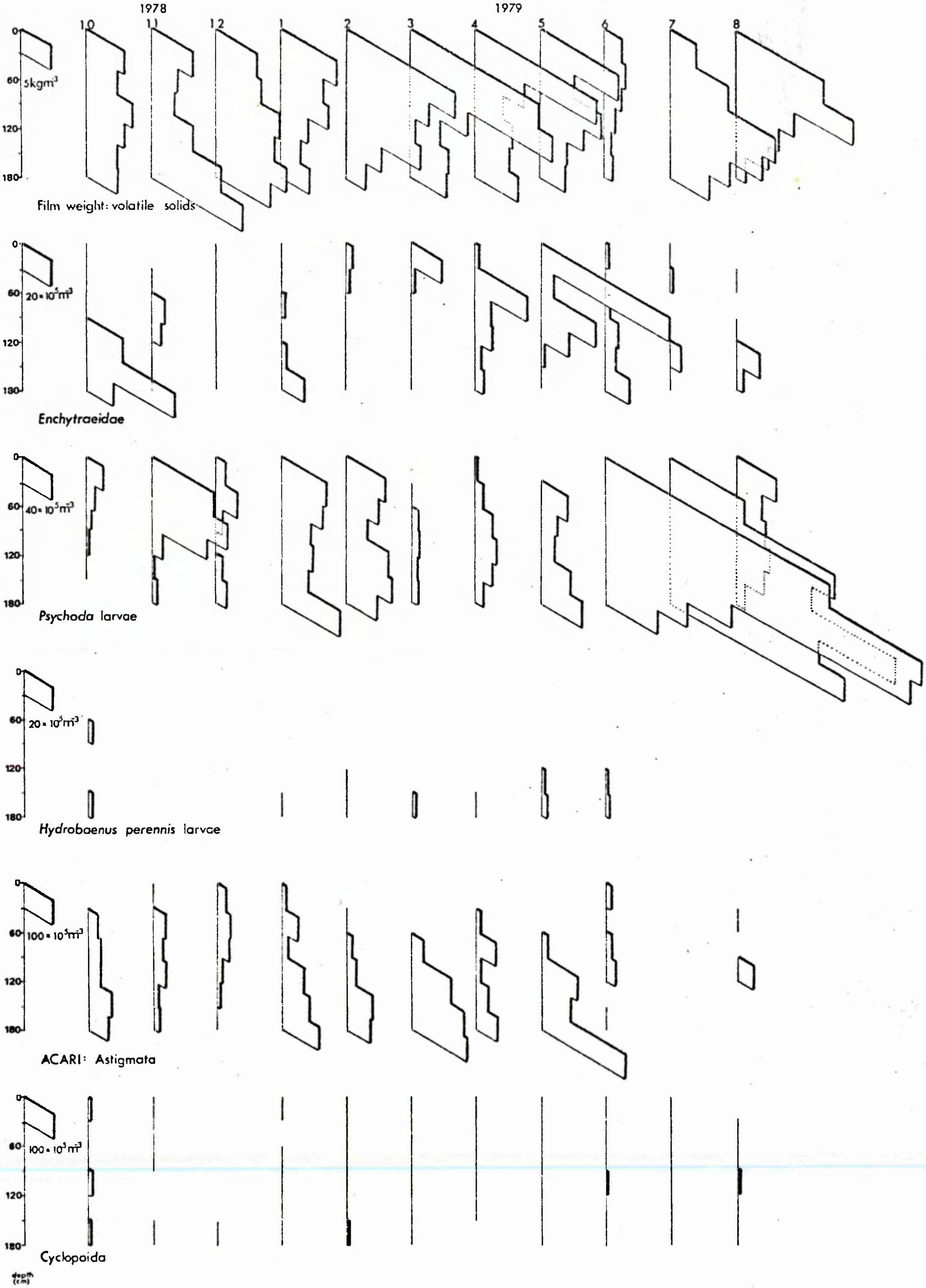


Figure: 5·31 Vertical Distribution of Film and Macrofauna, High Rate Mixed Filter.



Film weight: volatile solids

Enchytraeidae

Psychoda larvae

Hydrobaenus perennis larvae

ACARI: Astigmata

Cyclopoida

Figure: 5·32 Vertical Distribution of Film and Macrofauna, High Rate Plastic Filter.

Table 5.31: Correlations with the Psychodid larvae and various biological groups and environmental parameters

	SLAG	MIXED	PLASTIC
LOW RATE	Opercularia microdiscum(1+) Uronema nigricans (2+)		Ciliophora(3+) Paracyclops(1-) Effluent BOD (1+) Uronema nigricans (3+)
HIGH RATE	Subbaromyces splendens (2+) Nematoda (2-) Effluent BOD (1+) Opercularia microdiscum(1+)	Effluent BOD (3+) Uronema nigricans (3+)	Sphaerotilus natans (1-) Nematoda (2-) Organic Load (1+) Uronema nigricans (1+)
ALL LOADINGS	Ciliophora(2+) Nematoda (1-) Organic Load (2+) Effluent BOD (2+) Opercularia microdiscum(3+) Uronema nigricans (1+)	Organic Load (2+) Effluent BOD (2+)	Nematoda (1-) Organic Load (2+) Effluent BOD (3+) Uronema nigricans (1+)

number of larvae had generally diminished to very low numbers and were limited to the surface. But as mentioned previously, there is a time delay between film accumulation and the resulting increase in the grazing fauna, the length of which is dependent on the temperature. It may well be that the increase in the Psychoda population at various depths is in direct response to the film accumulated several months previously. Large numbers of adults were recorded within the filters with both species able to complete their life cycle within the filters. Therefore the principal restrictions on population density were the availability of nutrients and space.

The restriction in the surface accumulation of Psychoda spp. was due partly to its sensitivity to the hydraulic flow (Tomlinson and Hall, 1950; Hawkes, 1955; Lumb and Eastwood, 1958). The effect of various distributors was studied by Hawkes (1959), and he found that splash plates produced an even distribution of sewage resulting in a large accumulation of film and a high density of Psychoda in the top 600 mm. By increasing the velocity of application, the Psychoda populations were reduced in the surface layers being forced below 600 mm. This resulted in more film in the top layer. Tomlinson and Hall (1950) found that the abundance of the Psychoda larvae decreased if the hydraulic load exceeded 3.6 $m^3m^{-3}d^{-1}$ even though the film was thick. In their experimental filters, Bruce and Merkens (1970) found that large numbers of Psychoda larvae were present in filters loaded at 6.00 $m^3m^{-3}d^{-1}$. This was probably due to the higher voidage as it has been shown that smaller media restricted the natural life cycle of the insects (Tomlinson and Stride, 1945; Hawkes and Jenkins, 1951, 1955). Although Psychoda spp. can reproduce within filters, they were unable to leave or re-enter the pilot filters as they were continuously loaded. Hawkes and Jenkins (1955, 1958) found that the effect of hydraulic load was enhanced by larger voidage as the flow between the medium was also greater. This however would not be the case in the random plastic medium, Flocor RC, because it effectively redistributes the sewage within the filter (Wheatley and Williams, 1976; Porter and Smith, 1979).

5.9.3.2 Anisopodidae

Hawkes (1965b) suggested that certain genera of flies, the larvae of which are relatively active at lower temperatures may control the film accumulation during these periods. However, in the present study the abundance of larvae of most of the species recorded, including Sylvicola fenestralis, were reduced during the periods of low temperature.

Sylvicola fenestralis was widely distributed in all the pilot filters, both the pupae and larvae being recorded in large numbers. The larvae were generally absent or at least recorded in low numbers from January to April in all the filters at both loadings. The number of larvae increased considerably however with the increase in loading rate, maximum population densities occurring during June and July. Hawkes (1952a) recorded a doubling of the Sylvicola sp. population when the loadings of his filters were increased from 0.2 to 0.32 kg BOD m^{-3} d^{1}. The pupae were found throughout the experimental period in nearly all the filters being present in minimum numbers during February and March and in maximum numbers from July to August. As with the larvae, there was a large increase in the total number of pupae found at the higher loading. Data from the fly counts (Table 5.32) shows that Sylvicola fenestralis like Psychoda severini was recorded generally during the colder months, and this suggests that the adults may live for periods up to several months

The larvae were generally found in largest numbers within the top 600 mm while the pupae reached maximum density between 300 - 900 mm. Sylvicola sp. appears unaffected by competition with chironomid and psychodid larvae and was found throughout the filter. Tomlinson and Hall (1950) recorded that maximum densities always occurred in the top 600 mm irrespective of the organic or hydraulic loadings. Hawkes (1963), however, stated that the vertical distribution of the species could be altered by high instantaneous rates of sewage loadings although this is not supported by the present results. Hawkes (1952) found *Sylvicola* sp. abundance to be closely and directly related with film distribution; however the results from the pilot filters suggest an inverse correlation. It would seem that the amount of film is not an important factor determining the vertical distribution of this species. *Sylvicola fenestralis* is more successful in the plastic medium with the greatest number of larvae and pupae being recorded in the plastic filter. Each module of plastic medium has some of its surface area free from the film and often quite dry and this may be the reason why the pupae especially are found in comparatively large numbers in this filter. *Sylvicola* sp. requires a drier environment for successful pupation than that tolerated by the larvae (Hawkes, 1952), and this is thought to be the reason why the larvae are reported to migrate to drier areas in conventional plants (Learner, 1975b).

The adult *Sylvicola* has extremely large wings in comparison with other filter flies, and although quite powerful, it is unlikely that the flies could leave or enter the surface of filters which are continuously being sprayed with sewage. Therefore, like *Psychoda* spp., *Sylvicola fenestralis* is able to carry out its complete life cycle within the filter.

5.9.3.3 Chironomidae

Three chironomid species were recorded, *Hydrobaenus minimus*, *Hydrobaenus perennis* and *Metriocnemus hygropectricus*, all of which are widely distributed and commonly recorded from percolating filters.

The most successful of the three species was *Hydrobaenus perennis*, which is currently named *Chaetocladius perennis* (Meigen) (Pinder, 1978), this being present in relatively large numbers (Appendix II). The species was found in all three filters mainly from February to August (Tables 5.27 to 5.29). *Hydrobaenus perennis* was only recorded in small numbers in the plastic filter, the larvae being restricted to the lower 600 mm depth. In the mixed and slag filters, however, the population densities were much larger, although also restricted to the lower half of the filters (Figures 5.27 to 5.32), reaching maximum population densities during May to June each year. It can be seen from the vertical distribution graphs that *Hydrobaenus perennis* was indirectly related to the psychodid larvae.

Lloyd *et al*. (1940) recorded that *Hydrobaenus perennis* larvae, when in pure culture, burrowed deep into the film to pupate. It is most likely that a) the maximum abundance of larvae at the base of the filters, b) the high numbers of larvae washed out in the final effluent in comparison with other species and c) the scarcity of the pupae, were due to the downward migration of the larvae.

Metriocnemus hygropetricus was recorded at the low loading but rarely in the high rate filters. At the lower rate, the maximum abundance occurred during October and November in all the filters, the largest population being restricted to the top 300 mm during summer and the lower 600 mm during the autumn. Chironomid larvae are generally only found in large numbers in lightly loaded filters (Tomlinson and Stride, 1945) when the film accumulation is thin (Terry, 1956; Hawkes and Shephard, 1972). The upward migration of Metriocnemus hygropetricus larvae prior to pupation is well-known (Dyson and Lloyd, 1936) which may account for the greatest numbers of larvae being found at the surface.

Hydrobaenus minimus, currently named Limnophyes minimus (Meigen) (Pinder, 1978), was also restricted to the lower loading and was most successful during the thinner film conditions. The larvae were found from May to October and the adults from May through to September in the mixed and plastic filters. Generally this species was found at all depths, although there was a relatively large build-up at the surface during August and September in the plastic filter.

The chironomid larvae were only found in small numbers and so would have only a minor role in the purification process in the pilot filters. The larvae are capable of successfully competing with the other macroinvertebrates of the filter in favourable conditions. Lloyd et al., (1940) reported that chironomid larvae were able to compete with psychodid larvae for the available food, reducing the population densities of Psychoda spp. at the surface of the filter, and causing the extension of the species distribution deeper into the filter. In heavy film conditions the *Psychoda* and *Sylvicola* larvae are more able to cope than the larvae of the chironomid species, by utilising their respiratory siphons while buried in the thick layer of film. Both *Hydrobaenus minimus* and *Metriocnemus hygropetricus*, like *Psychoda severini*, have shorter life cycles than *Psychoda alternata* at the lower temperatures recorded in the filters. This may account for their relative success in the areas of the filters most affected by exposure to the air and so often relatively cold in comparison to the other areas of the filter.

5.9.3.4 Other dipteran species

Three other insect species were also recorded, *Scatella silacea*, *Spathiophora hydromyzina* and an unidentified leptoceran. All were found in low numbers, and so were comparatively unimportant in the overall energy flow within the filters. *Scatella silacea* was only recorded as pupae although the adults were quite abundant and were frequently recorded on the fly traps. The pupae were recorded in all three pilot filters at the lower loading rate during the summer and autumn, but at the higher loading they were restricted to the plastic filter from November to January (Tables 5.27 to 5.29). Adult *Leptocea* sp. and *Spathiophora hydromyzina* were frequently recorded on the fly traps and during fly counts, but only the pupae were recorded inside the filters. The leptoceran pupae were found in maximum numbers during the summer and autumn, being found generally in the top 600 mm of the filters, although they often extended throughout the filters. The pupae of *Spathiophora hydromyzina* were found in low numbers in the top of the filters during spring and in the bottom section during the summer. The pupae, which are comparatively large in size, may be washed downwards through the filters at high loadings and at times of low film accumulation.

5.9.3.5 Seasonal variation in fly populations

Table 5.32 summarises the periods of maximum abundance of the main filter flies recorded during the period June 1978 to September 1979. The period of maximum abundance coincides with the periods of peak emergence recorded by previous workers (Lloyd, 1945; Terry, 1951, 1952; Solbé *et al*., 1967). The maximum population of *Sylvicola fenestralis* occurred during June to July compared with April and May (Learner, 1975b). The distribution and emergence of all these species primarily depends on the temperature within the filter (Lloyd, 1945).

Flight and observed mating were generally restricted to the warmer months, although *Sylvicola fenestralis* and *Hydrobaenus perennis* were both recorded in flight during March in temperatures between 1.9 to 3.7°C. Threshold temperatures before flight occurs exist for all the species recorded in the pilot filters, and this and other factors affecting flight and mating have been reviewed by Learner (1975b).

Table 5.32: Summary of the data from the fly collections and fly traps

Species	Period of maximum abundance	Period when absent	Months when mating observed	Months when flight observed
Sylvicola fenestralis	June-July	November-February	June-July	June/July April/May
Scatella silacea	July-August	November-May	—	July
Psychoda alternata	June-July	December-April	July	June/July
Psychoda severini	June September-October	August, December-March	October	June/July
Spathiophora hydromyzina	June	September-May	July	June/July
Hydrobaenus minimus	July-August	October-May	July	June-August
Hydrobaenus perennis	April-May July	August-February	May-July	March-July
Staphylinidae	May-July	September-May	—	May-August

5.10 ARACHNIDA

The Class Arachnida is represented in percolating filters by the mites (Acari) and the spiders (Aranae). The present state of knowledge of this class in relation to waste water treatment has been reviewed by Baker (1975), in which he points out the general lack of information about the role of this group in the various purification processes. He also noted that no work has been carried out on either the seasonal incidence or spatial distribution of members of this class within percolating filters.

In the present investigation four species of Acari were recorded from all the pilot filters, three from the Order Astigmata which are slow moving invertebrates feeding on zoogloeal bacteria and other microorganisms found in the film; and one species from the Order Mesostigmata which is a quick moving mite feeding on the other macrofauna present including the Enchytraeidae and dipteran larvae. All four species Histiogaster carpio, Histiostoma feroniarum, Rhizoglyphus echinopus and the predatory Platyseius italicus have been recorded previously from percolating filters (Baker, 1961; Learner, 1975). The Astigmata were numerically dominant and found most frequently in the plastic filter at both loadings being found in the smallest numbers and least frequently in the slag filter (Table 5.33). The Astigmata were especially abundant in the drier areas of the medium.

The Astigmata were more successful during the lower loading rate, with the mean monthly population density falling by

Table 5.33: Mean monthly population densities of the Astigmatid mites (expressed as total number of individuals per litre of medium).

LOADING	DURATION (months)	slag filter			mixed filter			plastic filter		
		MEAN	maximum		MEAN	maximum		MEAN	maximum	
			TOTAL	MONTH		TOTAL	MONTH		TOTAL	MONTH
Low Loading	12	1750	3800	May	7063	18500	May	9296	32200	Apr
High Loading	11	896	2800	Oct	2309	7418	Jan	3586	9000	Mar
Both Loadings	23	1342			4789			6565		

between 48 to 67% after the laoding was increased to 3.37 $m^3m^{-3}d^{-1}$. The maximum mean population density recorded for any month was 32,200 individuals per litre of medium in the plastic filter during April at the lower loading (Table 5.33).

Histiostoma feroniarum was by far the most abundant species of mite recorded, being found in all the filters throughout most of the 23 month experimental period when the fauna was studied, except during the high loading period when it was not recorded in either the slag or plastic filters from June to August, nor in the mixed filter during July. At the lower loading the species was found throughout the pilot filters (Figure 5.27 to 5.32), with maximum population densities recorded during April and May.

The Astigmata were able to respond quickly to increases in film accumulation in comparison with the other macrograzers. Maximum population densities were recorded at least one month before the *Psychoda* larvae reached maximum numbers. Figures 5.27 to 5.32 clearly show that the abundance of the astigmatid mites was reduced by the presence of other macrograzers, in particular *Psychoda*. The mites were generally recorded in areas of moderate film accumulation and were not found during the periods of maximum abundance of psychodid larvae. The reproductive potential of the Astigmata and in particular *Histiostoma feroniarum* is far greater than that of the dipteran larvae (Learner, 1975b) or the Enchytraeidae (Learner, 1972). Hughes (1961) found that *Histiostoma feroniarum* completed its life cycle within 2 to 4 days at 20 to 25^{o}C, whereas *Rhizoglyphus echinopus* takes 9 - 13 days over a similar temperature range. Initially the mites took advantage of the large accumulation of film due to their fast reproductive rate, but the enormous numbers of psychodid larvae forced the mites into other areas of the pilot filters or caused a reduction in the total population densities. Hawkes (1951) recorded interspecific competition between the various species of insect present in the filter and Baker (1975) suggests that such competition could also exist between the dominant grazers.

Minimum populations of astigmatids coincided with very low film accumulations usually during August, when large numbers of the mites were washed out of the filters. The increased loading reduced the total numbers of mites present and restricted them to the lower half of the filters.

Correlation analysis between the Astigmata and the other major biological groups and various environmental parameters is summarised in Table 5.34. The direct relationship between the astigmatids and the Sarcomastigophora is due to _Histostoma feroniarum_ preferring the bacteria-rich layer of sewage which flows over the film and which is rich in flagellates.

Rhizoglyphus echinopus was also recorded in all three pilot filters being least abundant in the slag filter and not recorded in any of the filters during the colder months of January to March. Although _Histiogaster carpio_ was commonly found in the pilot filter it was not recorded in the survey of percolating filters by Baker (1961), but has since been recorded by other workers (Solbé _et al._, 1967; Learner, 1975).

Table 5.34: Correlations between the Acari-Astigmata and various biological groups and environmental parameters

	SLAG	MIXED	PLASTIC
LOW RATE	Sarcomastigophora (1+) *Paracyclops* (1+)		Sarcomastigophora (2+)
HIGH RATE		*Colpidium colpoda* (2+) *Chilodonella uncinata* (3+)	*Subbaromyces splendens* (1-) Nematoda (2+)
BOTH LOADINGS	Zoogloeal bacteria (1-) *Sphaerotilus natans* (1-) *Paracyclops* (3+)		*Subbaromyces splendens* (1-) Sarcomastigophora (2+)

It was found throughout the year, reaching maximum population densities during the autumn.

Platyseius italicus has been shown to feed on a wide variety of invertebrates, but mainly on *Lumbricillus rivalis*, although it does not eat the cocoons (Baker, 1961). It was closely associated with the Enchytraeidae in the present investigation, often being found on the surface together in large numbers, a phenomenon previously reported by Tomlinson (1946).

The success of *Histiostoma feroniarum* and the other Astigmata in the pilot filters at the lower loading is due to the continuous distribution system which produced a fine spray of low velocity onto the surface of the filters, creating the ideal environment for the mites. *Histiostoma feroniarum* has been shown to prefer a high humidity but is less frequent in very wet areas receiving strong flows of sewage, being more abundant in those areas receiving a more gentle spray of sewage (Baker, 1975). Reynoldson (1948) has shown that *Histiostoma feroniarum* can tolerate strong sewages, so the reduction in population numbers recorded in the pilot filters at the higher loading (Table 5.33) is possibly due to either a) the high hydraulic loading or b) the greater interspecific competition from other grazers present.

The Araeneae were not an important component of the present filters, being only occasionally recorded in low numbers. The particular species found were not identified but it was noticed that they were restricted to the drier areas of the filters, and were especially abundant in the base of the plastic filter and the top of the mixed filter. The spiders were more abundant in the plastic medium because of the dry areas associated with it (Section 2.4.2.). The commonest species was also recorded in the grass around the pilot filters and it is most likely that these spiders gained access to the filter by crawling either through the ventilation slits or by crawling up the side of the filters. The maximum numbers of spiders were recorded from August to December, a period when there would be a plentiful supply of adult flies within the filters.

5.11 CRUSTACEA-CYCLOPOIDEA

Only one crustacean was recorded in the pilot filters, this was *Paracyclops fimbriatus-chiltoni*. Learner (1975) found this species in 18% of the filters he surveyed, occurring in maximum numbers of 619 individuals per litre of medium. *Paracyclops* sp. are widely distributed and occur in a variety of habitats (Gurney, 1933).

The species was found throughout the two loading periods in all filters, reaching its greatest population density in the slag filter at the lower loading, and in the mixed filter during the higher loading (Table 5.35). It is shown in Figures 5.27 to 5.32 that *Paracyclops* sp. was more successful in the slag medium and this is reflected in the mean abundance figures given in Table 5.35. *Paracyclops* sp. was prone to being washed out in the final effluent throughout the year reaching a maximum during the spring sloughing period.

The vertical distribution graphs (Figures 5.27 to 5.32) indicate that the cyclopoids were most abundant in moderate film conditions, and it appears that the species was restricted by the increase in the numbers of psychodid larvae and mites. Although at the lower loading the species was found through the filters reaching maximum abundance below 900 mm, and also in the slag portion of the mixed filter. Maximum population densities occurred from July to September. This species was restricted to even lower depths in the filters at the higher loading, with minimum abundance occurring during the spring and summer.

Table 5.35: Mean monthly population density of *Paracyclops fimbriatus-chiltoni* (expressed as total number of individuals per litre of medium)

LOADING	DURATION (months)	SLAG FILTER			MIXED FILTER			PLASTIC FILTER		
		MEAN	MAXIMUM		MEAN	MAXIMUM		MEAN	MAXIMUM	
			TOTAL	MONTH		TOTAL	MONTH		TOTAL	MONTH
Low Loading	12	880	2187	Aug	830	2987	Aug	609	1147	Jan
High Loading	11	112	400	Oct	622	4267	Oct	56	267	Oct
Both Loadings	23	513			731			345		

The correlations of *Paracyclops* sp. with the other animal groups and important environmental parameters is summarised in Table 5.36. The analysis does not directly indicate the species is tolerant of heavy organic loadings, as noted by Learner (1975), although its association with *Paramecium aurelia* in the plastic filter, and *Subbaromyces splendens* and *Sphaerotilus natans* in the slag and mixed filters must indicate a degree of tolerance to large film accumulations associated in turn with heavy organic load. The species is indirectly related to the *Psychoda* larvae, which reflects the overall disruptive effect the psychodid larvae have on the film.

Table 5.36: Correlations between *Paracyclops fimbriatus-chiltoni* and various biological groups and environmental parameters

	SLAG	MIXED	PLASTIC
LOW RATE	Film weight(1-) *Subbaromyces splendens* (2+) Acari-Astigmata (1+) Temperature(1+)	*Subbaromyces splendens*(1+)	Film weight(2+) *Paramecium aurelia* (1+) *Uronema nigricans* (2-) Psychodid larvae (1-)
HIGH RATE	Ciliophora (2+)	*Sphaerotilus natans* (3+)	*Paramecium aurelia* (2+)
BOTH LOADINGS	Zoogloeal bacteria (1-) *Subbaromyces splendens* (2+) Acari-Astigmata (3+) *Sphaerotilus natans* (1-)		Zoogloeal bacteria (1-) *Paramecium aurelia* (1+) Organic Load (1-)

5.12 PERIODIC INVERTEBRATE VISITORS

Although several of the insect species and also the spiders could be classified as occasional visitors, the centipedes and slugs were regularly recorded making foraging expeditions into the filters, gaining entrance through the base or climbing up the walls.

5.12.1 CHILOPODA

A common visitor to the pilot filters was the centipede *Lithobius forficatus* (Tables 5.27 to 5.29). It was found in comparatively low numbers, usually less than 8 individuals per litre of medium, in the top 300 mm of all the filters at both loadings from March to May and again during October and November. Previously recorded by Baker (1942), it is an opportunist feeder moving rapidly through the medium.

5.12.2 GASTROPODA

The presence of molluscs in percolating filters has been reviewed by Learner (1975c), in which he notes that slugs, in particular *Agriolimax reticulatus*, have only occasionally been recorded in percolating filters. *Agriolimax reticulatus* was regularly recorded in the pilot filters, normally confined to the surface of the mixed and plastic filters although found at various depths up to 1200 mm in the plastic filter. This species was never recorded in the slag filter, and it is possible that the plastic medium, with the larger voidage, allowed greater access inside the filter. The species is terrestrial in origin, and so the plastic medium provided a slightly drier habitat than the slag medium. The species was absent from the plastic and mixed filters from February to August, being present in the filters for the rest of the year, reaching maximum population densities during October.

It seems apparent that most of the visiting species to the filters, overwintered in the relatively warm environment of the filters which is rich in food, until the spring when they were commonly recorded on the ground in the vicinity of the pilot plant.

6.1 INTRODUCTION

In the simplest terms, the performance of a percolating filter (i.e. its purification efficiency) is determined by the amount of active film, and the contact time between the active film and the influent sewage as it passes through the filter. This equilibrium is affected by changes in the composition and volume of the influent as well as by changes in environmental variables such as temperature and ventilation. Once the microfauna comprising the film has become established on the available surface area of the medium, then the performance will be regulated by the metabolic activity of the film and its capacity to adsorb and absorb the organic material present.

In this Chapter, the main chemical performance data from the three pilot filters are compared over the three different loading periods. Film accumulations, temperature of the filters and their retention times, all of which directly affect the efficiency of the filters, are discussed and their influence on the efficiency of performance examined. The chemical data is given in full in Appendix III, and a detailed correlation analysis is given in Appendix VII.

Initially, the pilot filters were matured for a period of three months at the very high loading rate of 5.72 $m^3m^{-3}d^{-1}$ (0.85 kg BOD $m^{-3}d^{-1}$). This was followed by the two main loadings during which biological samples were also taken. The first loading of 1.68 $m^3m^{-3}d^{-1}$ (0.28 kg BOD $m^{-3}d^{-1}$) for twelve months, which in fact covered thirteen sampling months, and the second loading of 3.37 $m^3m^{-3}d^{-1}$ (0.63 kg BOD $m^{-3}d^{-1}$)

for twelve months, again an experimental period of thirteen months.

6.2 CHEMICAL PERFORMANCE

6.2.1 BIOCHEMICAL OXYGEN DEMAND

At the lower loading (1.68 $m^3m^{-3}d^{-1}$), all three filters produced final effluents of similar quality, with the plastic filter producing the worst final effluent of 22.5 mgl^{-1}, and also the widest range of values (Table 6.1). The mean effluent quality of the filters for the year at the lower loading are shown to be similar in Figure 6.1, with the 95% confidence limits for all three filters overlapping. The smaller confidence limits indicate that the slag filter was producing a more consistent final effluent quality at both loadings, compared with the other filters.

At the higher loading of 0.628 kg BOD $m^{-3}d^{-1}$, the mean percentage removal remained similar in all three filters, although the effect of increasing the load was reflected in the poorer final effluent quality and the larger maximum BOD concentrations. Table 6.2 indicates that the increase in loading did not affect the percentage removal of BOD in either the mixed or plastic filters, although the slag filter suffered a significant reduction in removal efficiency of 5.2%. The difference between the removal efficiencies of the slag and mixed filters was found to be significantly different ($P < 0.01$) at the higher loading. The final effluent quality of all three pilot filters decreased at the higher loading with the slag producing the worst mean final effluent at 33.1 mgl^{-1}, an overall decrease in quality of 63.8% compared with the previous year. Although

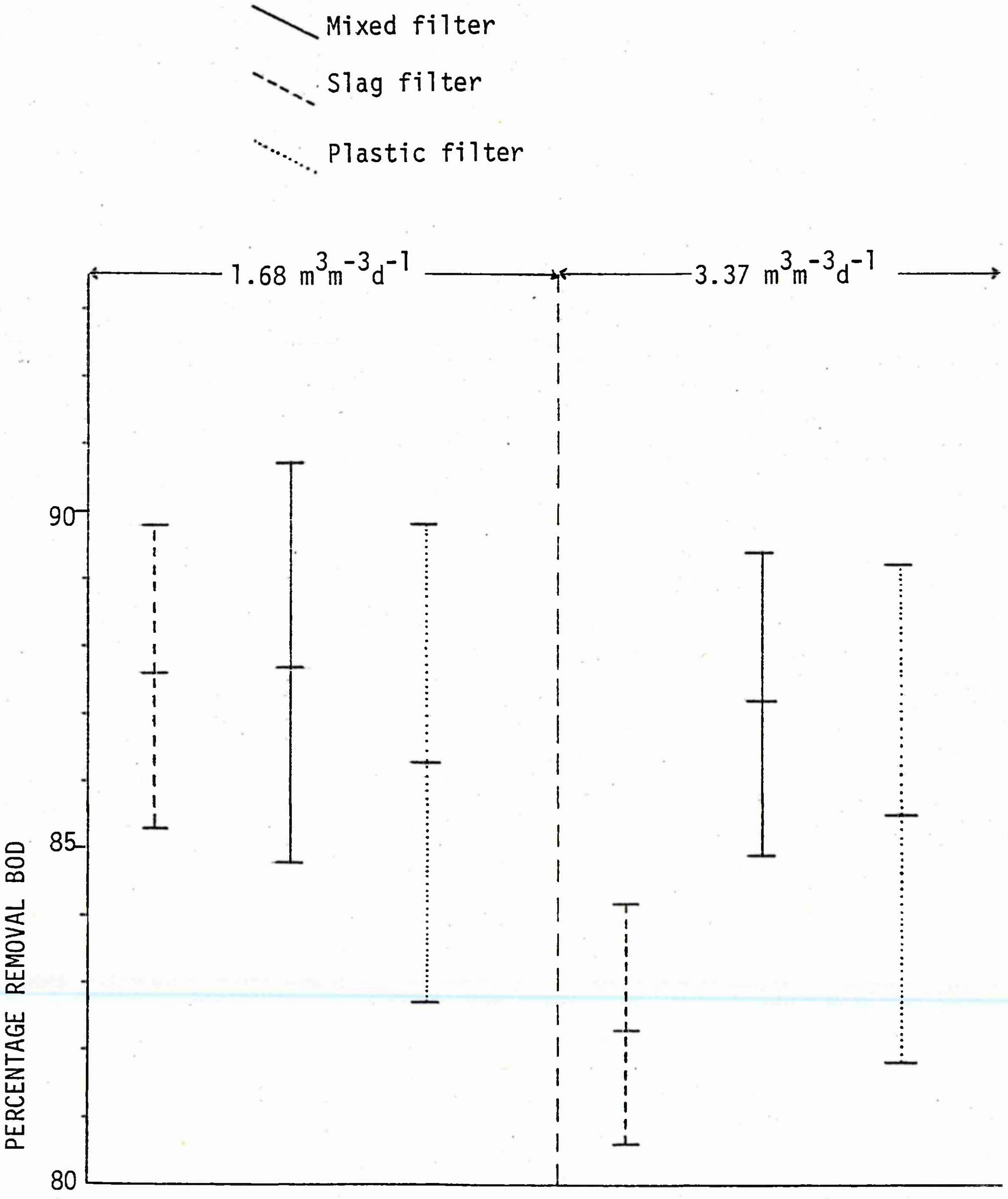
Table 6.1: Summary of the mean biochemical oxygen demand of the final effluents of the pilot filters loaded at 1.68 $m^3m^{-3}d^{-1}$ (0.28 kg BOD $m^{-3}d^{-1}$) over the thirteen months sampled.

		SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Effluent Quality (mgl^{-1})	Mean	20.2	20.5	22.5
	Minimum	9.6	6.0	6.1
	Maximum	48.4	53.0	61.9
	Range	38.0	47.0	55.8
	95% C.L.	6.6	7.9	8.5
	n	40	40	40
Percentage Removal (%)	Mean	87.6	87.7	86.3
	Minimum	81.2	77.4	75.4
	Maximum	93.4	94.1	93.1
	Range	12.2	16.7	17.7
	95% C.L.	2.3	3.0	3.6
	n	40	40	40

Table 6.2: Summary of the mean biochemical oxygen demand of the final effluents of the pilot filters loaded at 3.37 $m^3m^{-3}d^{-1}$(0.63 kg BOD $m^{-3}d^{-1}$) over the thirteen months sampled.

		SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Effluent Quality (mgl^{-1})	Mean	33.1	25.0	27.1
	Minimum	9.8	7.5	8.7
	Maximum	50.3	50.7	59.8
	Range	40.5	43.2	51.1
	95% C.L.	8.2	8.3	9.1
	n	35	35	35
Percentage Removal (%)	Mean	82.4	87.2	85.5
	Minimum	76.6	75.0	70.7
	Maximum	89.1	93.4	94.4
	Range	12.5	18.4	23.7
	95% C.L.	1.8	2.3	3.7
	n	35	35	35

Figure 6.1: Mean BOD removals, including 95% confidence limits for the pilot filters at 1.68 and 3.37 $m^3m^{-3}d^{-1}$.



the ranges of monthly mean BOD concentrations in the final effluents were not very different from those recorded at the lower loading, a significant difference between the mixed and slag filters was recorded, and is reflected by the greater separation of the confidence limits (Figure 6.1).

Although only tentative conclusions can be drawn from the results recorded during the very high loading period at 5.72 $m^3m^{-3}d^{-1}$, during the maturation of the filters; the percentage removal of BOD in both the slag and plastic filters were clearly restricted, producing final effluents containing 33.7 and 32.0 mgl^{-1} BOD respectively (Table 6.3). The mixed filter achieved the greatest removal efficiency of 74.5% for the period, a mean final effluent of 26.3 mgl^{-1} which was significantly better ($P < 0.1$) than that achieved by the slag filter.

Table 6.4 summarises the rate of removal of BOD from each filter over the three loading periods. A doubling of the hydraulic loading to 3.37 $m^3m^{-3}d^{-1}$ resulted in a similar increase in the rate of removal of BOD in all three filters, the mixed filter removing on average about 0.03 kg BOD $m^{-3}d^{-1}$ more than the slag filter. At the very high loading period of 5.72 $m^3m^{-3}d^{-1}$, the rates of removal increased in all the filters, with the mixed filter achieving the greatest removal at 0.64 kg BOD $m^{-3}d^{-1}$. Although the rate of BOD removal increased with organic load, only the more easily removable BOD fraction was being removed. This left the more difficult fraction untreated due to the relatively short retention time and the possible restriction of autotrophic bacteria at

Table 6.3: Summary of the mean performance of all three pilot filters at the various loadings

Hydraulic loading	1.68 $m^3m^{-3}d^{-1}$			3.37 $m^3m^{-3}d^{-1}$			5.72 $m^3m^{-3}d^{-1}$		
Duration of loading	13 months			13 months			3 months*		
Filter	SLAG	MIXED	PLASTIC	SLAG	MIXED	PLASTIC	SLAG	MIXED	PLASTIC
Organic Load (kg BOD $m^{-3}d^{-1}$)	0.280			0.628			0.854		
Effluent BOD (mgl^{-1})	20.20	20.53	22.54	33.09	25.03	27.12	33.70	26.25	32.00
Percentage Removal BOD	87.58	87.73	86.26	82.36	87.18	85.50	68.00	74.50	68.60
Suspended solids load (kg $m^{-3}d^{-1}$)	0.201			0.417			0.743		
Effluent s/s (mgl^{-1})	24.73	24.72	27.53	31.08	26.32	28.79	71.00	39.50	27.00
Percentage Removal s/s	77.82	77.67	75.66	72.20	77.00	78.30	41.60	60.10	66.40
Ammonia load (kg $m^{-3}d^{-1}$)	0.054			0.075			0.114		
Effluent ammonia (mgl^{-1})	14.71	17.80	20.73	17.98	15.75	19.09	16.90	16.60	16.70
Percentage Removal NH_3	52.81	44.97	34.86	21.08	32.42	17.75	7.75	8.45	8.2
Total Oxidised Nitrogen (mgl^{-1})	14.32	12.09	9.03	6.19	6.95	4.30	1.05	1.15	0.75
Effluent temperature (^oC)	8.97	8.78	8.94	10.86	10.64	11.09	-	-	-

*These results were collected over a shorter period during maturation of the filters, and so are not directly comparable to the results collected during the other loadings

Table 6.4: Rates of removal of biological oxygen demand

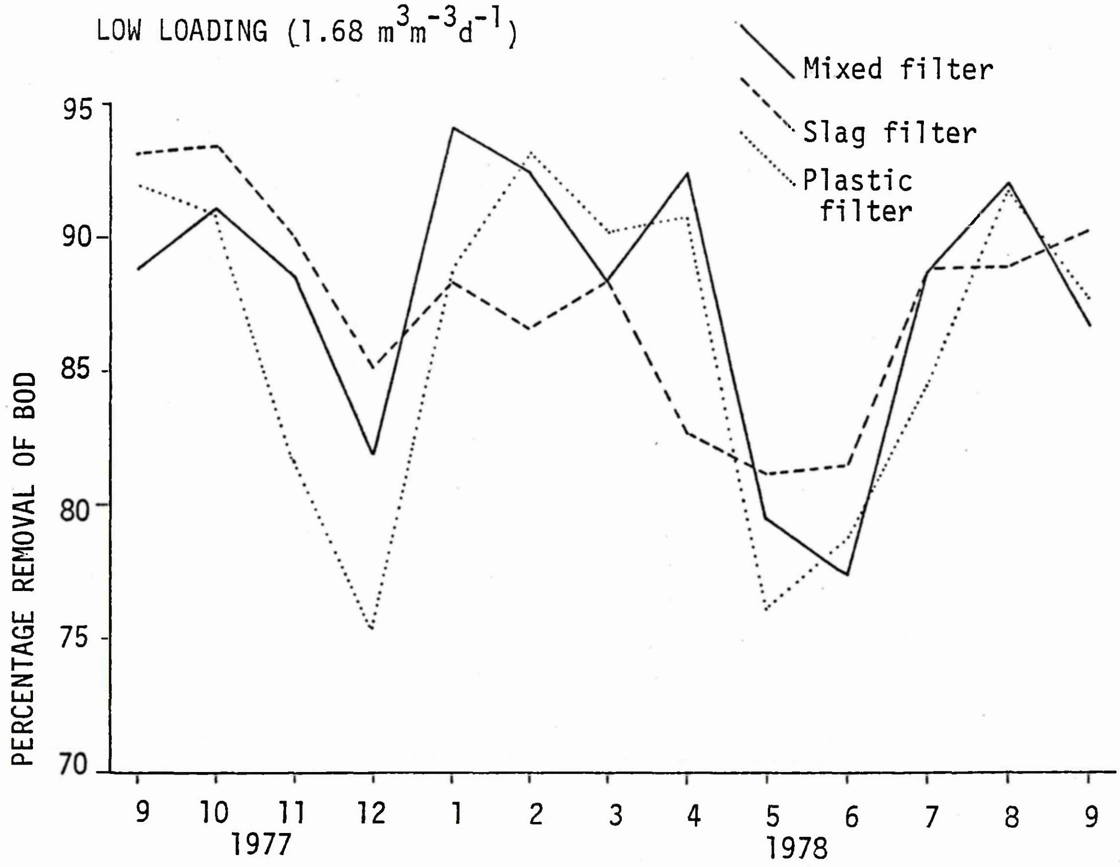
Hydraulic loading ($m^3 m^{-3} d^{-1}$)	Organic loading (kg BOD $m^{-3} d^{-1}$)	Rate of removal of BOD (kg BOD $m^{-3} d^{-1}$)		
		SLAG FILTER	MIXED FILTER	PLASTIC FILTER
1.68	0.28	0.25	0.25	0.24
3.37	0.63	0.52	0.55	0.54
5.72	0.85	0.58	0.64	0.59

the higher loading rates, which resulted in an overall decline in the final effluent quality.

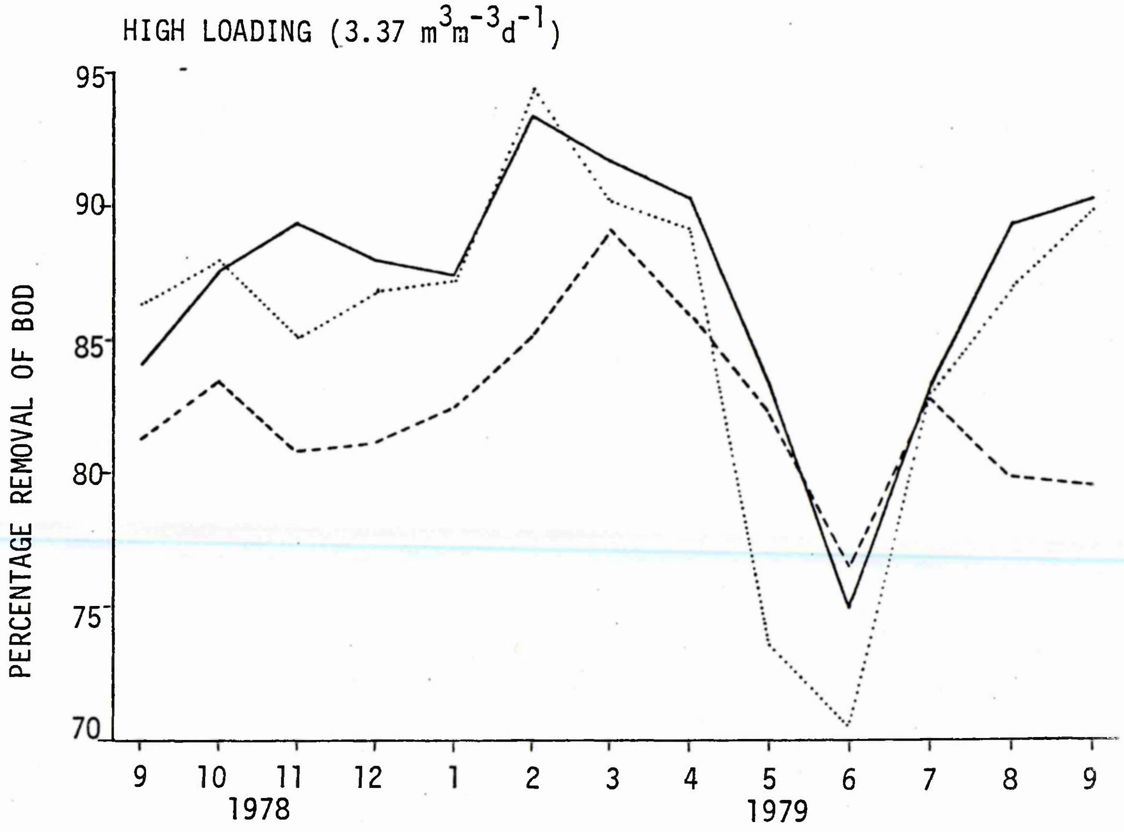
Seasonal variations in BOD removal and in the BOD concentration of the final effluent are shown in Figures 6.2 and 6.3 respectively. The seasonal patterns recorded from all the filters were similar at both the main loadings, with maximum removal occurring during periods of maximum rate of film accumulation. The plastic filter achieved maximum removal efficiencies immediately after the film had sloughed. The other filters, unable to increase film accumulation at the same rate, produced poorer final effluents during this period. There were also fewer grazers in the plastic filter during the higher loading to reduce the overall level of film accumulation. Surprisingly, the plastic filter was the least effective of the pilot filters in dealing with heavy organic loads, especially during the higher loading. The period of disruption, caused by the unloading of the film during the spring sloughing, was as prolonged in the plastic filter as in the other two, although it was thought that one of the advantages of the large voidage was that it encouraged the unloading of the film to proceed quickly (Howell and Atkinson, 1976).

At the lower loading, the slag and plastic filters produced final effluents with a mean BOD concentration of 20 mgl^{-1} or less for seven months out of a total of thirteen sampled, compared with nine months in the mixed filter. At the higher loading, the slag filter only produced a final effluent conforming to the Royal Commission Standard for three months out of thirteen sampled, compared with five months for the

Figure 6.2: Seasonal variation in the mean removal of BOD from the final effluent during the two loadings of 1.68 and 3.37 $m^3m^{-3}d^{-1}$.



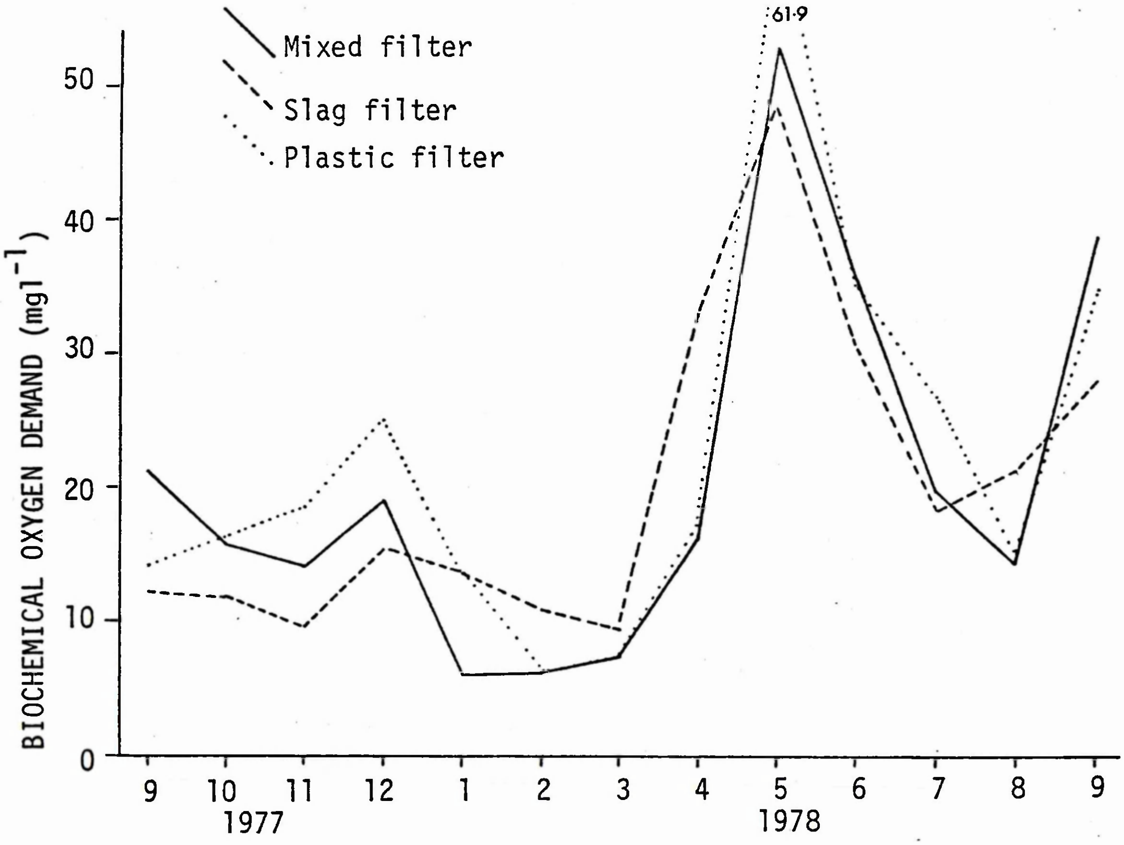
LOW LOADING (1.68 $m^3m^{-3}d^{-1}$)



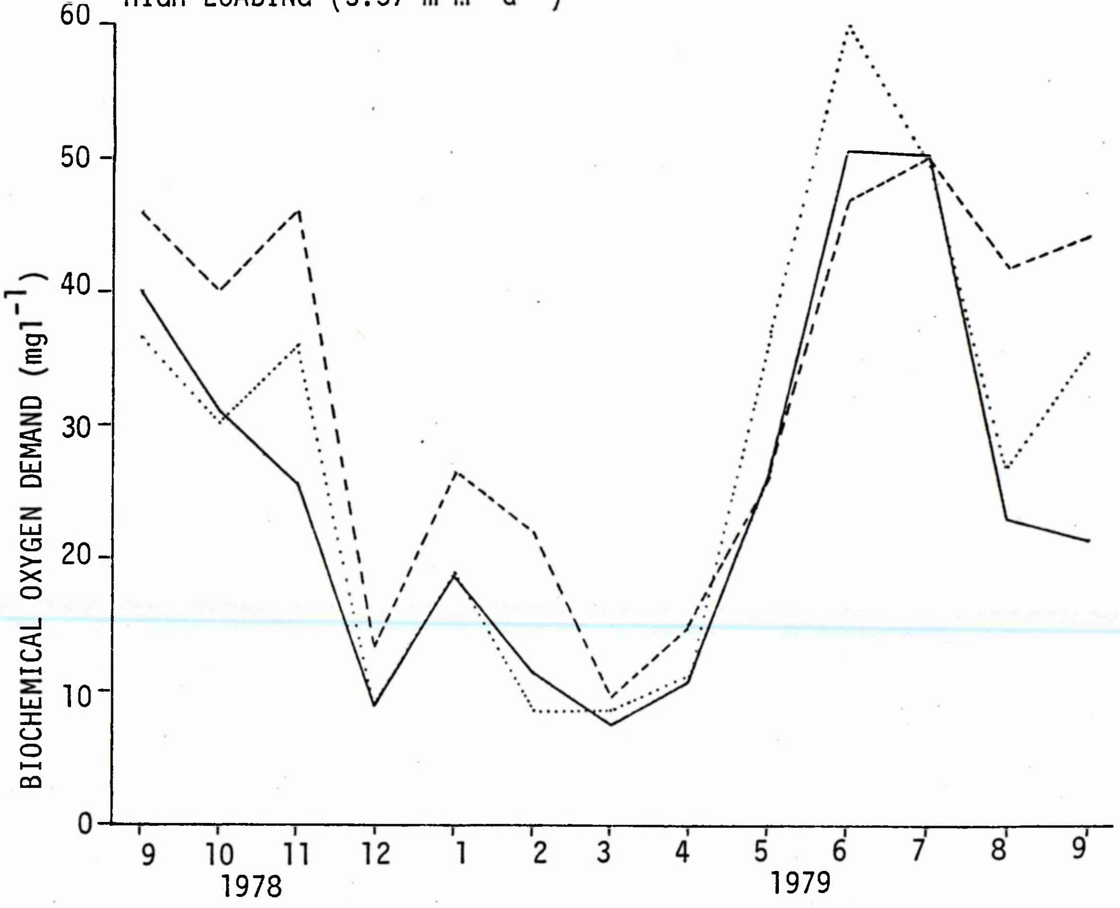
HIGH LOADING (3.37 $m^3m^{-3}d^{-1}$)

Figure 6.3: Seasonal variation in the mean BOD of the final effluent during the two loadings of 1.68 and 3.37 $m^3m^{-3}d^{-1}$.

LOW LOADING (1.68 $m^3m^{-3}d^{-1}$)



HIGH LOADING (3.37 $m^3m^{-3}d^{-1}$)



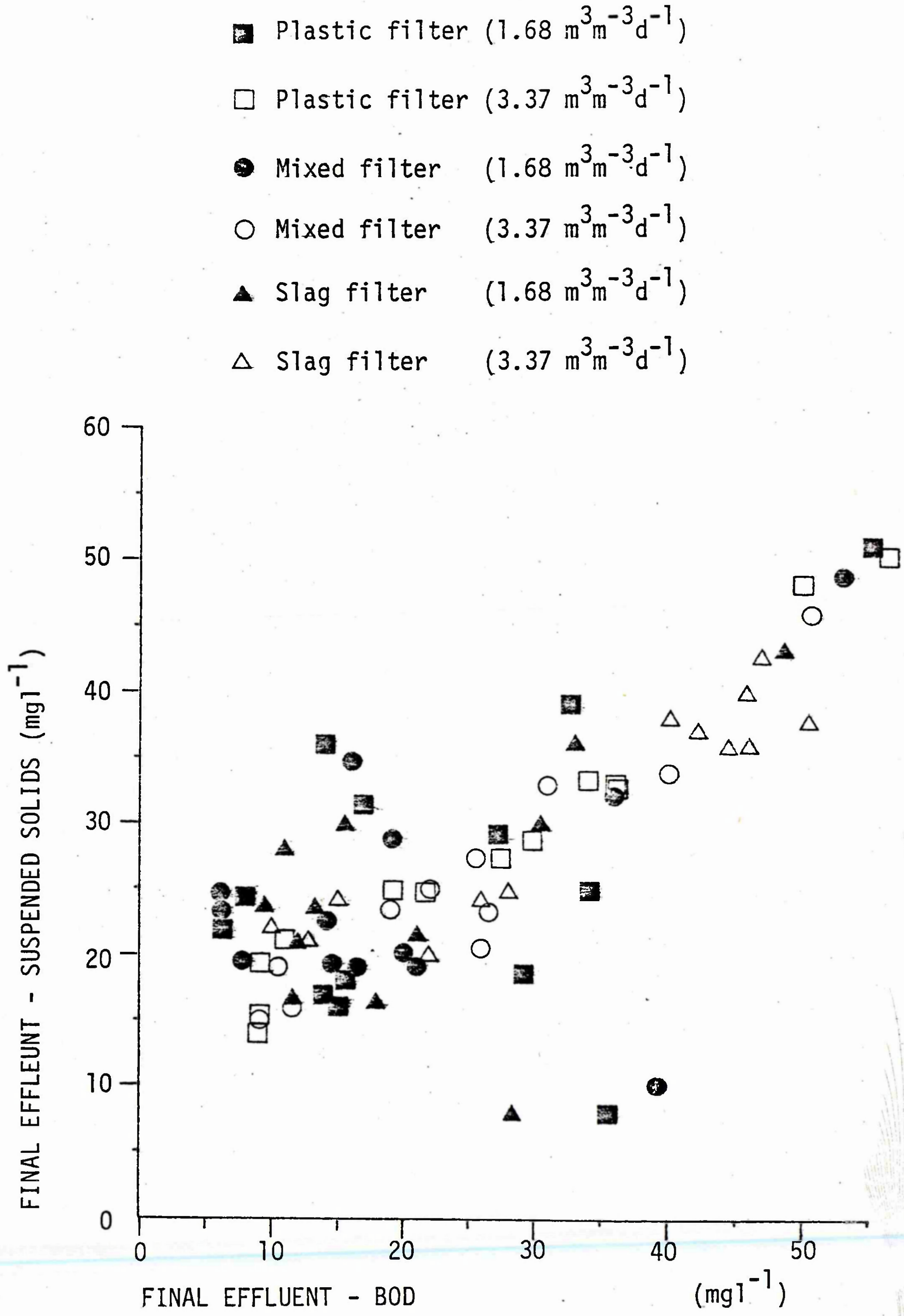
plastic and mixed filters. If the minimum BOD concentration limit was increased to 40 mgl^{-1} then the slag filter would have failed to achieve the new limit six months out of the year compared with only two months in the mixed and plastic filters. It must be noted however that when the BOD in the final effluent of the slag filter was in excess of 40 mgl^{-1}, the influent was always in excess of 200 mgl^{-1}.

Comparing the efficiency of the filters from month to month at the higher loading (Figure 6.3), the mixed filter produced the best final effluent for eleven months out of the possible thirteen months studied. The failure of the mixed filter during those two months to produce a better effluent than the slag filter was due to the greater amount of film being unloaded from the mixed filter at this time.

Generally, minimum BOD removal occurred at the same time as maximum accumulation of film and maximum population density of the grazing fauna. The disruption of the film by the grazers and the resultant increase in solids, accounted for the deterioration of final effluent quality. The unstable film conditions limited the rate of adsorption of the suspended material from the influent sewage and its subsequent degradation. The close correlation between final effluent BOD and suspended solids concentrations, seen during both loadings, proves that a reduction in the adsorption of solids resulted in an overall increase in the BOD (Figure 6.4; Appendix VII).

A clear relationship is apparent between the percentage

Figure 6.4: Scatter diagram showing relationship between BOD and suspended solids concentration in the final effluents of all three pilot filters at both main loadings.



removal of BOD at the various depths (Table 6.5) and the vertical distribution of the film (Figures 6.11 and 6.12). Large removals of BOD were associated with a relatively thin active film. This association continued until the film became so thick that it began to restrict the flow of sewage through the filter. This resulted in a shorter retention time due to channelling, and a subsequent decrease in removal efficiency.

During the low loading, most of the BOD in the influent was removed in the top 300 mm of the filters (Table 6.5a), with the plastic medium achieving slightly better removal efficiencies. In all the pilot filters, the percentage removal of BOD decreased with the depth. About three-quarters of all the available BOD was removed in the top 900 mm of the filters, with the slag removing 74.5% and the mixed and plastic filters both removing 79.5% of the influent BOD. Only at depths below 900 mm was no removal recorded at all.

At the higher loading the filters behaved more individually. The BOD removal efficiency of the top 300 mm of the slag filter decreased by 27.97% compared with the lower loading and maximum removal now occurred lower down the filter (Table 6.5b). In the mixed and plastic filters, maximum removals still took place in the top 300 mm, although the efficiencies were reduced slightly. There was a decrease in the overall removal efficiency of the top 900 mm to 61.73% in the slag, 65.71% in the mixed and 67.13% in the plastic filters. The 900 - 1500 mm section of all the filters was able to remove small weights of BOD, and in the mixed and plastic filters the mean removal efficiency of this section was approximately double what it

Table 6.5a: The percentage removal of the total BOD, in relation to depth, at low loading

	SLAG FILTER				MIXED FILTER				PLASTIC FILTER			
Depth in mm	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800
Low Loading 1.68 $m^3m^{-3}d^{-1}$												
Nov. 77	69.6	16.4	5.7	5.9	58.9	32.5	2.8	0.0	63.1	26.0	0.0	2.8
Dec. 77	30.0	17.1	27.5	4.3	26.9	15.4	29.7	0.0	30.0	27.1	16.3	0.0
Jan. 78	20.6	61.6	12.2	0.0	40.0	46.1	0.0	3.4	47.5	45.4	3.7	1.5
Feb. 78	32.7	21.6	45.6	0.0	43.7	46.1	0.0	4.5	66.9	31.9	0.0	0.8
Mar. 78	40.8	33.8	13.3	6.5	53.2	19.4	22.5	0.3	58.7	22.5	3.4	6.6
Apr. 78	-	-	-	-	-	-	-	-	-	-	-	-
May. 78	59.0	27.9	0.0	2.7	62.0	19.3	14.4	0.0	56.9	24.6	6.9	2.8
Jun. 78	38.8	37.3	0.0	12.4	34.4	50.3	0.6	4.5	68.3	0.4	10.1	3.9
Jul. 78	58.6	25.7	3.7	7.5	57.2	26.8	3.0	6.8	45.5	27.1	19.0	0.0
Aug. 78	73.1	15.9	0.0	1.9	48.1	39.5	3.6	1.9	45.7	37.9	9.9	0.0
Sep. 78	44.2	20.3	17.9	7.9	68.4	6.8	12.3	0.0	42.2	27.3	10.2	8.1
Mean	46.74	27.76	12.59	4.91	49.28	30.22	8.89	2.14	52.48	27.02	7.95	2.65
S.D.	17.56	13.96	14.69	3.91	13.08	14.96	10.47	2.50	12.29	11.62	6.43	2.84

Table 6.5b: The percentage removal of the total BOD, in relation to depth, at high loading

	SLAG FILTER				MIXED FILTER				PLASTIC FILTER			
Depth in mm	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800
High Loading 3.37 $m^3m^{-3}d^{-1}$												
Sep. 78	36.9	15.9	28.6	0.0	43.0	14.6	12.0	8.5	28.6	36.4	0.0	19.7
Oct. 78	32.0	43.3	9.6	0.0	54.2	13.6	9.6	8.8	35.7	46.9	0.0	12.8
Nov. 78	40.0	11.6	29.0	3.6	38.4	25.7	18.8	5.8	36.5	32.1	15.5	0.8
Dec. 78	2.1	10.6	54.2	0.7	59.9	11.9	7.8	2.1	38.7	2.9	33.8	0.0
Jan. 79	10.4	42.1	38.3	0.0	24.2	19.8	46.5	0.0	29.3	31.5	27.3	1.9
Feb. 79	45.3	39.8	10.1	0.0	61.1	14.0	17.1	0.0	51.4	25.2	12.2	4.5
Mar. 79	19.4	36.4	29.7	0.0	48.0	24.6	6.4	8.7	24.2	33.2	29.1	0.0
Apr. 79	60.4	19.8	11.0	0.3	73.9	12.1	6.3	3.0	75.3	0.0	13.2	3.0
May. 79	26.5	44.8	16.5	1.7	50.0	0.0	40.9	1.2	56.9	11.3	0.0	0.0
Jun. 79	20.0	47.7	10.5	0.0	4.5	57.4	9.8	0.0	41.5	10.4	19.3	0.0
Jul. 79	42.8	26.2	17.8	1.2	47.0	25.3	12.1	1.5	47.4	41.9	0.0	13.2
Aug. 79	17.5	51.3	9.3	4.2	33.4	39.8	15.6	4.2	33.6	42.9	16.7	0.0
Sep. 79	10.2	49.4	21.6	3.4	33.3	24.5	35.3	0.0	41.8	17.1	30.4	2.6
Mean	27.97	33.76	22.02	1.16	43.92	21.79	18.32	3.37	41.61	25.52	15.19	4.50
S.D.	16.72	14.92	13.57	1.57	17.83	14.39	13.62	3.49	13.71	15.68	12.49	6.48

had been at the lower loading. Therefore at the higher loading rate the depth to which the heterotrophic bacteria were found was extended to 1500 mm (Section 6.2.3). In the lowest 300 mm of the filters (1500 - 1800 mm) there was a very low mean removal efficiency, often falling to zero during the colder months of September to April.

An alternating pattern of film accumulation and maximum removal efficiency was discernible between the top and lower 300 mm of the filters (Figure 6.12). Initially the top half of the filters became heavily loaded with film, and the BOD and suspended solids removal dropped, increasing the organic load to the lower 900 mm. Film growth subsequently increased at the lower depth followed by an increase in removal efficiency. But as the film in the top half was removed by grazers, the area of maximum film growth and removal efficiency reverted back to the top half of the filters.

6.2.2 SUSPENDED SOLIDS

The mean removal efficiency of suspended solids increased in the plastic filter from 75.66 to 78.30% following the increase in loading from 1.68 to 3.37 $m^3m^{-3}d^{-1}$. At the lower loading, the mixed and slag filters produced final effluents with similar mean concentrations and percentage removals of suspended solids (Table 6.6). The increase in loading rate caused only a slight reduction in the removal efficiency of the mixed filter, but a significant decrease of 5.6% in the slag filter

Table 6.6: Summary of the mean suspended solids concentration of the final effluents of the pilot filters loaded at 1.68 $m^3m^{-3}d^{-1}$ (0.28 kg BOD $m^{-3}d^{-1}$) over the thirteen months sampled.

		SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Effluent Quality (mgl^{-1})	Mean	24.7	24.7	27.5
	Minimum	8.0	10.0	8.0
	Maximum	43.5	49.0	53.0
	Range	35.5	39.0	45.0
	95% C.L.	5.2	5.5	6.7
	n	42	42	42
Percentage Removal (%)	Mean	77.8	77.6	75.7
	Minimum	61.8	58.8	55.0
	Maximum	91.4	89.4	91.4
	Range	29.6	30.6	36.4
	95% C.L.	4.5	4.5	6.0
	n	42	42	42

Table 6.7: Summary of the mean suspended solids concentration of the final effluents of the pilot filters loaded at 3.37 $m^3m^{-3}d^{-1}$ (0.63 kg BOD $m^{-3}d^{-1}$) over the thirteen months sampled.

		SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Effluent Quality (mgl^{-1})	Mean	31.1	26.3	28.8
	Minimum	20.0	15.0	14.0
	Maximum	42.7	46.0	51.3
	Range	22.7	31.0	37.3
	95% C.L.	4.8	5.7	6.39
	n	37	37	37
Percentage Removal (%)	Mean	72.2	77.0	78.3
	Minimum	60.9	60.9	57.0
	Maximum	83.6	88.2	84.7
	Range	22.7	27.3	27.7
	95% C.L.	3.4	3.9	4.5
	n	37	37	37

(Table 6.7). The final effluents of the filters were generally worse than previously recorded at the lower loading with the mixed and plastic filters producing a mean final effluent within the Royal Commission Standard of 30 mgl^{-1} at 26.3 and 28.8 mgl^{-1} respectively, and the slag filter producing a mean final effluent of 31.1 mgl^{-1}. The t-test analysis showed that the percentage removal of suspended solids in the mixed and slag filters, was significantly different ($P < 0.1$) at the higher loading of 3.37 $m^3m^{-3}d^{-1}$.

During the maturation period when the filters were loaded at 5.72 $m^3m^{-3}d^{-1}$, the slag filter was unable to produce a satisfactory effluent, achieving only 41.6% removal compared with 60.1% in the mixed and 66.4% in the plastic filters, which were producing final effluents of 39.5 and 27.0 mgl^{-1} of suspended solids respectively.

The seasonal variation in the final effluent quality (Figure 6.5) of the three filters followed similar patterns at both loadings, while removal efficiency of suspended solids was observed to be far more unpredictable (Figure 6.6).

On a month to month basis (Figure 6.5; Table 6.7), the mixed filter produced a final effluent of less than 30 mgl^{-1} of suspended solids for nine months during each of the main loadings. This compares with seven (low) and eight (high) months, and eight and six months for the plastic and slag filters respectively. At the higher loading the mixed filter produced a better mean monthly final effluent than the slag filter in terms of suspended solids for eleven out of the

Figure 6.5: Seasonal variation in mean suspended solids of the final effluent during the two loadings of 1.68 and 3.37 $m^3m^{-3}d^{-1}$.

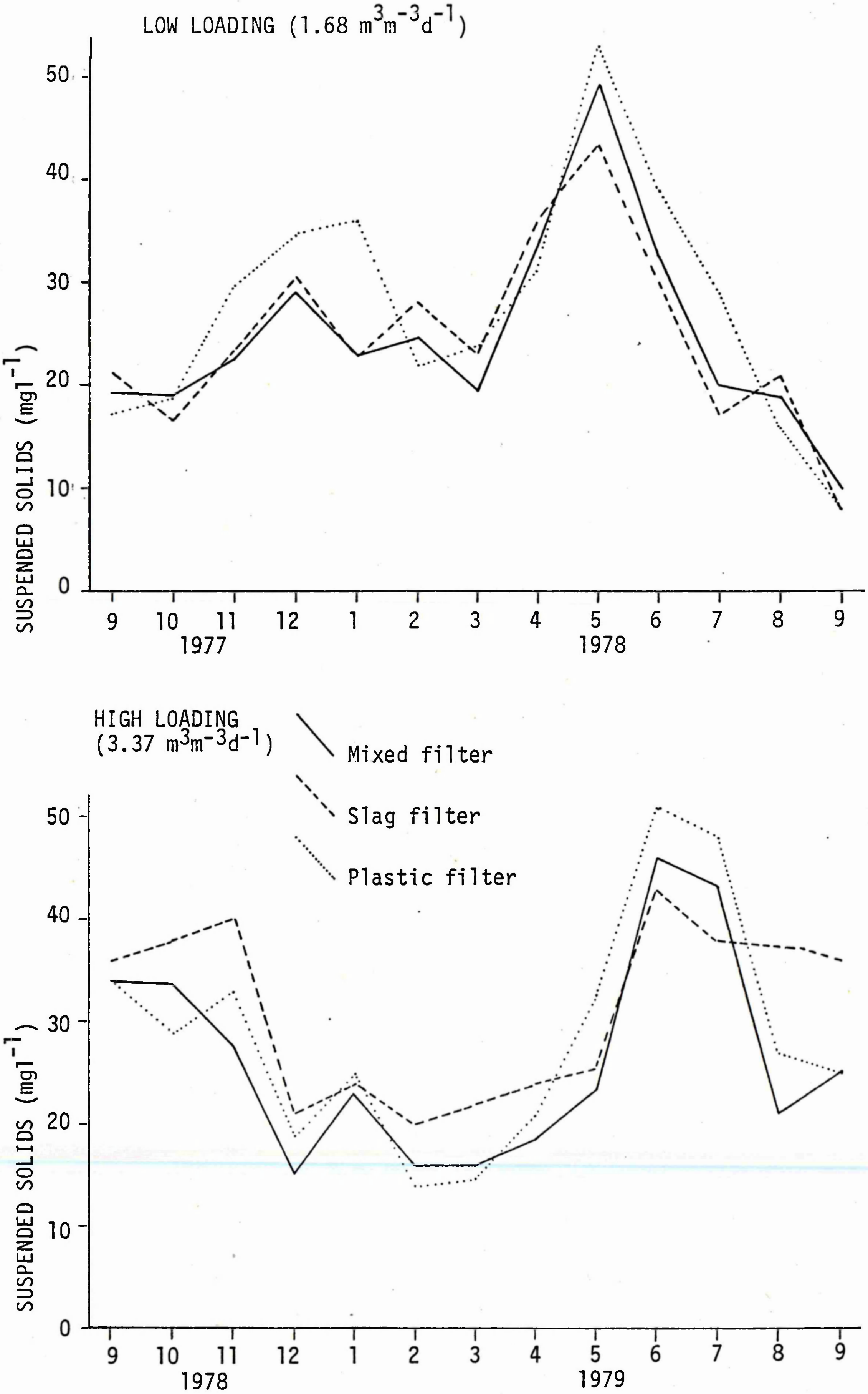
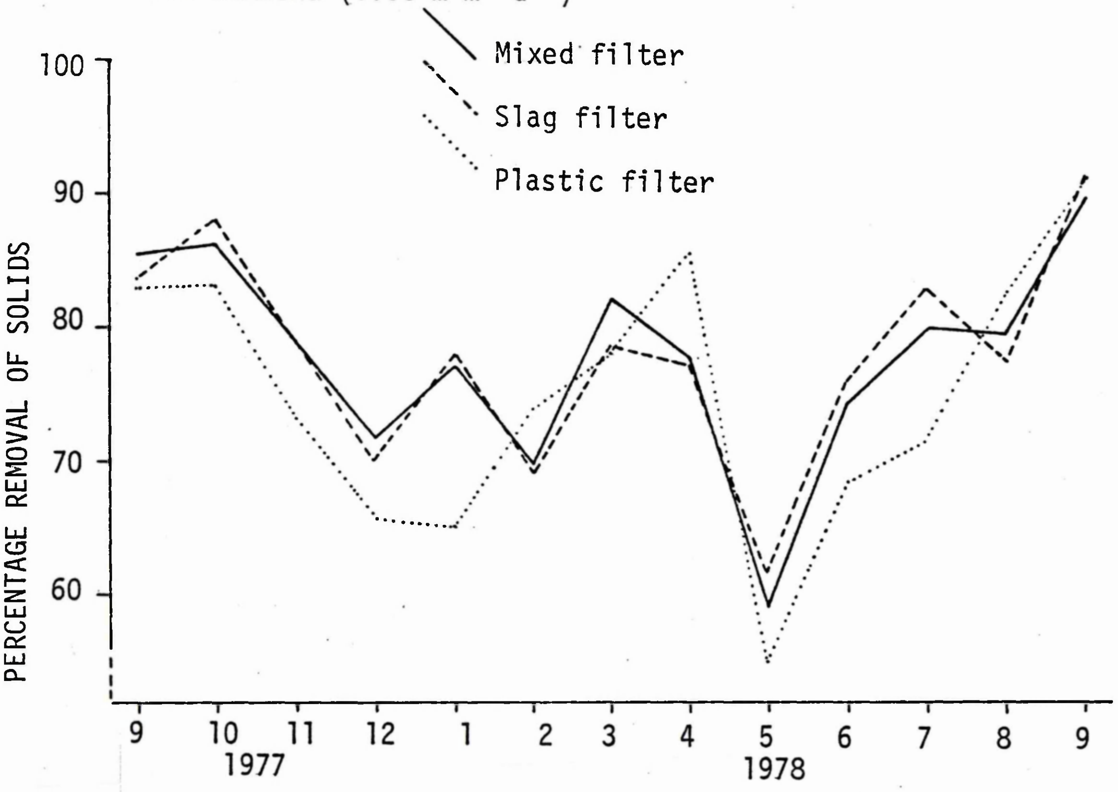
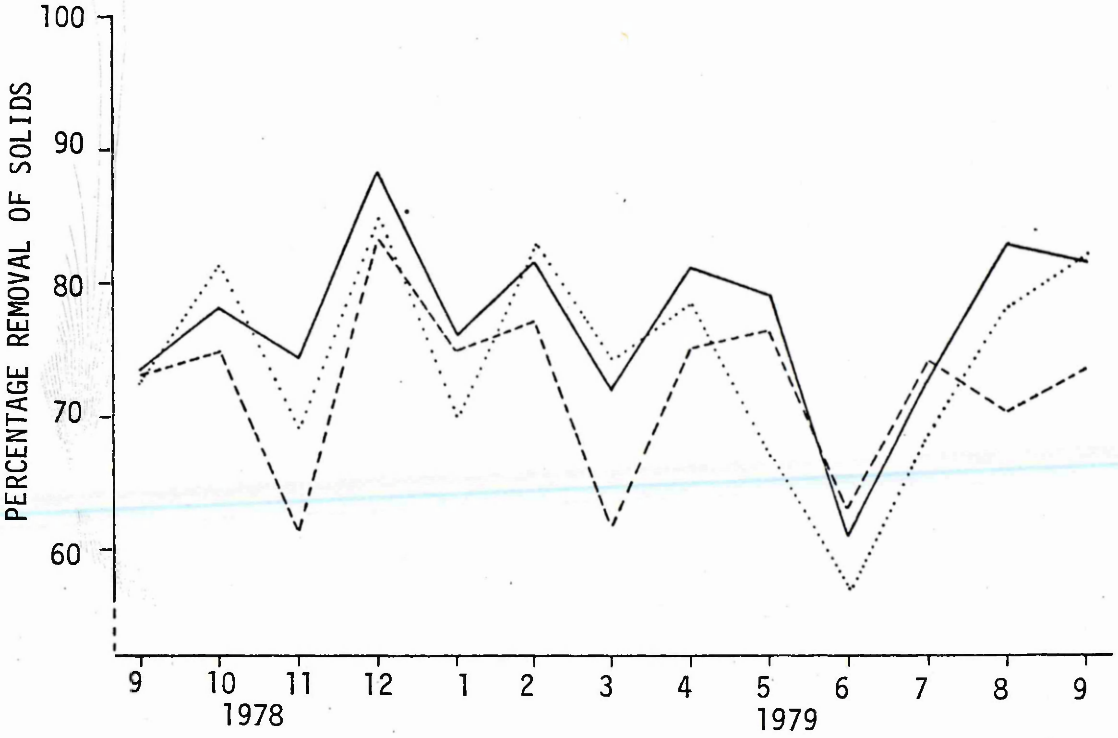


Figure 6.6: Seasonal variation in the mean removal of suspended solids from the final effluent during the two loadings of 1.68 and 3.37 $m^3m^{-3}d^{-1}$.

LOW LOADING (1.68 $m^3m^{-3}d^{-1}$)



HIGH LOADING (3.37 $m^3m^{-3}d^{-1}$)



thirteen months sampled compared with only eight months at the lower loading. As discussed in Section 6.2.1, the periods of poor performance in the mixed filter coincided with increased grazing activity and subsequent unloading of the film. The plastic filter as was the case with the BOD removal efficiency, produced the best final effluents during the months immediately after sloughing owing to the greater rate of film development.

At the lower rate of loading, the percentage removal of suspended solids decreased with depth (Table 6.8a). The percentage removal in the top 300 mm was generally very similar to the removal achieved in the next 600 mm resulting in overall removals in the top 900 mm of 61.8% in the slag, 60.7% in the mixed and 62.9% in the plastic filters. Maximum removal occurred where growth was most active, but decreased as the film reached maximum accumulation and then decreased to very low values as the film slowly disintegrated and washed out in the final effluent of the filters. The lowest section of the filters, 1500 - 1800 mm, had the lowest removal efficiencies compared with the other depths, especially during the spring unloading period. With the increase in loading, the removal of suspended solids increased in the top 300 mm causing greater accumulations of film to occur in this region, especially in the plastic filter. Correspondingly fewer suspended solids were removed by the remaining portion of the filters. The greatest removal still took place in the top 900 mm and the percentage removal of suspended solids increased in all the filters when the loading was increased. When the surface of the filters suffered from slight ponding, channelling of the sewage through the surface layers of the medium occurred,

Table 6.8a: The percentage removal of the total suspended solids in relation to depth, at low loading

	SLAG FILTER				MIXED FILTER				PLASTIC FILTER			
Depth in mm	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800
Low Loading 1.68 $m^3 m^{-3} d^{-1}$												
Nov. 77	24.4	33.7	16.3	7.0	27.9	41.9	6.9	0.0	18.6	34.9	11.6	14.0
Dec. 77	20.4	18.4	24.5	0.0	14.3	16.3	28.6	0.0	6.1	34.7	0.0	12.3
Jan. 78	13.0	55.5	13.0	0.0	30.0	53.3	0.0	0.0	20.2	50.0	11.1	0.0
Feb. 78	18.2	36.4	59.1	0.0	0.0	68.2	13.6	0.0	45.5	31.8	0.0	13.6
Mar. 78	52.3	23.1	9.2	0.0	50.8	20.0	15.4	0.0	47.7	12.3	15.4	3.1
Apr. 78	-	-	-	-	-	-	-	-	-	-	-	-
May. 78	50.0	0.0	12.5	2.5	5.0	20.0	47.5	0.0	20.0	32.5	0.0	7.5
Jun. 78	0.0	60.0	12.0	2.0	22.0	28.0	2.0	20.0	32.0	26.0	12.0	0.0
Jul. 78	42.3	28.9	7.7	9.6	42.3	24.1	9.6	4.8	32.7	25.0	17.3	0.0
Aug. 78	58.5	14.7	0.0	19.5	51.2	22.0	14.6	0.0	39.0	39.1	7.3	0.0
Sep. 78	31.9	36.2	14.9	8.5	66.0	4.2	8.5	10.7	57.5	14.8	10.7	8.5
Mean	31.1	30.69	16.92	4.91	30.95	29.80	14.67	3.55	31.93	30.11	8.54	5.90
S.D.	19.16	18.12	16.09	6.35	21.50	19.15	14.04	6.76	15.85	11.17	6.47	5.98

Table 6.8b: The percentage removal of the total suspended solids in relation to depth at high loading

	SLAG FILTER				MIXED FILTER				PLASTIC FILTER			
Depth in mm	0-300	300-900	900 1500	1500-1800	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800
High Loading 3.37$m^3m^{-3}d^{-1}$												
Sep. 78	28.0	26.7	13.3	0.0	49.3	8.0	6.7	2.7	49.3	9.4	1.3	9.3
Oct. 78	40.5	30.9	10.7	0.0	60.7	8.4	8.3	4.7	57.1	22.7	2.3	7.2
Nov. 78	30.0	5.0	31.7	0.0	25.0	16.7	25.0	0.0	36.7	0.0	28.3	0.0
Dec. 78	75.8	3.0	18.2	0.0	75.8	15.1	3.0	4.6	75.8	12.1	3.0	6.1
Jan. 79	4.7	48.8	23.2	0.0	25.6	13.9	37.2	2.4	32.6	25.5	21.0	0.0
Feb. 79	65.2	20.7	7.6	0.0	73.9	4.4	16.3	0.0	64.1	29.4	1.1	0.0
Mar. 79	41.4	17.2	17.3	0.0	55.2	13.8	10.3	0.0	34.5	34.5	17.2	0.0
Apr. 79	69.7	10.6	5.2	0.0	76.3	11.9	0.0	0.0	72.4	3.9	10.5	0.0
May 79	36.8	21.1	7.9	0.0	2.6	25.7	36.9	10.5	68.4	5.3	0.0	2.6
Jun. 79	60.9	0.0	0.0	6.5	0.0	39.1	10.9	2.2	26.1	0.0	19.6	4.3
Jul. 79	40.0	30.9	15.5	1.8	58.2	11.8	6.4	0.9	53.6	25.5	0.0	26.4
Aug. 79	22.8	26.3	10.6	5.2	29.8	24.6	14.0	10.6	38.6	24.6	14.0	3.5
Sep. 79	30.7	20.9	4.9	12.9	53.2	14.5	13.0	0.0	56.5	0.0	50.0	0.0
Mean	42.04	20.16	12.78	2.03	45.05	15.84	14.46	2.97	51.21	14.84	12.95	4.58
S.D.	20.55	13.43	8.50	3.93	26.15	8.99	11.80	3.76	16.36	12.56	14.62	7.29

and the percentage removal at the lower depths increased accordingly. The greater removal efficiency of suspended solids shown by the plastic filter at the higher loading was due to the increased use of the available surface area of the medium and an associated increase in film accumulation (Table 6.8b). In the slag filter, however, the percentage removal decreased when the loading was increased due to an increase in the film and so a reduction in the available surface area, and contact time between the sewage and the film (Section 6.5). The percentage removal efficiency in the top 900 mm fell less than the overall removal efficiency of the filters, due to the larger amounts of nutrients available during the higher loading, thus allowing preferential removal of specific components in the sewage more readily metabolised by the film. The organic residue remaining would be more refractory and not easily removed especially at the higher loading rates, when the retention time would be shorter than during the low loading. This preferential removal at the surface is not only reflected in the suspended solids results, but also in the BOD, PV, COD, Ammonia concentrations and the turbidity results (Appendix III).

6.2.3 NITRIFICATION

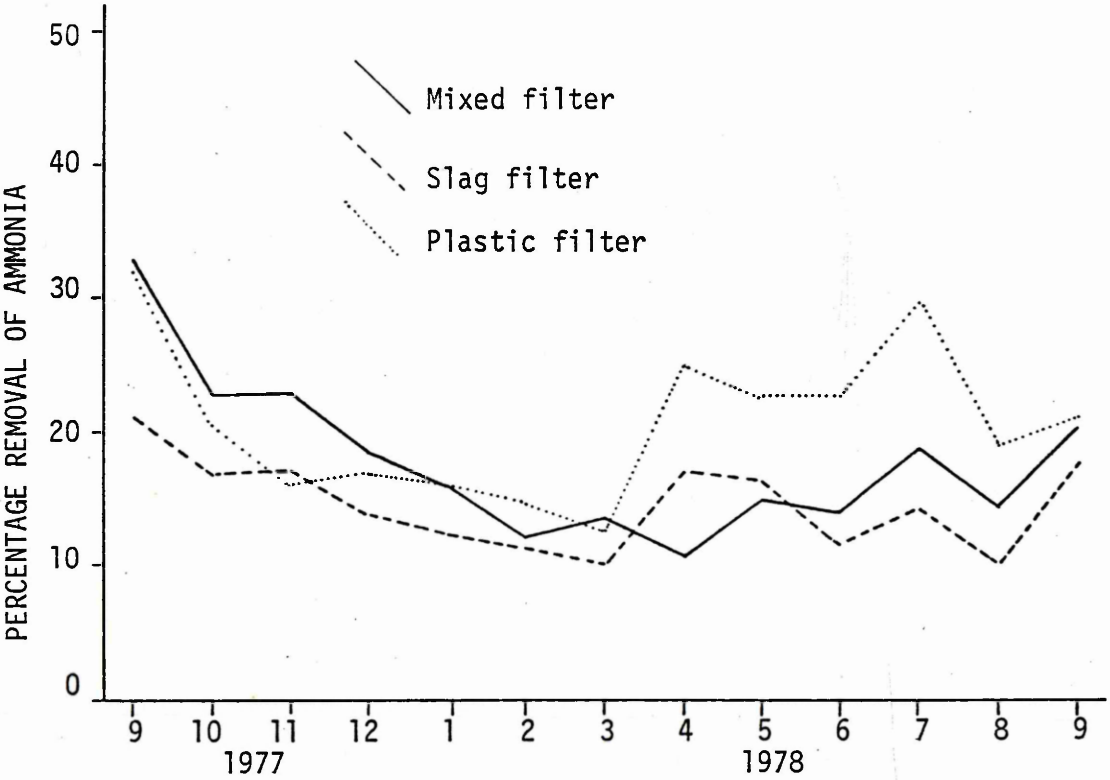
It is well known that nitrification is virtually eliminated at hydraulic loadings of domestic sewage in excess of 2.5 $m^3m^{-3}d^{-1}$. The autotrophic bacteria responsible for nitrification have a reduced growth rate in competitive situations and this is possibly why the process is so sensitive to changes in operation (Hawkes, 1963). Research has shown that the process is also inhibited when the oxygen concentration in the influent sewage is limited (Heukelekian, 1947; Hawkes, 1963; Tomlinson and Snaddon, 1966). Although Painter (1970) showed that organic matter did not directly inhibit nitrification, he indicated that the nitrifying organisms needed to be attached to a stable surface, suggesting that inhibition may be due to competition for space. It therefore appears that at the higher rates of filtration, nitrification is restricted because of the enhanced heterotrophic growth, a phenomenon which has been observed during numerous studies of high rate filtration (Bruce _et_ _al_., 1970: Joslin _et_ _al_., 1971; Bruce _et_ _al_., 1975).

In the present investigation nitrification was very erratic at the lower loading (Figure 6.7) with the slag filter achieving the best mean removal efficiency of 52.8%, which was equivalent to a mean final effluent of 14.7 mgl^{-1} of ammonia (Table 6.9). Examining the significance of the differences in performance using the t-test, it was clear that at the lower loading there was a significant difference in the mean removal efficiency between the slag and mixed filters ($P < 0.1$) and also between the mixed and plastic filters ($P < 0.1$). The ammonia concentration of the final effluents of the slag and plastic filters were also highly significantly different ($P < 0.01$).

Nitrification was greatly reduced at the higher loading with the percentage removal of ammonia being effectively halved in

Figure 6.7: Seasonal variation in the mean removal of ammonia from the final effluent during the two loadings of 1.68 and 3.37 $m^3m^{-3}d^{-1}$

LOW LOADING (1.68 $m^3m^{-3}d^{-1}$)



HIGH LOADING (3.37 $m^3m^{-3}d^{-1}$)

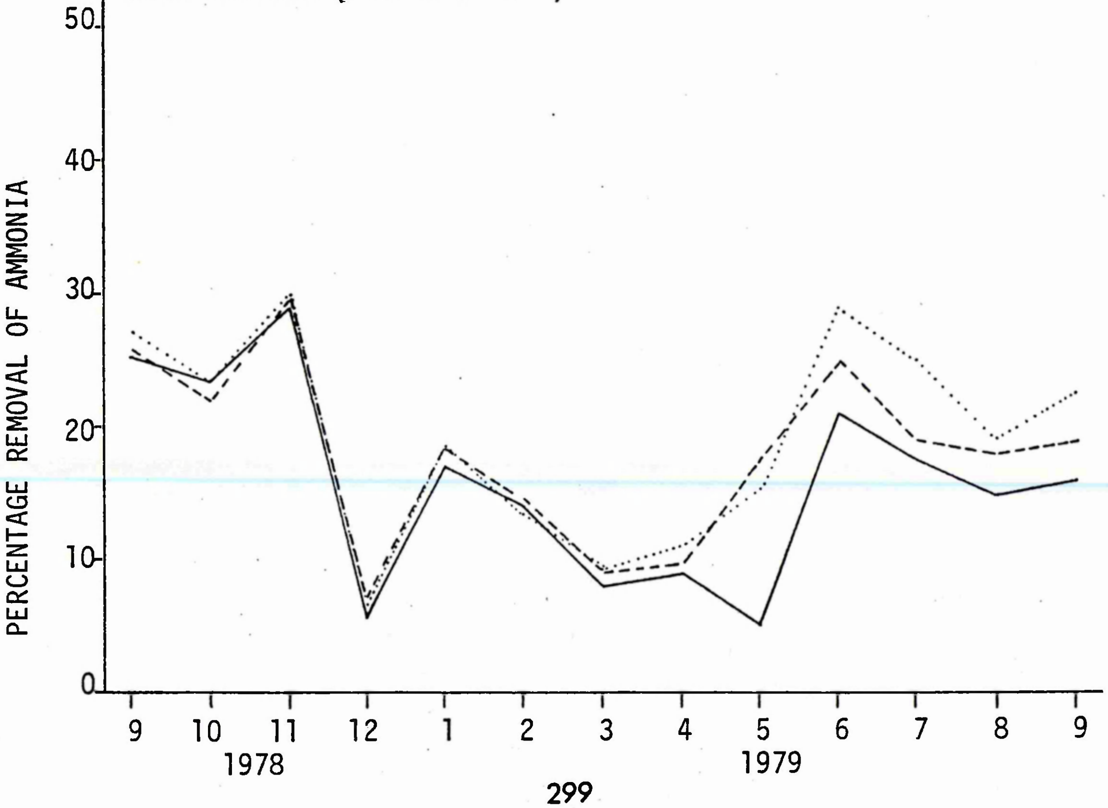


Table 6.9: Summary of the mean ammonical nitrogen concentration of the final effluents of the pilot filters loaded at 1.68 $m^3m^{-3}d^{-1}$ (0.28 kg BOD $m^{-3}d^{-1}$) over the thirteen months sampled.

		SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Effluent Quality (mgl^{-1})	Mean	14.7	17.8	20.7
	Minimum	10.0	10.8	12.4
	Maximum	20.8	32.7	32.1
	Range	10.8	21.9	19.7
	95% C.L.	1.8	3.4	3.3
	n	24	24	24
Percentage Removal (%)	Mean	52.8	45.0	34.9
	Minimum	41.3	14.1	5.0
	Maximum	66.6	67.5	54.3
	Range	25.3	43.4	49.3
	95% C.L.	4.2	6.7	9.4
	n	24	24	24

Table 6.10: Summary of the mean ammonical nitrogen concentration of the final effluents of the pilot filters loaded at 3.37 $m^3m^{-3}d^{-1}$ (0.63 kg BOD $m^{-3}d^{-1}$) over the thirteen months sampled.

		SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Effluent Quality (mgl^{-1})	Mean	18.0	15.8	19.1
	Minimum	6.7	5.2	6.2
	Maximum	29.3	28.4	29.1
	Range	22.6	23.2	22.9
	95% C.L.	3.8	4.2	4.3
	n	27	27	27
Percentage Removal (%)	Mean	21.1	32.4	17.8
	Minimum	0.0	16.0	0.0
	Maximum	56.4	67.1	58.5
	Range	56.4	51.1	58.5
	95% C.L.	8.2	9.1	9.3
	n	27	27	27

both the slag and plastic filters to 21.1 and 17.8% respectively (Table 6.10). The mixed filter achieved the best removal efficiency of ammonia at this higher loading at 32.4%. The percentage removal of ammonia achieved by the mixed filter was significantly better ($P < 0.01$) than the plastic filter, and the former produced a final effluent during the loading with significantly less ammonia ($P < 0.1$) than the slag filter. As shown in Table 6.3, nitrification was almost totally absent at the very high loading of 5.72 $m^3m^{-3}d^{-1}$, with removal efficiencies of less than 10% being recorded in all the pilot filters.

At the lower loading the total oxidised nitrogen results reflected the concentration of ammonia removed by each filter (Table 6.11), whereas at the higher loading the total oxidised nitrogen results were much smaller and did not reflect the overall changes in the ammonia concentration (Table 6.12). From the monthly analysis, it appears that ammonia was being stored in the film and was being released during times of film loss. It was noticed, however, that even at times of low film accumulation when the grazing population was still large, the ammonia concentration in the final effluents of the filters was high. This suggested that the observed increase in the ammonia concentration was due to the excretion products from the grazing fauna. Hemmings and Wheatley (1979) who examined the use of random plastic medium in low rate filtration also recorded discrepancies in the total nitrogen balance of their filters. They found that ammonical nitrogen was being produced within the filter from the deamination of organic nitrogen and causing an increase in the concentration

Table 6.11: Mean concentrations of ammonical and oxidised nitrogen in the final effluents from the pilot filters during the lower loading of 1.68 $m^3m^{-3}d^{-1}$.

	mgl^{-1}		
	Ammonia	Total oxidised nitrogen	Total nitrogen
Slag filter	14.71	14.32	29.03
Mixed filter	17.80	12.09	29.89
Plastic filter	20.73	9.03	29.76

Table 6.12: Mean concentrations of ammonical and oxidised nitrogen in the final effluents from the pilot filters during the higher loading of 3.37 $m^3m^{-3}d^{-1}$.

	mgl^{-1}		
	Ammonia	Total oxidised nitrogen	Total nitrogen
Slag filter	17.98	6.19	24.17
Mixed filter	15.75	6.95	22.70
Plastic filter	19.09	4.30	23.39

of ammonia in the final effluent. Painter (1970) proposed three potential sources of ammonia from the metabolism of the film micro-organisms, and assumed that the relatively small quantities of ammonia produced in this way were used in cell synthesis. Wheatley and Williams (1976) thought that ammonia in excess of that required for growth may be formed when C:N ratios were low, and so cause an increase of ammonia within the filter. Therefore the discrepancies between the mean total nitrogen results in Table 6.12 could be due to either excess ammonia production as described by Hemmings and Wheatley (1979) or storage and subsequent release. From the results the principal reason for the discrepancies recorded (Tables 6.11, 6.12) appears to be storage and release. It is expected that the equation of total nitrogen in and total nitrogen out of the filters would balance over a sufficiently long period of time.

Nitrification occurred at all depths at the lower loading with maximum removals being achieved between 900 - 1500 mm in all the filters (Table 6.13). With the increase in loading the degree of nitrification decreased and the depth at which maximum nitrification occurred was pushed to the base of the filters between 1500 - 1800 mm in both the mixed and slag filters.

Maximum abundance of nitrifying bacteria always occurred in the lower half of the filters, mainly at times of least film accumulation (Table 6.13, Figure 6.12). Although minimum removals of ammonia coincided with maximum film accumulation and also with the sloughing period, the time level of

Table 6.13a: The percentage removal of ammonical nitrogen in relation to depth, at low loading

	SLAG FILTER				MIXED FILTER				PLASTIC FILTER			
Depth in mm	0-300	300-900	900 - 1500	1500-1800	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800
Low Loading $1.68 m^3 m^{-3} d^{-1}$												
Jun. 78	4.6	0.0	42.1	0.0	6.8	0.0	2.3	52.3	1.1	0.0	0.0	1.1
Jul. 78	-	-	-	-	-	-	-	-	-	-	-	-
Aug. 78	0.0	25.5	35.2	8.3	0.0	0.7	53.1	0.0	22.1	0.0	33.1	0.0
Sep. 78	7.5	24.2	23.1	0.5	9.1	5.0	31.6	3.6	25.1	0.0	15.6	6.5
Mean	4.03	16.58	33.47	2.93	5.30	1.90	29.00	18.63	16.10	0.00	16.23	2.53
S.D.	3.78	14.38	9.62	4.65	4.73	2.07	25.50	29.21	13.08	0.00	16.56	3.48

Table 6.13b: The percentage removal of ammonical nitrogen in relation to depth, at high loading

	SLAG FILTER				MIXED FILTER				PLASTIC FILTER			
Depth in mm	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800	0-300	300-900	900-1500	1500-1800
High Loading $3.37m^3m^{-3}d^{-1}$												
Oct. 78	8.5	3.3	11.7	7.9	0.0	0.0	0.0	23.5	8.5	0.0	30.1	0.0
Nov. 78	5.7	0.0	9.1	16.0	2.9	7.4	0.0	23.4	0.0			0.0
Dec. 78	-	-	-	-	-	-	-	-	-	-	-	-
Jan. 79	15.9	0.0	4.0	0.8	0.0	0.0	4.0	7.9	0.0	0.0	0.0	0.0
Feb. 79	8.4	0.0	32.8	0.0	0.0	16.0	0.8	17.7	0.0	41.2	0.0	3.4
Mar. 79	11.6	0.0	18.6	0.0	8.1	0.0	12.8	17.4	0.0	0.0	7.0	11.6
Apr. 79	0.0	0.0	0.0	61.5	0.0	0.0	23.1	51.9	0.0	0.0	0.0	61.5
May 79	21.5	3.8	5.1	0.0	0.0	12.7	49.3	5.1	6.3	14.0	5.0	0.0
Jun. 79	8.3	0.0	0.0	12.0	0.0	1.5	3.0	11.3	8.3	5.2	0.0	0.0
Jul. 79	2.0	16.4	0.0	16.3	6.8	10.9	1.4	25.8	17.7	0.0	0.7	0.0
Aug. 79	25.5	0.0	0.0	0.0	5.3	0.0	1.1	18.1	8.5	0.0	0.0	0.0
Sep. 79	0.0	0.0	0.0	11.6	0.0	0.0	0.0	25.0	0.0	0.0	17.1	0.0
Mean	9.76	2.14	7.39	11.46	2.10	4.41	8.68	20.65	4.48	5.49	7.78	6.96
S.D.	8.36	4.94	10.41	17.89	3.16	6.16	15.26	12.47	5.88	12.61	11.26	18.43

nitrification was masked by the release of ammonia in the solids washed out. The increased loading rate also reduced the contact time between the nitrifying bacteria and the influent sewage (Section 6.5), so reducing the removal efficiency of ammonia. The direct correlation between the ammonical nitrogen concentration in the final effluent and the organic load (Appendix VII) indicates how nitrification was reduced with increasing organic load in all the filters.

Temperature has a marked influence on nitrification (Painter, 1970) and the large fluctuations in temperature recorded in the plastic filter may account for the low degree of nitrification recorded. Although the threshold temperature for the process is below 10°C, a few degrees reduction in the temperature below 10°C is likely to have a disproportionate reduction on nitrification (Bruce et al., 1975). It is not surprising that the plastic filter, which was unable to protect itself against changes in ambient temperature as successfully as the slag filter, achieved the lowest nitrification of all the pilot filters.

6.2.4 SLUDGE PRODUCTION

The pilot plant did not have humus tanks from which samples of the sludge could be obtained. All sludge measurements were therefore made directly from the final effluents of the pilot filters. Sludge production was normally assessed by volume; actual weights were only measured every two to three months (Section 4.2.16). Because of the difficulty in concentrating the humus sludge sufficiently, its dewaterability was not determined. The mean monthly results presented in Table 6.14 show that although no significant difference in sludge production was recorded between the individual filters at either loading, significantly greater sludge production occurred in all three filters at the higher loading. This indicated that more work was being done by the filters in flocculating the suspended material present. In the mixed and plastic filters the increase was far in excess of that recorded in the slag filter. Sludge production followed a seasonal pattern, low at times of high adsorption of solids when the rate of film accumulation was greatest and high during times of maximum film accumulation when fewer solids were being adsorbed and also when the film was being unloaded. Bruce and Boon (1971), showed that the less organic matter present in a filter sludge, the more stable it was, and they recorded typical organic contents of 60% for low rate filters and 80% for high rate filters. Table 6.15 summarises the organic content of the sludges collected from the pilot filters during August at the two loading rates of 1.68 and 3.37 $m^3m^{-3}d^{-1}$.

The slag filter produced the most stable sludge during the lower loading but the most unstable sludge, containing the largest proportion of organic matter, at the higher loading rate; when the sludge from the mixed filter was most stable.

The settling rates of the sludges were measured throughout the low and high rate loading periods and the time for 90%

Table 6.14: Monthly sludge production of pilot filters, expressed in cm^3 of sludge per litre of final effluent

LOW LOADING	$1.68\ m^3m^{-3}d^{-1}$					HIGH LOADING	$3.37\ m^3m^{-3}d^{-1}$			
	cm^3l^{-1}						cm^3l^{-1}			
*	INF	S	M	P		*	INF	S	M	P
Oct.77	0.00	0.8	0.5	0.6		Sep.78	0.00	4.3	4.2	2.7
Nov.77	0.05	0.9	0.6	0.9		Oct.78	0.00	3.2	3.1	1.4
Dec.77	0.10	1.1	2.9	0.9		Nov.78	0.10	5.9	3.9	4.4
Jan.78	0.00	1.2	0.7	2.0		Dec.78	1.50	7.8	2.8	8.1
Feb.78	0.00	5.2	0.6	0.5		Jan.79	0.60	2.5	2.6	3.8
Mar.78	0.15	0.9	0.3	0.4		Feb.79	1.10	2.1	1.8	2.5
Apr.78	0.20	1.1	3.3	0.3		Mar.79	0.10	3.5	1.9	1.7
May 78	0.00	7.6	3.1	2.3		Apr.79	2.90	3.5	3.5	6.6
Jun.78	0.10	0.8	0.7	0.9		May 79	1.80	4.3	8.3	4.9
Jul.78	0.05	1.2	0.6	0.5		Jun.79	0.50	2.8	2.3	1.9
Aug.78	0.00	3.2	2.2	2.4		Jul.79	0.40	3.7	2.1	1.3
Sep.78	0.00	1.8	1.3	0.5		Aug.79	0.00	5.6	3.6	4.5
						Sep.79	0.05	2.1	4.1	2.6
Mean	0.05	2.15	1.40	1.02		Mean	0.70	3.95	3.40	3.57
S.D.	0.07	2.15	1.14	0.77		S.D.	0.90	1.66	1.69	2.08

* where INF is the influent, S, M and P the final effluents from the slag, mixed and plastic filters respectively.

Table 6.15: Settleability and organic content of the sludges produced by the pilot filters at 1.68 and 3.37 $m^3m^{-3}d^{-1}$.

	1.68 $m^3m^{-3}d^{-1}$		3.37 $m^3\ m^{-3}d^{-1}$	
	Organic matter (%)	90% settlement (mins)	Organic matter (%)	90% settlement (mins)
Slag Filter	57.8	15.7	80.8	27.5
Mixed Filter	60.2	13.3	71.0	25.5
Plastic Filter	61.8	15.5	76.4	20.5

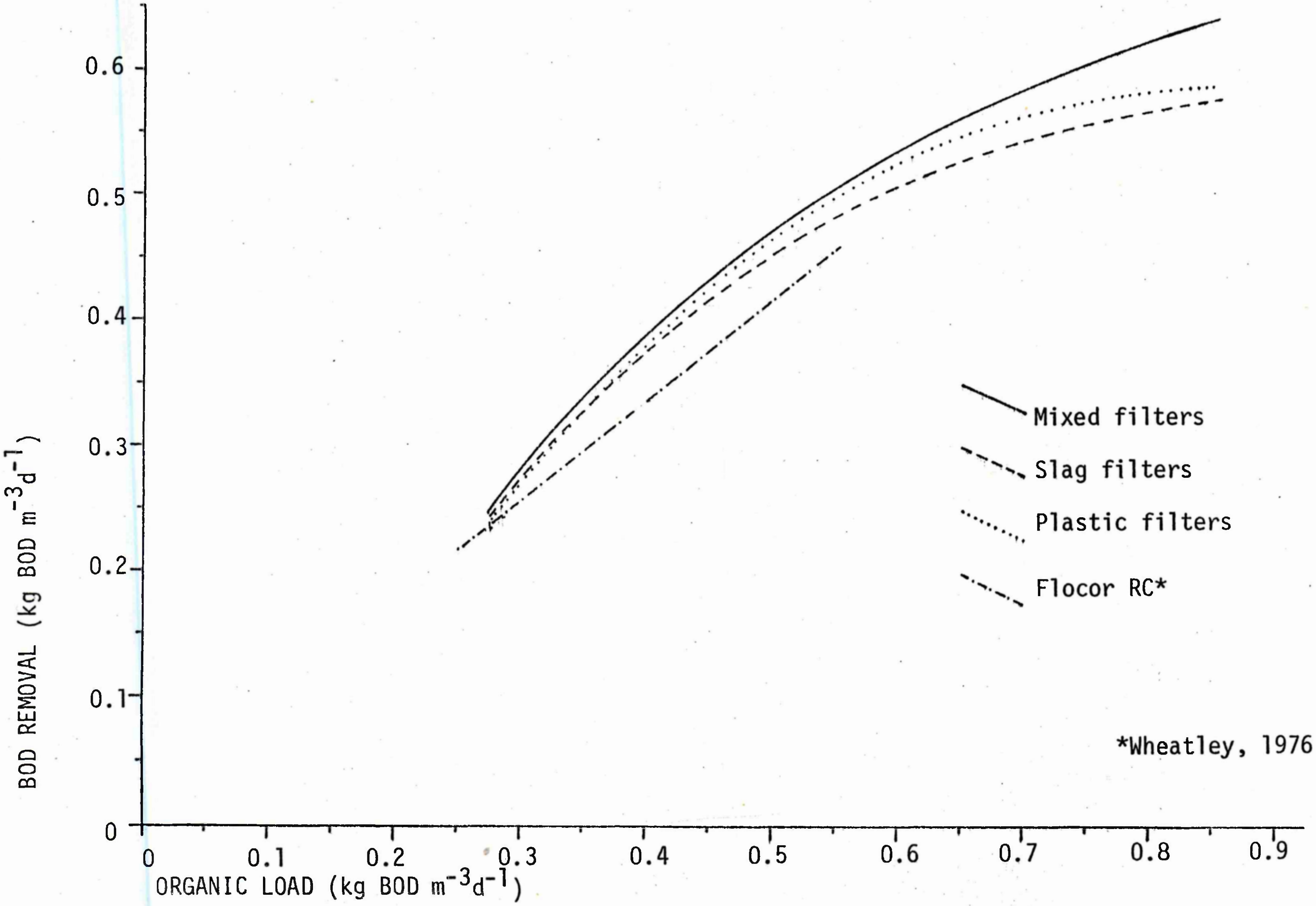
settlement measured. The settling rates for all the pilot filters were similar during the lower loading (Table 6.15). At the higher loading the mean settling time of the sludge from the slag filter was seven minutes longer than that recorded for the sludge from the plastic filter. Solbé, Williams and Roberts (1967) reported that macroinvertebrate debris settled more rapidly than non-animal fragments and that the presence of animals increased the settleability of the sludge. The population densities of the various macroinvertebrates were generally much larger in the plastic than in the slag filter at the higher loading, and this may well account for the overall greater settleability of the sludge recorded.

6.2.5 PERFORMANCE ANALYSIS

It is clear from the data that at the lower loading of 1.68 $m^3m^{-3}d^{-1}$, the slag and mixed filters performed similarly, although the slag filter produced a significantly better nitrified final effluent ($P < 0.01$). But with an increase in the loading to 3.37 $m^3m^{-3}d^{-1}$ the performance of the slag filter decreased more rapidly than either the plastic or mixed filters. At this higher loading, the performance of the mixed filter was significantly better than that of the slag filter in terms of BOD ($P < 0.01$) suspended solids ($P < 0.1$) and ammonia removal ($P < 0.01$). The mixed filter was also significantly more efficient than the plastic filter in removing ammonia from the influent ($P < 0.01$). The shorter experimental period at the very high loading of 5.52 $m^3m^{-3}d^{-1}$ indicated that the mixed filter was well able to cope with the large increase in organic load, performing consistently better than either the plastic or slag filters.

Table 6.4 compares the weight of BOD removed per day by each filter at the various organic loadings, with the mixed filter being the most efficient at the higher loadings. This is shown graphically in Figure 6.8, where the results obtained by Wheatley (1976) using the same random plastic medium, Flocor RC, can be directly compared. At the higher organic loadings, Wheatley's filters, which treated a domestic sewage similar in strength to that applied to the pilot filters, achieved a similar removal efficiency compared with the three pilot filters. Linear regressions of the organic load in relation to final effluent BOD concentration, using the data from the two main loading periods, were calculated for the three pilot filters (Figure 6.9). The slopes of the three lines, for the mixed and plastic filters, are much less steep compared with that for the slag filter (Table 6.16). The two former lines run almost in parallel over the entire experimental range of organic loading. The linear regression plot for the slag filter intersects the regression lines for the other filters, indicating that the mean BOD performance of the slag filter is better than the mixed filter at loadings of less than 0.18 kg BOD $m^{-3}d^{-1}$, and better than the plastic filter at loadings of less than 0.31 kg BOD $m^{-3}d^{-1}$. Figure 6.9 shows the mixed filter consistently produced a better final BOD effluent than the plastic filter at all loadings. The similarity of the plotted lines for the plastic and mixed filters

Figure 6.8: Mean efficiency of BOD removal by the pilot filters during the complete experimental period of 27 months compared to the plastic filters of Wheatley.



*Wheatley, 1976

Figure 6.9: Predicted final effluents of the pilot filters over the main experimental periods of 24 months

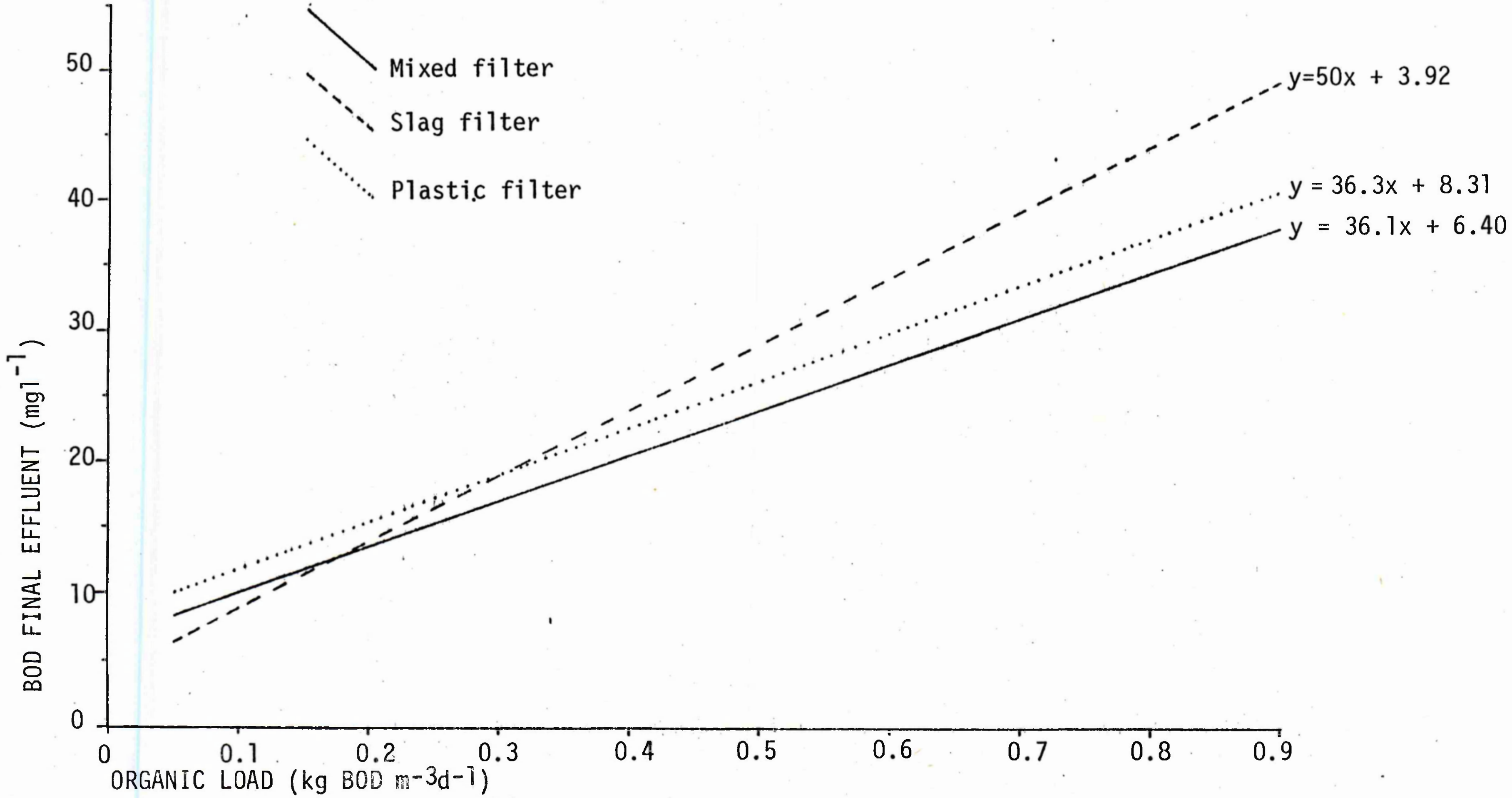


Table 6.16: Linear regression equations of a) final effluent BOD concentration against organic load, and b) the percentage removal of ammonical nitrogen in final effluents against organic load, over the two main loadings and all the measured loadings.

	MAIN LOADINGS ONLY	ALL LOADINGS
Loadings($m^3m^{-3}d^{-1}$)	1.68 and 3.37	1.68,3.37 and 5.72
Experimental period	24 months	27 months
a) BOD Effluent v. Organic Load		
Slag Filter	y = 50.0x + 3.9	y = 46.2x + 5.1
Mixed Filter	y = 36.1x + 6.4	y = 31.6x + 7.8
Plastic Filter	y = 36.3x + 8.3	y = 33.2x + 9.3
b) Percentage Removal of Ammonia v. Organic Load		
Slag Filter	y =-53.1x + 61.4	y = -56.7x + 62.3
Mixed Filter	y =-29.9x + 52.3	y = 37.0x + 54.4
Plastic Filter	y =-44.52x + 46.54	y = -44.45x + 46.47

is due to most of the BOD removal taking place in the top 750 mm of the filters (Table 6.5), which is the random plastic medium, Flocor RC, in both the pilot filters. The removal of the more resistant BOD fractions did not occur so readily. Their removal is restricted to the lower halves of conventional low rate filters (Wheatley, 1976). The resistant BOD fraction appeared more efficiently removed by the slag portion of the mixed filter at the higher loading than by either the plastic or slag filters. Table 6.17 is a summary of the predicted maximum organic loads producing mean final effluents of specific BOD quality for each filter. These results have been extrapolated from the regression analysis of all the data collected over 27 months.

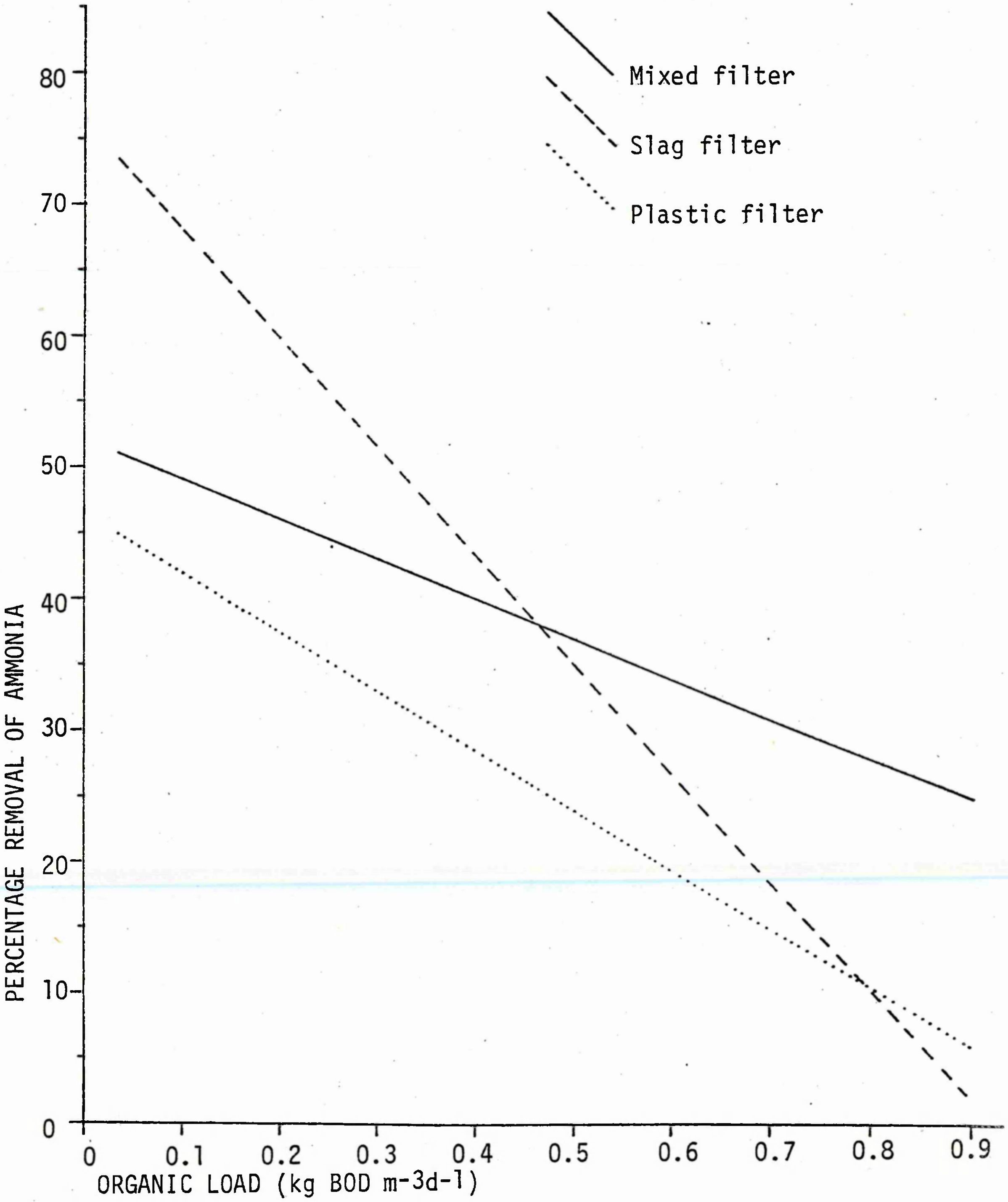
As stated in Section 6.2.3, nitrification in percolating filters decreases with an increase in the hydraulic and organic loading, and Figure 6.10 illustrates this decline in removal of ammonia with load. Least ammonia removal occurred in the plastic filter at all the various loadings. The linear regression plots for the mixed and slag filters crossed at the organic loading of 0.47 kg BOD $m^{-3}d^{-1}$, showing that the slag achieved better nitrification at loadings below 0.47 kg BOD $m^{-3}d^{-1}$ while the mixed filter removed more ammonia at loadings in excess of this loading (Figure 6.10).

The greater efficiency of the mixed filter at the higher loading compared with both the slag and plastic filters must be attributed primarily to the top layer of plastic medium which removed the bulk of the BOD. The medium itself causes better redistribution within the filter (Wheatley and Williams, 1976; Hemmings and Wheatley, 1979) and this would ensure

Table 6.17: Predicted maximum organic loading of the pilot filters to achieve specified final BOD effluents from all 27 months of operation.

Mean final effluent (mgl^{-1})	MEAN ORGANIC LOAD $(kg\ BOD\ m^{-3}d^{-1})$				
	Slag Filter	Mixed Filter			Plastic Filter
	Organic Load	% increase over slag	Organic Load	% increase over plastic	Organic Load
15	0.220	9.1	0.240	41.2	0.170
20	0.330	19.7	0.395	23.4	0.320
30	0.540	30.6	0.705	12.1	0.620
40	0.755	33.8	1.010	9.7	0.920

Figure 6.10: Predicted percentage removal efficiency of ammonia from the pilot filters over the main experimental period of 24 months



better utilisation of the lower slag portion.

It is unlikely that the top plastic layer would remove enough BOD and suspended solids to allow the rest of the mixed filter (i.e. the slag portion), to act as a normal single pass filter, producing a highly clarified final effluent when loaded at three or four times the normal loading for a single mineral filter. The mixed filter does, however, achieve a greater removal of the more resistant BOD fraction, better solids removal and finally more efficient nitrification than single medium filters at the higher loadings studied.

6.3 FILM

6.3.1 SEASONAL FILM ACCUMULATION

The three filters all displayed similar seasonal fluctuations in film accumulation. Generally the minimum quantity of film occurred during the summer and the maximum quantity in the winter, at both loadings (Figure 6.14; Table 6.18). This phenomenon has been previously recorded both in low rate (Hawkes, 1957) and in high rate filters (Bruce and Merkens, 1973). A double maxima of film accumulation, separated by two to three months, was observed during the winter in all the filters, although less well defined in the mixed filter at the higher loading rate. Examination of the horizontal distribution of film using the extra sampling baskets placed in the surface of the filters (Section 4.1) and subsequent analysis showed that there was no significant difference at the 10% level or less. This clearly showed that the horizontal distribution of the film in the surface baskets (Appendix IV) was similar. Therefore the results of film accumulation in the baskets from the sampling column were representative of the whole filter, as far as the limited horizontal analysis could show.

The slag filter contained the greatest mean accumulation of film during the lower loading period, with a range of film weights almost double that found in the other two filters (Table 6.19). At the higher loading, both the mixed and

Table 6.18: Seasonal variation in mean film weight (volatile solids) kgm^{-3}.

	LOW LOADING (1.68 m^{3}m^{-3}d^{-1})		
Date	Slag Filter	Mixed Filter	Plastic Filter
10.77	3.05	6.68	5.53
11.77	6.37	9.16	8.31
12.77	9.53	5.66	8.89
1.78	10.18	4.10	6.85
2.78	6.87	4.66	6.20
3.78	14.39	8.81	6.70
4.78	13.74	6.60	5.00
5.78	8.32	3.22	2.33
6.78	1.78	1.63	2.02
7.78	2.98	1.54	1.02
8.78	2.53	2.58	2.27
9.78	4.03	2.72	4.71

	HIGH LOADING (3.37 m^{3}m^{-3}d^{-1})		
Date	Slag Filter	Mixed Filter	Plastic Filter
10.78	4.20	5.22	6.11
11.78	7.95	6.09	8.59
12.78	3.11	6.85	9.65
1.79	7.81	6.51	6.45
2.79	8.88	13.89	11.38
3.79	11.33	9.65	13.33
4.79	4.57	4.91	9.05
5.79	4.77	5.79	7.73
6.79	5.61	2.77	2.23
7.79	5.07	6.34	10.90
8.79	3.71	5.51	9.85

Table. 6.19: Summary of the mean film accumulation (as volatile solids) of the pilot filters loaded at 1.67 $m^3m^{-3}d^{-1}$(0.28 kg BOD $m^{-3}d^{-1}$) over the twelve months sampled.

	Volatile solids (kg m^{-3})		
	Slag Filter	Mixed Filter	Plastic Filter
Mean	6.98	4.78	4.99
Minimum	1.78	1.54	1.02
Maximum	14.39	9.16	8.89
Range	12.61	7.62	7.89
95% C.L.	2.45	1.48	1.46

Table 6.20: Summary of the mean film accumulation (as volatile solids) of the pilot filters loaded at 3.37 $m^3m^{-3}d^{-1}$(0.63 kg BOD $m^{-3}d^{-1}$) over the eleven months sampled.

	Volatile solids (kg m^{-3})		
	Slag Filter	Mixed Filter	Plastic Filter
Mean	6.09	6.69	8.66
Minimum	3.11	2.77	2.23
Maximum	11.33	13.89	13.33
Range	8.22	11.12	11.10
95% C.L.	1.51	1.71	1.78

plastic filters contained larger mean weights of film than at the previous loading with increased ranges. All three filters had larger minimum weights at the higher loading although the mean, maximum and range of film accumulation in the slag filter were reduced at this new loading (Table 6.20). Wheatley (1976) recorded a maximum film accumulation of 4.0 kgm^{-3} (equivalent to 5% occupation of the voidage) at the higher loading in his pilot filters containing Flocor RC medium, which were loaded at 1.2 and 2.4 $m^3m^{-3}d^{-1}$. Although this weight of film is similar to the mean film accumulation recorded in the plastic filter during the lower loading at 1.68 $m^3m^{-3}d^{-1}$, it is less than half the mean weight of 8.66 kgm^{-3} recorded at the higher loadings. The maximum film accumulations recorded in the plastic filter were 8.89 kgm^{-3} during low rate and 11.10 kgm^{-3} at the higher loading. These are greatly in excess of the maximum weights recorded by Wheatley. In the present investigation the greater accumulations of film in the plastic filter may account for the longer retention times and better performance recorded compared with Wheatley's filters.

The vertical distribution of the film in the pilot filters (Figures 6.11 - 6.12), reflects the seasonal variation of the mean film accumulations of the three filters (Figure 6.14). The vertical distribution of the fauna is directly compared to the film in Figures 5.2 - 5.7 and 5.27 - 5.32, and the existing relationships are discussed fully in Chapter 5. At the lower loading, most of the film was recorded in the top 300 mm of all the filters and in the lower half of the filters below 900 mm. Examination of the medium showed that

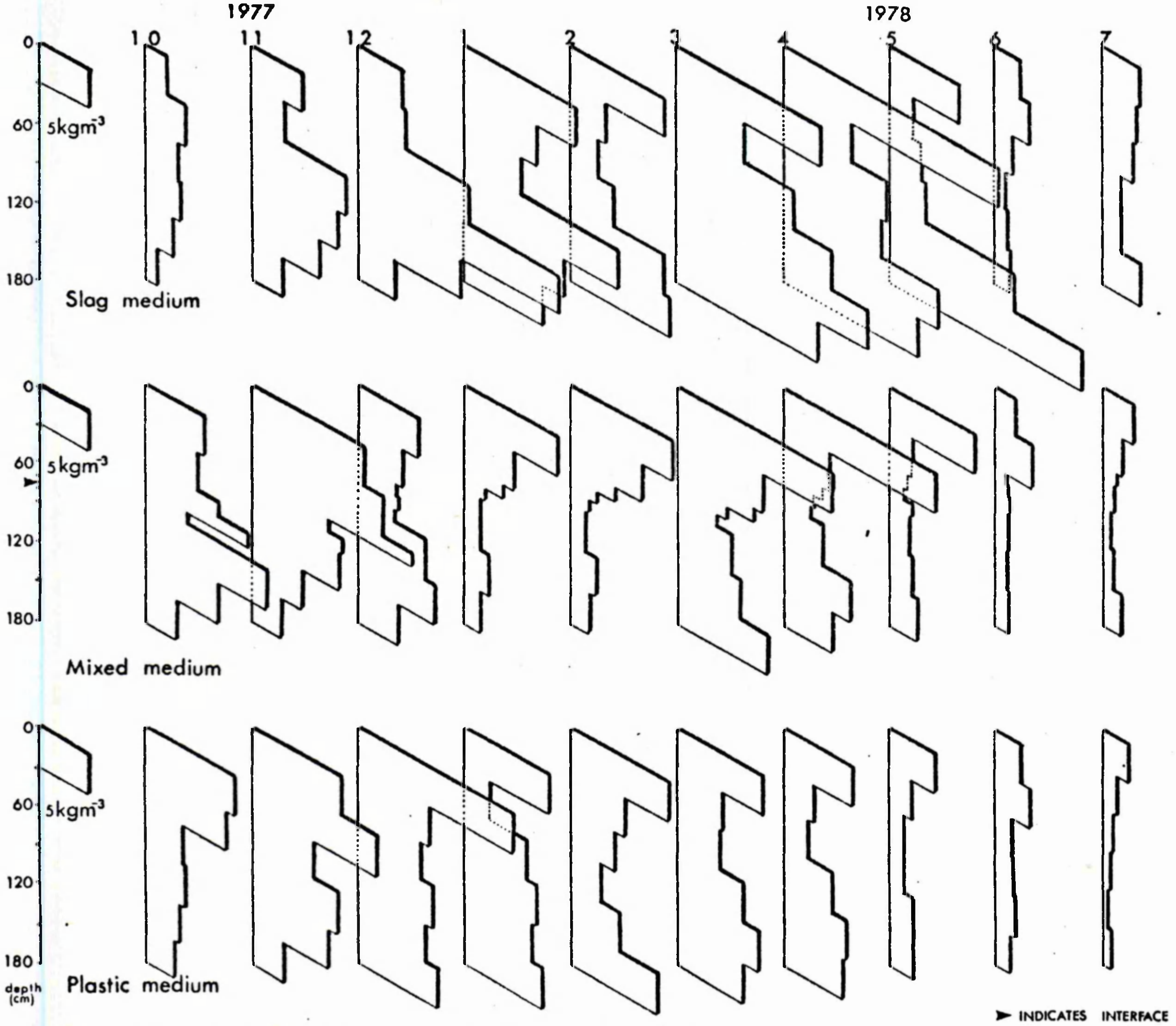


Figure:6·11 Vertical Distribution of Film (Volatile Solids) in Low Rate Filters.

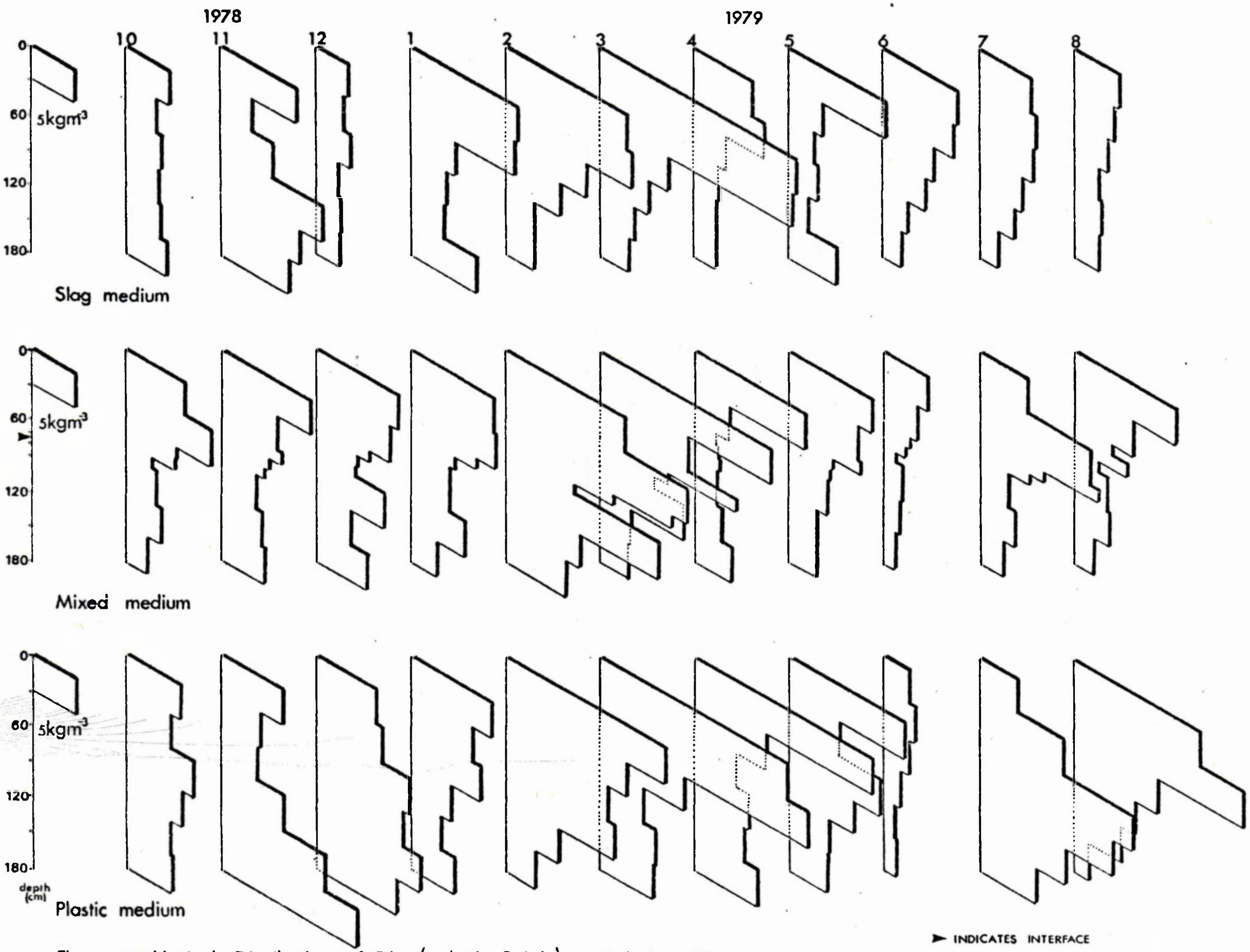
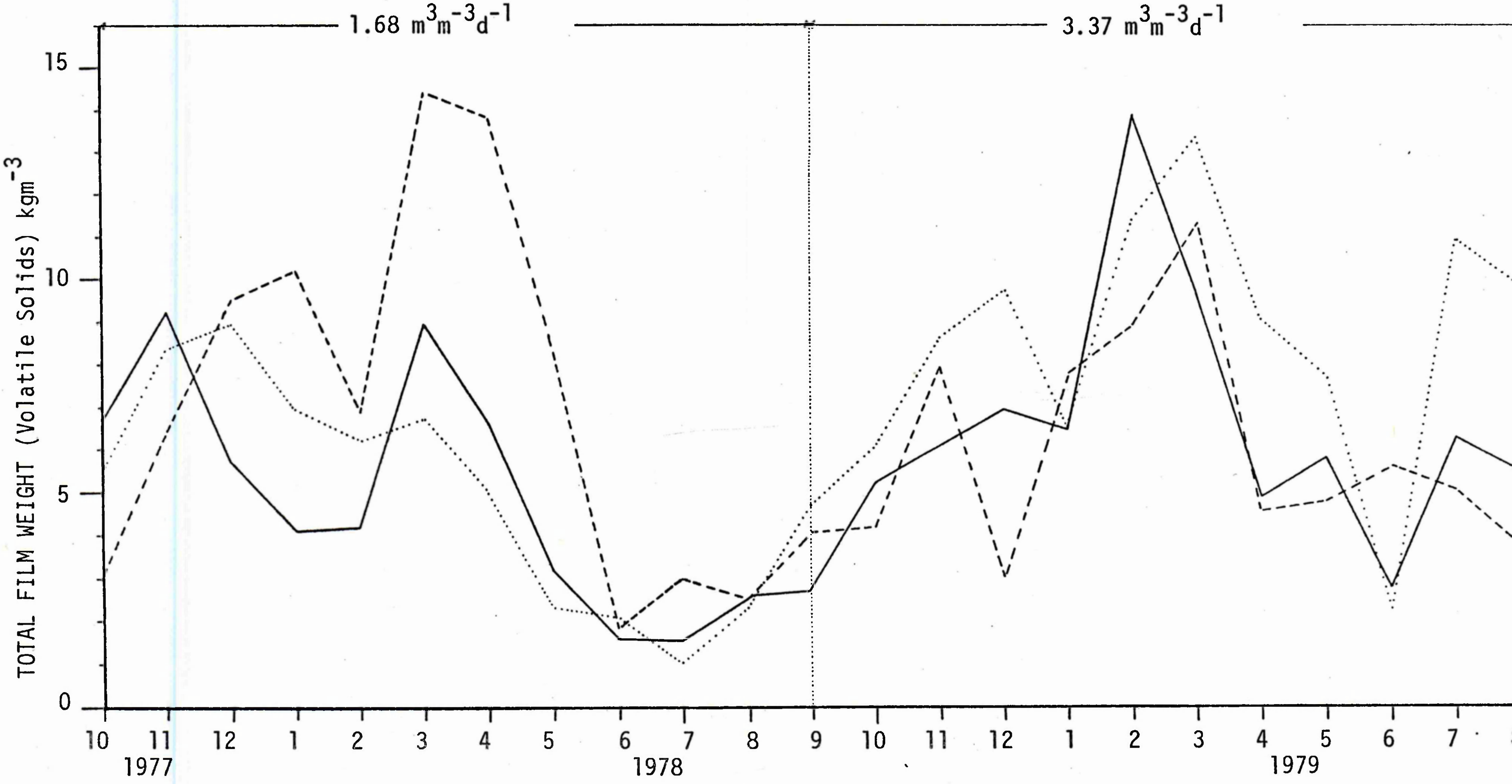


Figure:6·12 Vertical Distribution of Film (Volatile Solids) in High Rate Filters.

Figure 6.14: Mean monthly film accumulation



the film found lower down the filters was comprised mainly of humus solids and animal debris and not active film. At the higher loading the maximum accumulation of film occurred in the top half of the slag filter while in the plastic filter maximum accumulation was recorded in the surface from October to December and nearer the base from January to August. Most of the film occurred in the plastic portion of the mixed filter at both loadings, although heavy accumulation also occurred in the top 300 mm of the slag portion during periods of maximum film accumulation. The distribution of the film was associated, as expected, with the depth at which the BOD and suspended solids removal occurred (Sections 6.2.1 and 6.2.2). But during periods of maximum film accumulation and the subsequent unloading period, the BOD removal was reduced and nitrification was restricted to the very base of the filters. As observed by Hawkes (1957), the performance of the pilot filters was found to be associated with the film accumulation and temperature, although Wheatley (1976) observed that the film accumulation was not linked to the performance.

Wheatley and Williams (1976) found that no single factor directly influenced film accumulation within their experimental filters, but suggested that it was controlled by the interaction of a number of factors, namely ambient temperature, organic load, the distribution system, the microbial characteristics of the film and the activity of grazers.

Temperature was shown to be an important factor in film accumulation by Hawkes and Shephard (1971), who demonstrated that below 10^{o}C the rate of film accumulation increased rapidly. Reynoldson (1939), Lloyd (1945), Tomlinson (1946b) and Hawkes (1957; 1963) all considered the macroinvertebrate grazers to be of primary importance in film control, with the film accumulating during the winter months when both the population density and the activity of the grazers were suppressed. On the other hand, Holtje (1943), Henkelekian (1945) and Cooke and Hirsch (1958) considered the fluctuations in film accumulation to be due to differential microbial activity at different temperatures. Shephard and Hawkes (1976) in a comparative experiment using laboratory filters with and without the macroinvertebrate grazing fauna at 5 and 20°C, examined the effects of grazers and temperature on film accumulation. They proved that at higher temperatures a greater proportion of the BOD removed by adsorption would be oxidised, and therefore fewer solids accumulated. The rate of oxidation decreased as the temperature fell, although the rate of adsorption remained unaltered. Therefore at the lower temperatures, there was a gradual increase in solids accumulation which eventually resulted in the filters becoming clogged.

In the present investigation, all the major micro-organisms of the film, such as zoogloeal bacteria and Sphærotilus natans were positively and significantly correlated to the film weight (Table 6.21), indicating their importance in film accumulation. The Nematoda were also positively correlated with the film weight, a relationship also observed by Shephard and Hawkes (1976), who proposed that the nematodes acted as micro-grazers. Without exception all the filters exhibited significant negative correlations between effluent temperature and film accumulation. This supports the earlier findings of

Table 6.21: Correlations between the film weight and various biological and environmental variables measured.

	SLAG FILTER	MIXED FILTER	PLASTIC FILTER
Low Rate	*Subbaromyces splendens* (2+) *Sphaerotilus natans* (2+) *Paracyclops* (1-) Temperature (2-)	Sarcomastigophora (1-) Temperature (1-)	*Paracyclops* (2+) Temperature (2-) Organic Load (1-)
High Rate		Zoogloeal bacteria (3+) Temperature (1-)	Effluent BOD (1-)
Both Loadings	*Subbaromyces splendens* (2-) Temperature (2-)	Zoogloeal bacteria (3+) Temperature (2-) Effluent BOD (1-)	Zoogloeal bacteria (2+) *Subbaromyces splendens* (1+) *Sphaerotilus natans* (2+) Temperature (1-)

Shephard and Hawkes (1976) who concluded that film accumulation was controlled by the temperature of the film. A positive correlation between the quantity of the fungus Subbaromyces splendens and the amount of film in the plastic filter and a negative correlation between the same parameters in the slag filter reflects the relative abundance of the species. Subbaromyces splendens was far more successful in the plastic medium where it was associated with the initial and rapid accumulation of solids immediately preceding the decline of the grazing fauna when the film accumulation was at a minimum. As shown in Section 5.3.1, this fungus was restricted to the lower film conditions in the filters.

Bruce and Merkens (1973) showed that the surface area of the medium was a major factor determining the performance of a high rate filter. A negative correlation between the amount of film and the effluent BOD concentration was recorded in the mixed and plastic filters only. The greater surface area of the plastic medium allowed more film to accumulate and therefore greater removal of the available BOD.

The increase in film accumulation in early winter, owing to the low population densities of the grazing fauna during the autumn and reduced microbial activity due to the temperature, reached a peak in November and December. This peak was reduced by a resultant increase of grazing fauna presumably stimulated by the increase in film and because the temperature was still mild. But as the temperature decreased towards the middle of winter, there was a decrease in grazing activity and once more the film began to increase toward a maximum accumulation in the spring, producing the characteristic second winter maximum in accumulation. With increase in temperature during the spring and a resultant increase in grazers and grazing activity, the film was reduced to its minimum accumulation by June. The increase in grazing fauna during the early winter suppressed the second peak of film accumulation in March, which had the effect of restricting the grazing fauna in the spring due to less successful reproduction during the winter peak in grazing fauna, caused by the decreasing temperature. There would have been a smaller residual grazing population, as well as fewer cocoons and eggs in the filters in the spring, resulting in a delay before the population density of the grazing fauna reached maximum numbers, thus delaying the unloading of the film.

Once the subsequent unloading, greatly accelerated by the macro-grazers, was complete, the grazing fauna began to decline due to a shortage of food. An increase in the amount of film followed immediately, and unlike the other filters, the plastic filter built up its film accumulation more rapidly due to the presence of Subbaromyces splendens, especially during the higher loading when the film accumulation rose from the minimum weight of 2.23 kgm^{-3} to 10.9 kgm^{-3} within one month. This ability to recover rapidly after sloughing (unloading) was also seen to a lesser extent in the plastic section of the mixed filter.

It has been shown in Chapter 5, that various organisms responded to changes in the film within the pilot filters by altering their population densities. Other organisms, especially the Protozoa, have been recorded as being restricted to certain film weights. The rapid decline of film accumulation from maximum to minimum weights (Figure 6.14) reflects the effectiveness of the grazing fauna at reducing the film. As discussed in Chapter 5, the Enchytraeidae always reached maximum population densities before the psychodid larvae, and this is clearly shown in Table 6.22. It is not coincidental that the lowest performance efficiency was also recorded during this unloading period due to excessive solids and debris being washed out in the final effluent of the filters.

6.3.2 CORRECTION FACTORS FOR MACROINVERTEBRATES

The film is comprised of a mixture of organisms and solids, the latter accumulated from suspended solids, flocculation and adsorption of solids from the influent, or resulting from biological activity within the filter, for example faeces of grazers. The organisms constitute two distinct feeding groups, those which feed on the adsorbed solids and nutrients in the sewage and which are directly involved in the purification process, and those which graze on the film and its associated micro-organisms. Difficulties arise in deciding what exactly constitutes the film and whether certain groups of organisms should be excluded. In the present investigation all the solids and debris including all the animals, except the lumbricids, the larger molluscs and the occasional visitors to the filters, were classed as the film and have been used in the presentation of the results. However Shephard (1967)

Table 6.22: Month of maximum population density of the Enchytraeidae and the Psychodid larvae in the pilot filters at both loadings.

FILTER	LOW LOADING (1.68 $m^3m^{-3}d^{-1}$)		HIGH LOADING (3.37 $m^3m^{-3}d^{-1}$)	
	Enchytraeidae	Psychodid larvae	Enchytraeidae	Psychodid larvae
Slag	February/May*	June	April	August
Mixed	January/May*	June	June	July
Plastic	Feb./April*	June	May	June

* secondary population maximum

suggested that the grazing fauna played no direct role in the purification process, and so should not be considered as part of the film. He corrected all his measurements of film weight expressed as volatile solids by subtracting the organic weight of all the macrograzers present. Comparison of the correction factors used by Shephard (1979) and of those determined during the present investigation (Table 6.23), clearly show that discrepancies exist between all the estimates. The most significant difference in weight was recorded between the psychodid larvae, the mean weight recorded for the larvae collected from the pilot filters being 62% less than that recorded by Shephard.

In estimating the mean weight of the larvae, equal numbers of all four instars were taken. But if only the third and fourth instars of the psychodid larvae were taken and weighed then the organic contents ranged from 0.202 to 0.222g per 1000 individuals. It is possible that the correction factor for the psychodid larvae, used by Shephard, was obtained by measuring samples containing mainly the larger instars.

Three film weights were directly compared: a) uncorrected film weight as used in the present investigation, b) corrected film weights using the correction factors determined in the present investigation, and c) corrected film weights using the correction factors determined by Shephard (1967). The various values for film weight (Tables 6.24 - 6.26) were correlated with the performance and biological data. Both the corrected sets of film data proved to be significantly more correlated with the performance and biological results

Table 6.23: Comparison of the organic weights of various grazers found in percolating filters for use as correction factors for film accumulation estimates.

Macrograzers (including Pupae)	Weight in grammes per 1000 individuals			
	Shephard (1967)	Present Investigation		n
Astigmatid mites	0.10	0.150	(0.02)	750
Psychodid pupae	-	0.185	(0.02)	1800
Psychodid larvae	0.20	0.076	(0.01)	5000
Chironomid larvae*	0.20	-	-	-
Sylvicola fenestralis larvae	-	0.832	(0.07)	1200
pupae	-	2.086	(0.20)	400
Enchytraeidae	0.20	0.150	(0.02)	5000
Eiseniella tetraedra	-	14.280	(1.52)	100

*Not estimated as chironomid larvae were not found in large numbers.

Standard deviation of weight estimate is given in parenthesis.

than the uncorrected data. Although the significance level of the correlations between the two sets of corrected data and the performance and biological results was the same, the film data using Shephard's correction factors had slightly larger coefficient values.

It has been shown that the active film is clearly responsible for the performance and in order to estimate the true accumulation of active film accurately, then all the macro- and micro-fauna present, including the Protozoa, Rotifera and Nematoda must be compensated for. As it is not possible to compensate for the non-active solids and debris in the same way, then it would seem sensible to take the entire weight of film, solids and animals present (excluding the largest organisms) as the value of accumulated film.

When the film accumulation was near to or greater than the mean accumulation, then the overestimation of the macroinvertebrate biomass obtained when using Shephard's correction factor would also in part compensate for the other fauna and debris present not accounted for. Problems were encountered in compensating for the large number of macroinvertebrates present during the higher loading when minimum film weights occurred during June in the mixed and plastic filters (Tables 6.24 - 6.26). By using Shephard's correction factor, the overcompensation of the macroinvertebrate biomass resulted in large negative weights of film being estimated. This phenomenon did not occur when using the smaller correction factors estimated during the present investigation.

Table 6.24: Film accumulation expressed in corrected and uncorrected forms, including percentage saturation of voids in the slag filter.

SLAG MEDIUM	Film Weight (V.S.)	Film Weight (Total)	Film V.S.(NG) - macro	Film V.S.(MS) - macro	Neutron Probe % Sat.
	kgm^{-3}	kgm^{-3}	kgm^{-3}	kgm^{-3}	%
10/77	3.05	-	2.98	2.86	17.69
11/77	6.37	-	5.99	5.73	19.07
12/77	9.53	274.27	9.37	9.25	22.64
1/78	10.18	335.23	9.80	9.61	28.33
2/78	6.87	240.07	6.68	6.58	29.33
3/78	14.39	391.01	14.30	14.25	31.93
4/78	13.74	388.40	13.69	13.65	32.75
5/78	8.32	255.21	7.81	7.38	24.93
6/78	1.78	128.24	1.13	0.36	12.39
7/78	2.98	156.07	2.82	2.62	14.41
8/78	2.53	147.95	2.33	2.18	14.40
9/78	4.03	177.13	3.70	3.53	-
10/78	4.20	203.49	3.99	3.81	-
11/78	7.95	288.69	7.79	7.63	-
12/78	3.11	173.89	2.81	2.51	-
1/79	7.81	271.87	7.30	6.60	23.64
2/79	8.88	260.55	8.54	8.06	-
3/79	11.33	294.02	11.10	10.99	-
4/79	4.57	186.73	3.20	2.70	-
5/79	4.77	163.70	3.98	3.64	28.52
6/79	5.61	216.24	4.66	3.40	-
7/79	5.07	184.26	4.29	3.36	-
8/79	3.71	171.25	2.84	1.52	-

Where V.S. is volatile solids,

N.G. is volatile solids corrected with macroinvertebrate biomass values as measured by the author.

M.S. is volatile solids corrected with macroinvertebrate biomass values as measured by Shephard (1967).

Table 6.25: Film accumulation expressed in corrected and uncorrected forms, excluding the percentage saturation of voids, in the mixed filter.

MIXED MEDIUM	Film Weight (V.S.)	Film Weight (Total)	Film V.S.(NG) - macro	Film V.S.(MS) - macro
	kgm^{-3}	kgm^{-3}	kgm^{-3}	kgm^{-3}
10/77	6.68	-	6.53	6.29
11	9.16	-	9.03	8.93
12	5.66	153.53	5.15	4.46
1/78	4.10	142.17	3.74	3.52
2	4.66	147.75	4.19	4.00
3	8.81	240.48	8.65	8.52
4	6.60	192.48	6.36	6.25
5	3.22	124.42	2.59	1.97
6	1.63	72.51	1.44	1.26
7	1.54	85.57	1.39	1.22
8	2.58	97.40	2.54	2.51
9	2.72	122.19	2.43	2.24
10/78	5.22	185.79	5.12	5.06
11	6.09	173.70	5.65	5.15
12	6.85	235.83	6.61	6.45
1/79	6.51	204.15	6.05	5.55
2	13.89	329.05	13.59	13.30
3	9.65	227.13	9.46	9.35
4	4.91	143.09	4.61	4.44
5	5.79	175.53	4.00	3.16
6	2.77	93.17	0.47	-4.85
7	6.34	175.67	4.46	1.54
8	5.51	167.67	5.16	4.51

Table 6.26 : Film accumulation expressed in corrected and uncorrected forms including percentage saturation of voids in the mixed filter.

PLASTIC MEDIUM	Film Weight (V.S.)	Film Weight (Total)	Film V.S.(NG) - macro	Film V.S.(MS) - macro	Neutron Probe % Sat.
	kgm^{-3}	kgm^{-3}	kgm^{-3}	kgm^{-3}	%
10/77	5.53	-	5.31	4.97	3.68
11	8.31	-	8.16	8.09	6.09
12	8.89	192.75	8.78	8.72	4.48
1/78	6.85	145.54	6.29	5.93	4.03
2	6.20	143.66	5.53	5.20	3.84
3	6.70	130.35	6.40	6.13	4.24
4	5.00	124.56	4.63	4.26	2.84
5	2.33	51.66	1.51	0.40	1.72
6	2.02	47.47	1.25	0.08	1.22
7	1.02	35.89	0.87	0.65	1.23
8	2.27	61.53	2.26	2.23	2.26
9	4.71	108.66	4.50	4.37	-
10/78	6.11	150.43	5.81	5.64	-
11	8.59	206.76	8.12	7.52	-
12	9.65	246.03	9.57	9.45	-
1/79	6.45	136.60	6.02	5.37	6.01
2	11.38	201.53	11.01	10.42	-
3	13.33	256.93	13.24	13.17	-
4	9.05	156.19	8.78	8.56	-
5	7.73	168.29	7.14	6.67	2.11
6	2.23	42.84	0.19	-2.99	-
7	10.90	189.15	9.24	6.59	-
8	9.85	215.09	9.55	9.11	-

6.3.3 FILM ESTIMATION BY THE NEUTRON SCATTERING TECHNIQUE

Under normal operating conditions it is very difficult to determine when or whereabouts a filter is becoming choked, or to estimate the degree of utilisation of the medium within the filter. The neutron scattering method does not record the amount of active film present (Section 4.2.2), but simply measures the amount of water present whether this is present as film, animals, humus or even reservoirs of sewage held within the medium. It does, however, provide a useful comparative assessment of the film accumulation without disturbing the medium.

Normal moisture contents in 50 mm slag medium are in the order of 20%, while values in excess of 30% indicate excessive film accumulation and possibly ponding. In the random plastic medium, the voidage was much greater than in the slag and so the film accumulation occupied a smaller proportion of the available space within the medium. Normal moisture contents were less than 10% in the Flocor RC medium, and moisture contents in excess of 15% indicated excessive film.

The neutron scattering results are given in full in Appendix V, and summarised in Tables 6.27-6.29. The slag filter suffered from excessive film accumulation, during the lower loading, not only at the surface but throughout most of its depth from January until April, reaching a critical stage in April prior to sloughing when the film accumulation was extremely heavy. At the higher loading the film accumulation was excessively heavy in the top half of the filter, even in May just after sloughing had occurred. In the mixed filter (Table 6.28) the accumulation of solids in the plastic portion was always low except for thick surface film growth (top 200 mm) in March prior to sloughing during the lower loading. Film accumulation in the slag portion was greatly reduced, compared to the same depth in the slag filter. The interface region especially appeared to be free from heavy weights of film. At the higher loading more film accumulated in both the slag and plastic portions, although from the results available, not excessively. In the plastic filter, film accumulation was extremely low, with occasional surface accumulations in excess of 15% saturation of the voids during November and March at the lower loading, prior to sloughing. At the higher loading, more film was recorded from the lower depths in the filter, but were well below the 10% level (Table 6.29).

Table 6.27: Film accumulation with depth in the slag filter, as measured by the neutron scattering technique.

(Italics indicate excessive film accumulation)

	Monthly mean moisture content (Percentage saturation of voids)													
	1.68 $m^3m^{-3}d^{-1}$											3.37 $m^3m^{-3}d^{-1}$		
Depth	10.77	11.77	12.77	1.78	2.78	3.78	4.78	5.78	6.78	7.78	8.78	9.78	1.79	5.79
20cm	12.9	24.1	24.3	*34.0*	*32.7*	*35.8*	28.6	26.2	11.6	24.5	15.3	-	*36.7*	*31.7*
35cm	16.9	21.7	22.2	28.2	27.6	28.4	22.6	21.5	12.5	20.1	14.4	-	*32.2*	*38.0*
50cm	19.0	22.8	22.6	27.5	*30.8*	*34.8*	*33.0*	29.9	12.7	16.9	15.6	-	*31.0*	*40.2*
65cm	19.0	24.5	24.4	27.9	29.3	*35.2*	*36.8*	22.2	12.4	13.7	15.0	-	28.5	*38.3*
80cm	19.4	20.5	25.2	29.0	24.8	28.6	*32.1*	16.3	11.7	12.2	14.1	-	24.9	*30.6*
95cm	18.6	19.0	25.4	*31.6*	27.0	29.0	28.9	15.3	11.5	11.5	13.5	-	21.7	22.8
110cm	19.8	19.7	25.4	*32.3*	*30.5*	*32.6*	*32.4*	18.4	11.7	11.6	13.6	-	19.6	19.0
125cm	19.4	19.0	25.1	*30.4*	*31.7*	*33.9*	*35.8*	24.7	12.5	12.0	14.1	-	18.3	19.2
140cm	18.0	16.5	21.5	27.8	*32.8*	*35.8*	*39.0*	29.5	12.1	11.3	13.7	-	16.9	19.2
155cm	17.8	15.2	20.2	26.5	*31.2*	*33.6*	*37.1*	*32.0*	12.9	12.9	14.4	-	17.8	23.6
170cm	16.7	13.7	18.5	23.9	28.6	29.5	*35.0*	*32.6*	13.6	13.3	15.0	-	18.3	29.5
180cm	14.8	12.1	16.9	20.8	24.9	25.9	31.7	*30.6*	13.5	12.9	14.2	-	17.9	*30.2*

Table 6.28: Film accumulation with depth in the mixed filter, as measured by the neutron scattering technique.

	Monthly mean moisture content (Percentage saturation of voids)													
	$1.68\ m^3m^{-3}d^{-1}$											$3.37\ m^3m^{-3}d^{-1}$		
Depth	10.77	11.77	12.77	1.78	2.78	3.78	4.78	5.78	6.78	7.78	8.78	9.78	1.79	5.79
20cm	5.2	7.9	6.2	6.9	11.4	*16.9*	9.1	5.0	2.0	2.3	5.3	3.2	12.2	7.9
35cm	7.7	8.9	4.1	4.3	7.5	8.1	3.6	1.4	1.3	1.8	3.5	2.5	9.9	7.3
50cm	8.0	9.0	3.4	3.7	6.4	6.6	3.5	1.4	1.3	1.9	2.5	2.8	9.6	5.9
65cm	7.2	7.7	3.4	3.3	4.9	6.1	3.8	1.5	1.5	1.8	2.1	2.7	7.2	3.6 *
80cm	12.7	13.4	7.1	6.6	7.7	10.6	7.1	3.7	3.3	3.5	3.7	5.5	12.1	5.1
95cm	17.9	18.9	12.9	11.5	11.6	15.9	12.5	8.3	7.5	7.6	7.7	10.0	18.5	9.7
110cm	20.6	24.1	16.8	15.5	16.1	19.8	17.5	13.5	11.2	11.0	10.9	13.4	21.7	12.8
125cm	20.1	25.8	18.2	16.8	17.2	21.1	20.1	16.0	12.6	12.5	12.4	14.7	22.7	14.4
140cm	18.2	22.9	17.2	16.1	16.6	19.6	18.8	16.0	12.7	12.6	13.0	15.1	21.2	14.1
155cm	16.6	20.0	16.5	15.5	16.0	19.1	19.0	15.7	12.6	13.0	13.0	14.8	19.7	14.4
170cm	16.3	17.7	16.8	15.5	16.1	18.3	18.2	16.4	13.3	13.1	13.1	14.9	21.0	16.4
180cm	15.2	15.5	15.9	14.6	14.7	17.2	16.8	15.4	12.4	12.1	12.2	13.9	19.6	15.1

*Broken line indicates interface between the plastic and slag medium
(Italics indicate excessive film accumulation)

Table 6.29: Film accumulation with depth in the plastic filter, as measured by the neutron scattering technique.

	Monthly mean moisture content (Percentage saturation of voids)													
	$1.68\ m^3m^{-3}d^{-1}$											$3.37\ m^3m^{-3}d^{-1}$		
Depth	10.77	11.77	12.77	1.78	2.78	3.78	4.78	5.78	6.78	7.78	8.78	9.78	1.79	5.79
20cm	4.1	11.7	6.5	7.7	10.7	*15.6*	6.8	4.0	1.6	1.9	6.4	-	12.2	4.6
35cm	5.3	*17.0*	5.2	4.2	4.7	4.2	2.3	1.3	0.9	1.4	4.4	-	9.1	2.7
50cm	5.6	8.8	5.1	3.7	3.4	3.2	2.3	1.2	1.1	1.3	3.0	-	8.0	3.5
65cm	4.3	5.8	4.7	3.6	3.2	3.0	2.3	1.1	1.1	1.1	1.8	-	6.6	2.9
80cm	3.9	5.0	5.1	4.6	3.4	3.1	2.2	1.3	1.1	1.1	1.4	-	6.1	2.1
95cm	3.4	4.6	4.6	4.6	3.5	3.4	2.3	1.2	1.2	1.1	1.5	-	5.1	1.4
110cm	3.3	4.3	4.6	4.0	3.6	3.5	2.4	1.4	1.2	1.1	1.5	-	4.9	1.3
125cm	3.2	3.7	3.9	3.4	3.1	3.3	2.5	1.5	1.1	1.1	1.4	-	4.3	1.2
140cm	2.9	3.5	3.7	3.2	2.7	3.2	2.6	1.6	1.3	1.1	1.4	-	4.2	1.3
155cm	2.9	3.2	3.6	3.2	2.5	2.9	2.6	1.8	1.3	1.1	1.5	-	4.2	1.4
170cm	2.7	3.0	3.5	3.1	2.7	2.8	2.8	2.1	1.3	1.2	1.6	-	3.8	1.4
180cm	2.5	2.5	3.3	3.1	2.6	2.7	3.0	2.1	1.4	1.2	1.4	-	3.7	1.5

(Italics indicate excessive film accumulation)

6.4 TEMPERATURE

The performance of filters has been shown to vary seasonally, possibly in response to variations in the ambient (air) temperature (Hawkes, 1957; Bayley and Downing, 1963), the indirect effect of lower temperatures on restricting the life cycles of grazers (Solbé, Ripley and Tomlinson, 1974), and in the accumulation of film (Shephard and Hawkes, 1976).

The recorded changes in the influent temperature during the investigation were between 30 - 50% less than those recorded for the air temperature. The influent temperature varied from 6.5 to 18.0^{o}C, a total range of 11.5^{o}C, while the air temperature varied from -7.2 to 23.2^{o}C, a total range of 30.4^{o}C for the entire 24 month period at the two main loadings (Table 6.30). The seasonal changes in the influent and air temperatures followed similar patterns, both reaching maximum and minimum temperatures during the same periods. The influent temperature remained extremely constant during both main loading periods with mean temperature for each period being 12.4^{o}C. The difference between maximum and minimum air temperature (the range) increased from 20.4 to 30.4^{o}C with the increase in loading, this being due to the extremely low temperatures recorded in January 1979 of -7.2^{o}C.

Reynoldson (1939) noted that the temperature variation within percolating filters was normally less than one third of the change normally occurring in the ambient temperature. This

Table 6.30: Summary of temperature of the final effluents, influent and air at low and high rate loadings during the twenty-four sampling months.

	TEMPERATURE				
	Influent (^oC)	Slag filter (^oC)	Mixed filter (^oC)	Plastic filter (^oC)	Air (^oC)
1.68 $m^3m^{-3}d^{-1}$					
Mean	12.4	9.7	9.4	9.5	9.2
Minimum	7.8	2.1	2.5	2.1	-1.0
Maximum	18.0	17.0	17.0	17.5	19.4
Range	10.2	14.9	14.5	15.4	20.4
S.D.	3.04	4.12	4.04	4.19	5.33
95% C.L.	0.95	1.29	1.27	1.32	1.67
n	49	49	49	49	49
3.37 $m^3m^{-3}d^{-1}$					
Mean	12.4	10.7	10.6	11.1	10.3
Minimum	6.5	3.6	3.7	3.7	-7.2
Maximum	17.5	16.8	17.1	17.9	23.2
Range	11.0	13.2	13.4	14.2	30.4
S.D.	3.84	4.07	4.11	4.43	7.23
95% C.L.	1.33	1.41	1.42	1.54	2.51
n	37	37	37	37	37

was due to smaller seasonal changes in the temperature of the settled sewage and to the heat produced by the metabolic activity of the film, and has been similarly demonstrated by numerous other workers (Lloyd, 1945; Mills, 1945; Tomlinson and Hall, 1950; Hawkes, 1963).

At the low loading rate the minimum, mean and maximum temperatures were similar in all three pilot filters (Table 6.30). On average the warmest effluent (9.7°C) was recorded in the slag filter, with the plastic filter having the widest variation in temperature for the year. At the higher loading the range of final effluent temperatures from all the pilot filters decreased by about 1°C compared to the previous lower loading. The mean final effluent temperatures all increased at the higher loading with the plastic filter having the highest mean temperature at 11.1°C and also the widest range of temperatures at 14.2°C. The final effluent temperature of the three pilot filters followed a similar seasonal pattern (Figure 6.15), with the plastic filter being more affected by extremes of air temperature than either the slag or mixed filters.

The temperature of all the final effluents at the higher loading (Figure 6.16) followed the seasonal variations in influent temperature. With a greater correlation than recorded at the lower loading, indicating the effect of the increased volume of influent sewage on the overall temperature of the final effluents. The final effluent temperature of the slag filter followed the influent temperature more closely than either the other filters, indicating that the fluctuations in the air temperature had least effect on this filter. The

Figure 6.15: Seasonal changes in influent, final effluents and air temperatures during low rate loading (1.67 $m^3m^{-3}d^{-1}$)

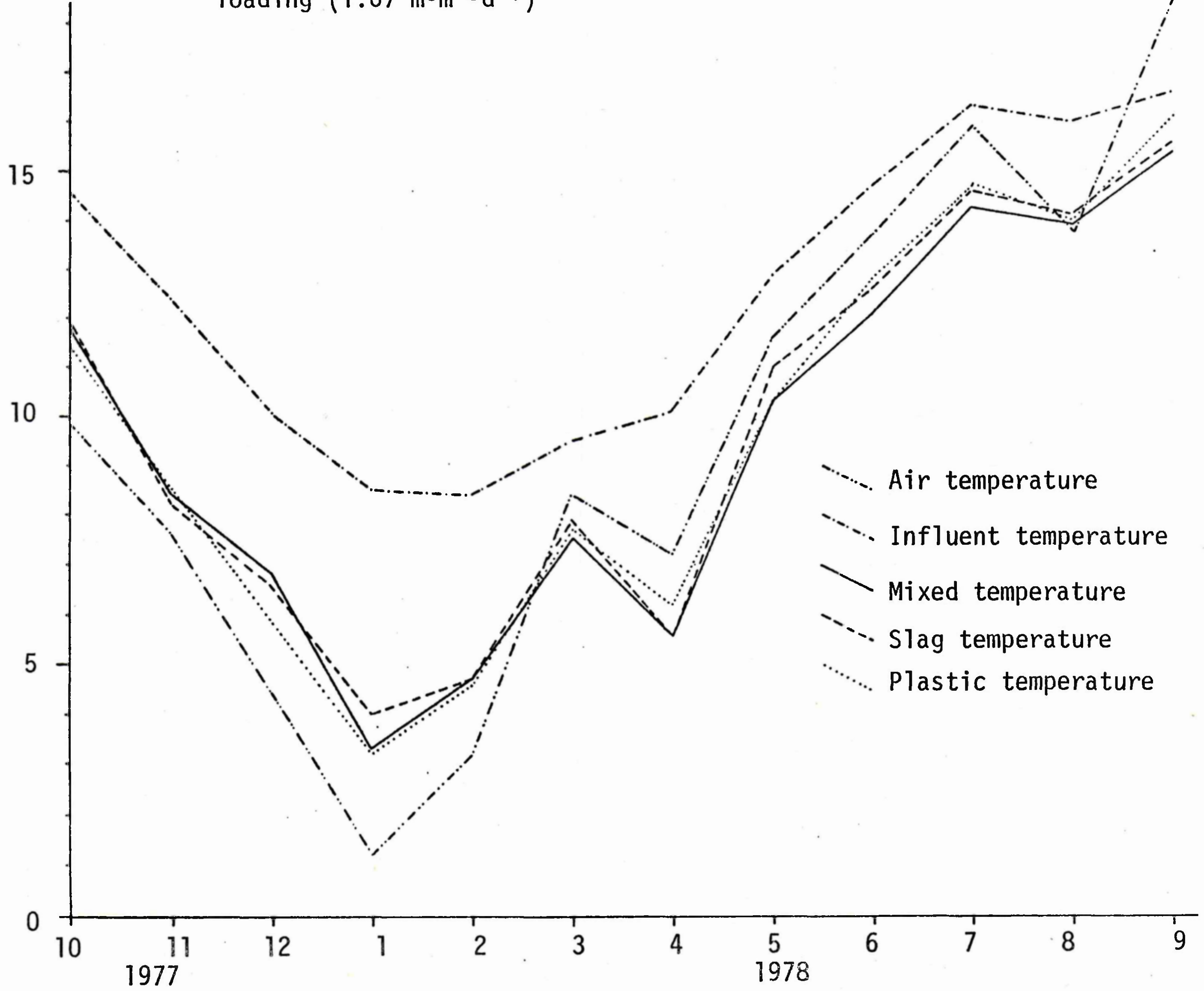
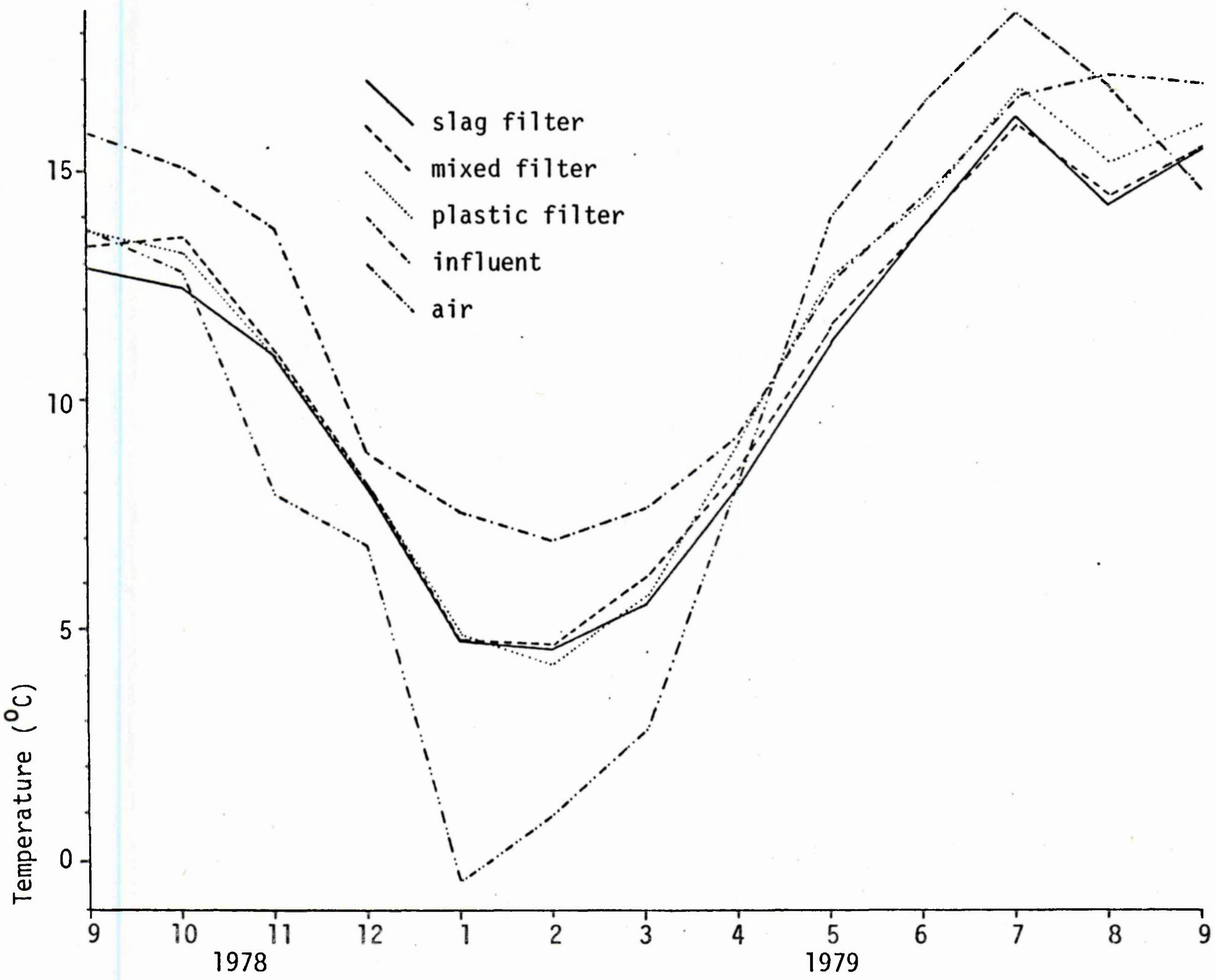


Figure 6.16: Seasonal changes in influent, final effluents and air temperatures during high rate loading period (3.37 $m^3m^{-3}d^{-1}$)



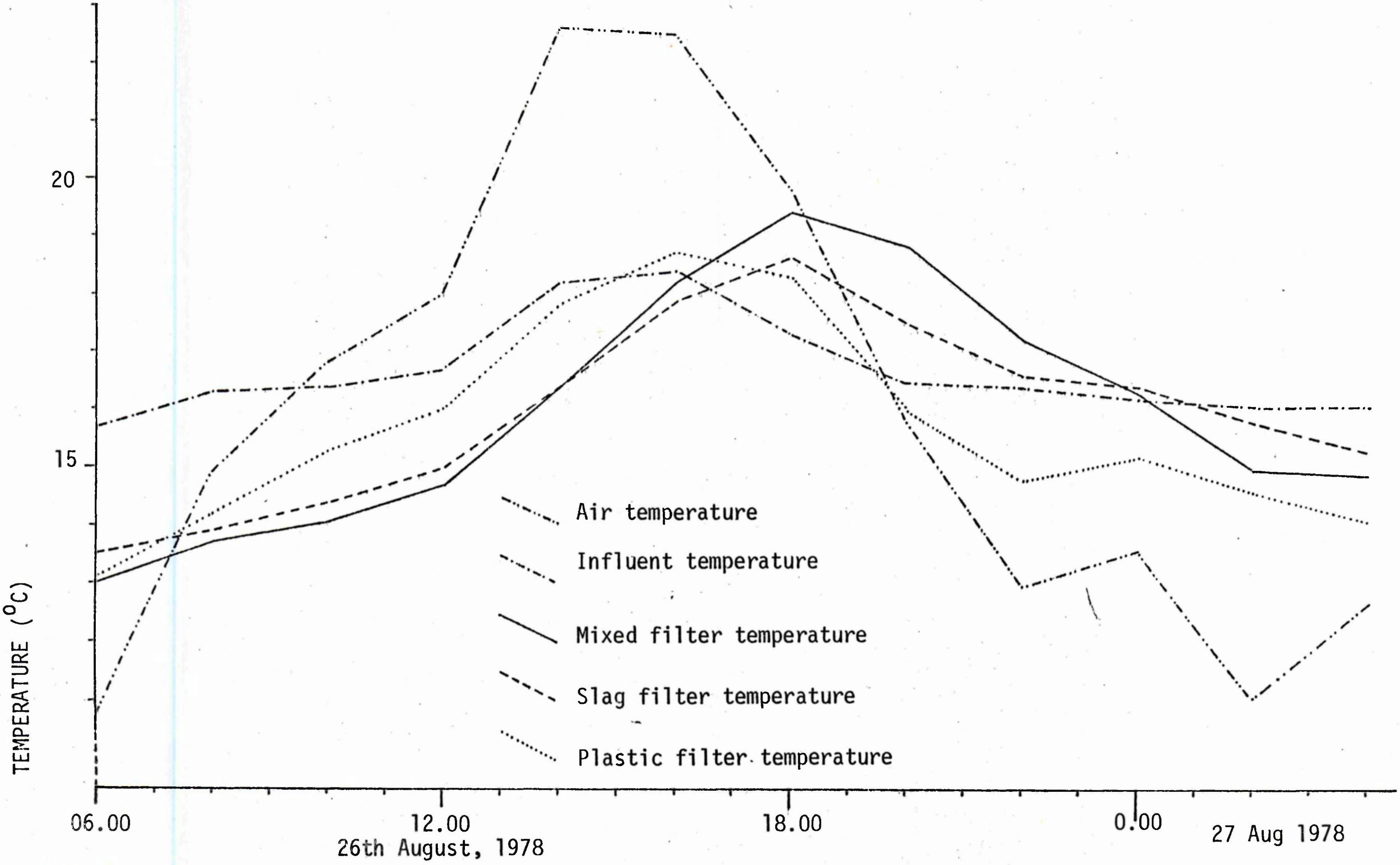
temperature of the slag and mixed filters appeared related at the higher loading, although the temperature of the mixed filter was also affected by the air temperature. For example the final effluent temperature in the mixed filter was lower than the slag filter during the colder months but in July 1979 when the maximum air temperature was recorded, the final effluent temperature in the mixed filter exceeded that of the slag filter.

The final effluent temperature of the plastic filter was influenced by both the influent and the air temperatures. The final effluent temperature never fell below 3.7°C, but responded to increases in the air temperature during the spring and summer by producing a consistently warmer final effluent than the other pilot filters.

Appreciable diurnal variations in the air temperature were recorded at both loadings. At the low loading (Figure 6.17), both the influent and air temperatures had the same diurnal pattern, indicating that the influent temperature was affected by the air temperature. The final effluent from the plastic filter was subject to relatively large and sudden variations in temperature compared with either of the other filters. A time lag between maximum air and influent temperatures, and the resulting maximum temperatures of the final effluents, was observed. In the plastic filter the time lag was about half that recorded for either the mixed or slag filters.

During the night and early hours of the morning, the influent temperature maintained the temperature of all the filters

Figure 6.17: Diurnal variation in influent, final effluent and air temperature at the low loading (1.68 $m^3m^{-3}d^{-1}$)

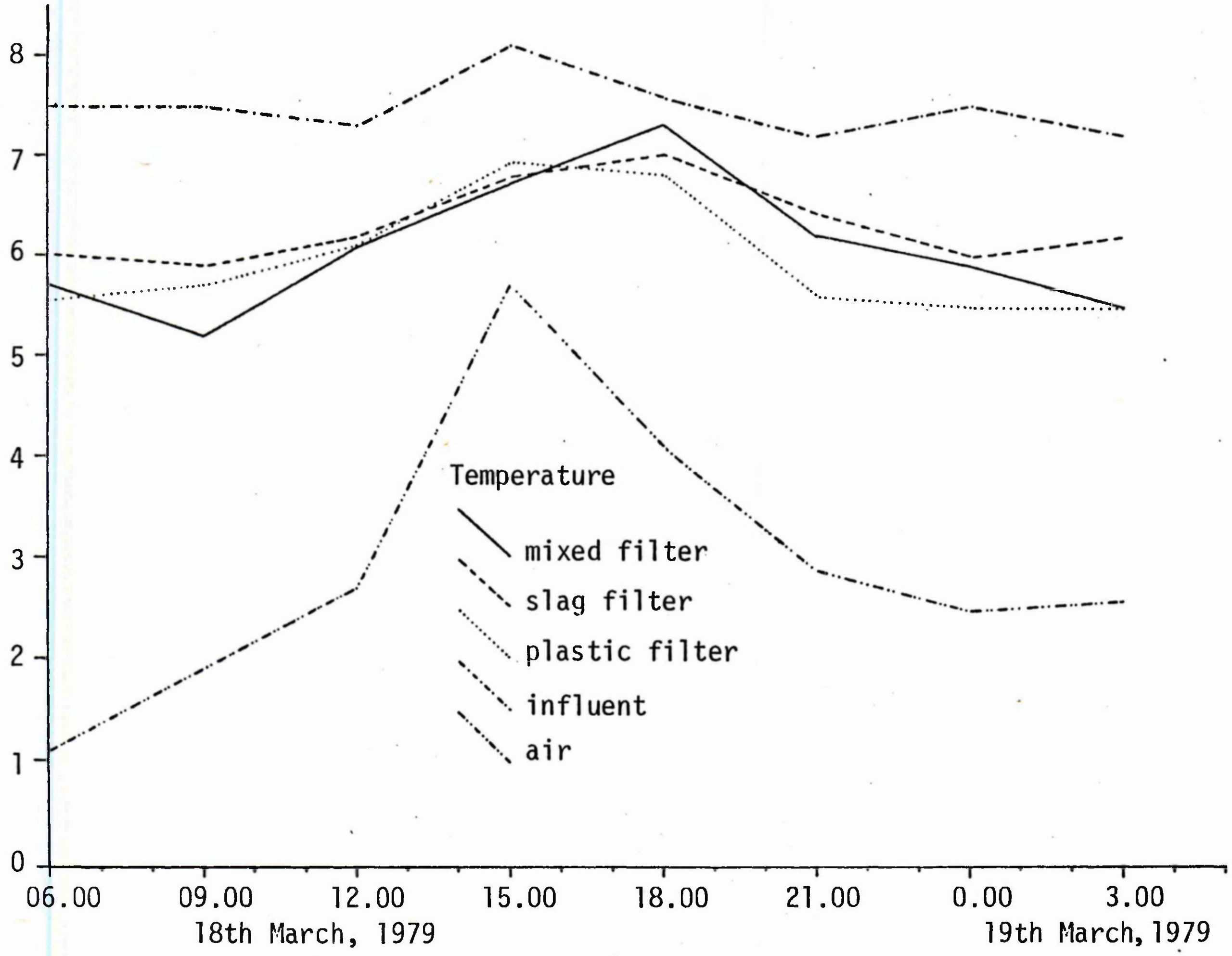


against the lower air temperature. The increase in the air temperature during the day resulted in the filters producing final effluents during the early evening which were several degrees warmer than the influent temperature. It appears that the plastic filter (Figure 6.17) is more affected by changes in the air temperature, and is observed to respond quickly. The slag filter appeared 'buffered' against sudden changes in the air temperature, although when it is higher than the filter temperature, some heating of the medium is recorded after a period of several hours. The plastic layer lowered the heat retention and production capacity in the mixed filter compared with the slag filter, resulting in lower heat retention during 0.00 to 12.00 hrs, but greater heat assimilation than the slag filter during the hours 12.00 to 0.00 daily.

The diurnal variation in temperature at the higher rate is shown in Figure 6.18. The temperature scale has been expanded over the smaller range as the variation of temperature is much reduced compared to the previous loading. All the filters responded to the influent and air temperatures as before, with the plastic filter associated with the air temperature, and all three filters reproducing the lag response to the maximum air and influent temperatures. Least variation was observed in the slag filters with greatest variations in diurnal temperatures recorded in the mixed and plastic filters.

The temperature variations recorded in the pilot filters were in excess of those normally associated with biological filtration (Wheatley, 1976). The temperature differences recorded in the pilot filters were therefore most likely exaggerated

Figure 6.18: Diurnal variation in influent, final effluent and air temperature at 3.37 $m^3m^{-3}d^{-1}$



with variations in the temperature having a greater effect due to the small scale of the pilot filters. There was also a problem with heat transfer through the walls of the filters. The pilot filters were built above the ground and the concrete walls, although thick enough to offer some insulation, allowed heat transfer between the filter medium and the air outside. Changes in the air temperature, wind velocity affecting heat loss from the walls, and the absorption of heat by solar radiation all caused temperature changes to occur in the medium immediately adjacent to the walls within the filters, which were closely recorded by the thermocouples inside the pilot filters. There was a clear diurnal variation in the temperature in the medium immediately adjacent to the wall, getting warmer during the day and cooler during the night. The temperature of the central core of the filters remained far more constant. In fact the core temperature in the slag medium, as measured by the central thermocouple column, remained extremely constant with small changes in temperature occurring over long periods, i.e. in excess of six hours, whereas the temperature in the plastic medium changed far more rapidly, often by 1°C within thirty minutes.

There was some loss of heat from the influent as it left the distributor and reached the surface of the filters, a distance of 500 mm. During the winter the temperature gradually increased with depth due to heat production from microbial activity, although the medium adjacent to the walls of the filters remained cooler. In the summer the influent retained more of its original heat and the greater microbial activity meant that again the temperature of the influent sewage increased with depth but to a greater degree than before. The metabolic rate increases exponentially with temperature and so greater temperature productions are to be expected during the warmer months. This was reflected in the performance results, which were generally worse during the colder months except during the sloughing period in the spring.

During the present investigation the temperature of the slag filter was closely related at both loadings to the temperature of the influent. The temperature of the influent sewage was affected by the air temperature (Figures 6.15, 6.16), and during extremely cold conditions the influent was also cooled considerably in the fall from the nozzle to the surface of the medium. Although the temperature of the surface layer of medium was clearly related to the influent temperature, the core temperature of the filter remained more or less constant due to the heat production from biological oxidation. This was shown by the close correlation between the influent temperature and the performance of the slag filter at both loadings which was not seen in either the mixed or plastic filters.

The slag filter comprises of 48.5% solid material which is able to retain the heat compared to 8.7% in the plastic and 31.9% in the mixed filters. Therefore with more heat retaining material, there is less voidage and so lower potential ventilation than in either the plastic or mixed filters, and it can be seen why the slag filter is such an effective buffer against the changes in air temperature, the central core of the filter being kept at constant temperature by the heat produced from biological oxidation.

The temperature of the plastic filter was influenced far more by the air temperature than that of the influent due to the greater voidage giving rise to excessive ventilation and therefore more heat exchange. The plastic filter was seen to respond quickly to changes in air temperature (Figure 6.17) after showing large variations in diurnal temperature which was not reflected in the seasonal data. Bayley and Downing (1963) suggested that with synthetic media with a high voidage, the air temperature and rate of flow of air influenced the temperature of the voidage, but that the temperature of the influent was still the main factor in maintaining the temperature, and to a lesser extent the rate of reaction within the microbial film. The temperature of the influent always prevented extremes of temperature within the plastic filter, and this was seen much more clearly at the higher loading. This is also shown in the very highly significant correlation ($P < 0.001$) between the performance of the plastic filter and the air temperature at the lower rate of loading but with both the influent and air temperature during the higher loading rate. At the higher loading the volume of heated influent obviously had a greater effect on the overall temperature of the pilot filters generally than at the previous loading.

The mixed filter had a lower portion of slag medium which had a warmer central core, similar to that found in the slag filter. But there were greater fluctuations in the temperature in this part of the filter than in the slag due to less microbial activity controlling the temperature by a steady output of heat from biological oxidation. Although the top plastic layer was affected by the influent and air temperature more than the same layer in the slag filter, the final effluent temperature of both the slag and mixed filters were always associated. Correlation analysis showed that better relationships existed between the air temperature and the performance of the mixed filter at the low loading, and between the effluent temperature and performance at the higher loading.

The diurnal variations (Figures 6.17 and 6.18) in the mixed filter were not as large as those recorded for the plastic filter but are greater than those in the slag filter. The mixed filter had a smaller area of heat retaining material than the slag, and so heat retention only occurred to a greater extent in the lower half of the filters. The filter was affected by the greater ventilation and the greater potential heat loss at the surface. But when the air temperature increased, then the mixed filter was able to respond more efficiently by gradually increasing the temperature in the top plastic layer which in turn caused the lower slag portion to gradually heat up. When the air temperature was about equal to or just above that of the sewage, the temperature within the plastic and mixed filters increased continuously with increased distance from the surface by an amount depending on the rate of biological oxidation, and to a lesser extent by the amount of heat transferred through the filter walls.

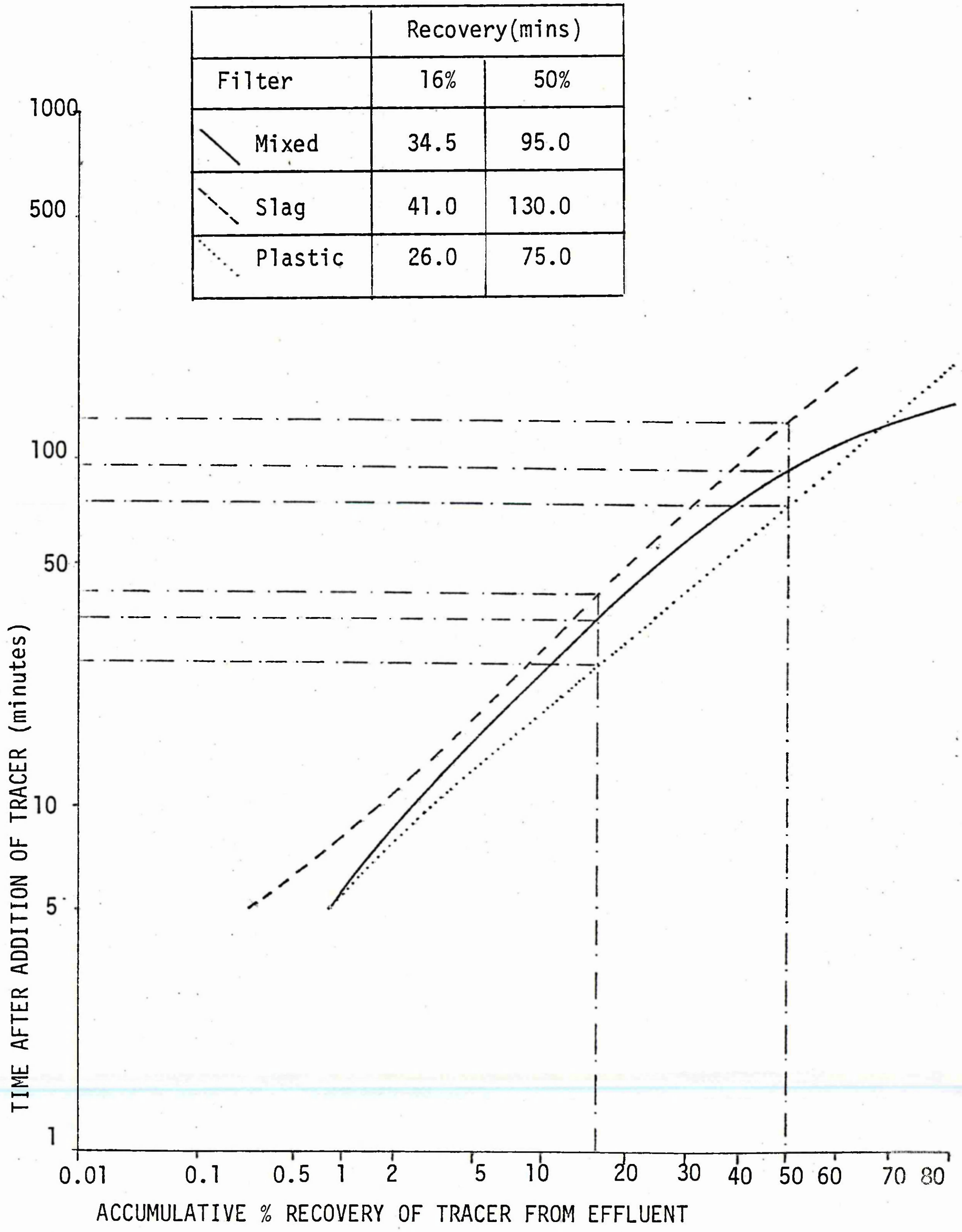
6.5 RETENTION TIME

The importance of retention time, also referred to as residence or contact time, in the assessment of the efficiency of percolating filters has been stressed from the earliest times (Royal Commission on Sewage Disposal, 1908). The theory that increased retention time allows more time for the influent sewage to be in intimate contact with the film, therefore allowing maximum exchange of nutrients, has been studied by many workers (Eden, Brendish and Harvey, 1964; Craft et al., 1972; Craft and Ingols, 1973; Cook and Katzberger, 1977), many of whom found that the retention time was associated with the performance. Tomlinson and Hall (1950) studied filter performance over a wide range of hydraulic loadings from 0.4 to 8.0 $m^3m^{-3}d^{-1}$. They found a direct relationship between the permanganate value of the settled final effluents and the hydraulic load, also a logarithmic relationship between the BOD of the settled final effluent and the hydraulic load. The results showed that at a hydraulic loading of 8.0 $m^3m^{-3}d^{-1}$ the filter removed 32% of the BOD load at a rate of 0.73 kg BOD $m^{-3}d^{-1}$, whereas at 0.8 $m^3m^{-3}d^{-1}$, although 86% of the BOD load was removed, the removal rate was only 0.20 kg BOD $m^{-3}d^{-1}$. Using the retention time data from the filters at the different hydraulic loadings to determine the rate constant of BOD removal, Tomlinson and Hall discovered that there were in fact two rate constants. They concluded that because the initial removal was so rapid it was likely to be a purely physical process. A similar conclusion had been drawn by Stoddart (1909) some fifty years previously, who had found that as the hydraulic flow increased, the mechanism of removal changed from being primarily a biological process to a physical one. Eden et al. (1964) examining the measurement and significance of retention in percolating filters, found that there were three controlling factors, the hydraulic flow, film accumulation and the size and shape of the medium. They concluded that although the performance could not be directly related to the film accumulation, the performance could be calculated from the retention time data.

The results of the retention tests carried out during the investigation are summarised in Table 6.31. The data is expressed as times required for the recovery of 16% (t_{16}) and 50% (t_{50}) of the added tracer, taken from the plot of percentage of tracer recovered against time on logarithmic probability paper (Figures 6.19 - 6.23), on which a log normal distribution gives a straight line. The 16 percentile and the 50 percentile (or median) values are chosen since (t_{50}/ t_{16}) = σ, the standard deviation of the log normal distribution (Eden et al., 1964).

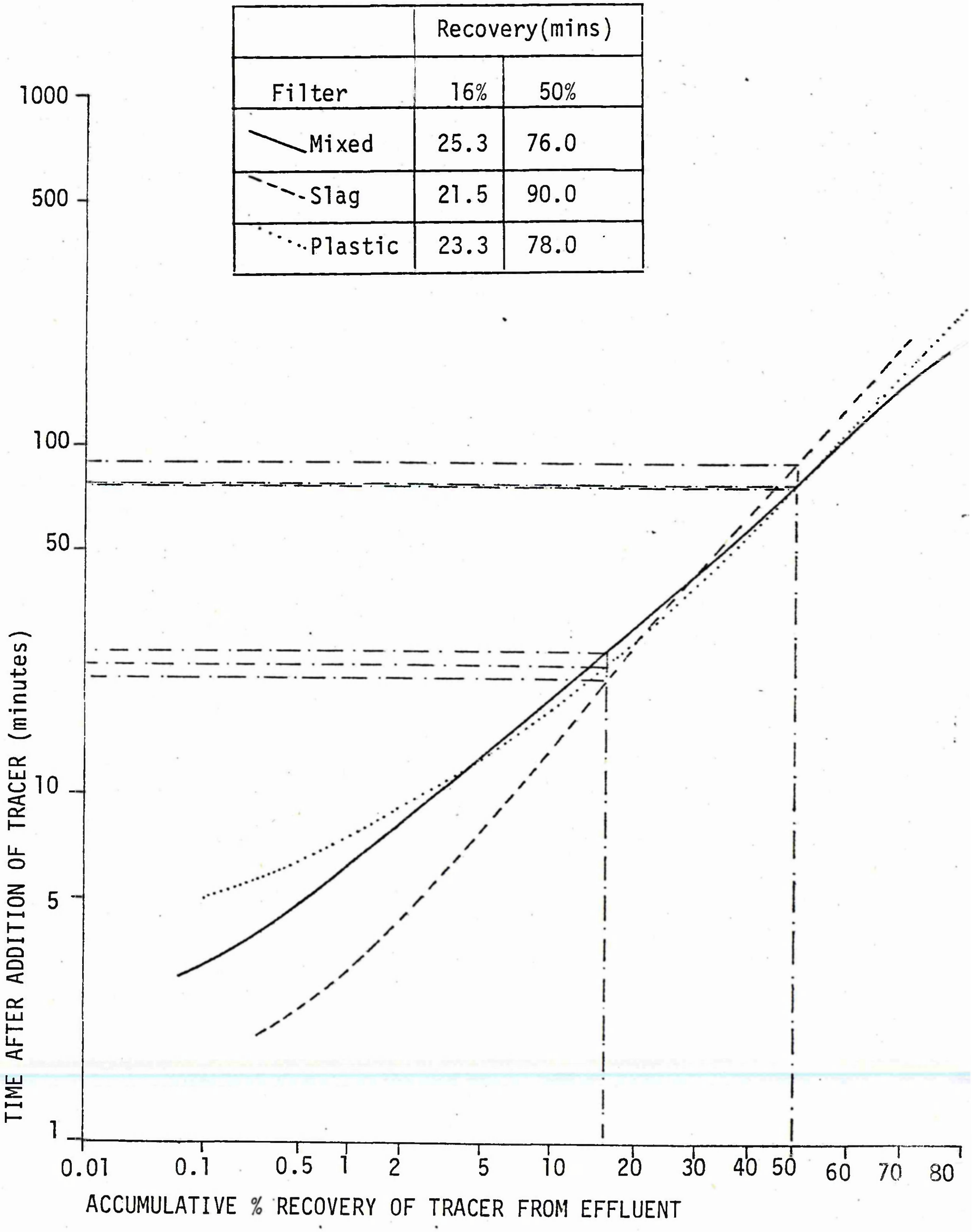
At the lower loading the slag filter had the longest median retention time (MRT). With a decrease in the film accumulation however, the MRT decreased in both the slag and the mixed filters, remaining constant only in the plastic filter. It has been shown by other workers, and in the case of the present investigation, that the MRT increases with increases in film accumulation at conventional loadings. It is apparent that the flow of influent sewage in the plastic filter at the lower loading is unimpeded during normal film conditions, and

Figure 6.19: Retention test of low rate filters, 4th May, 1978



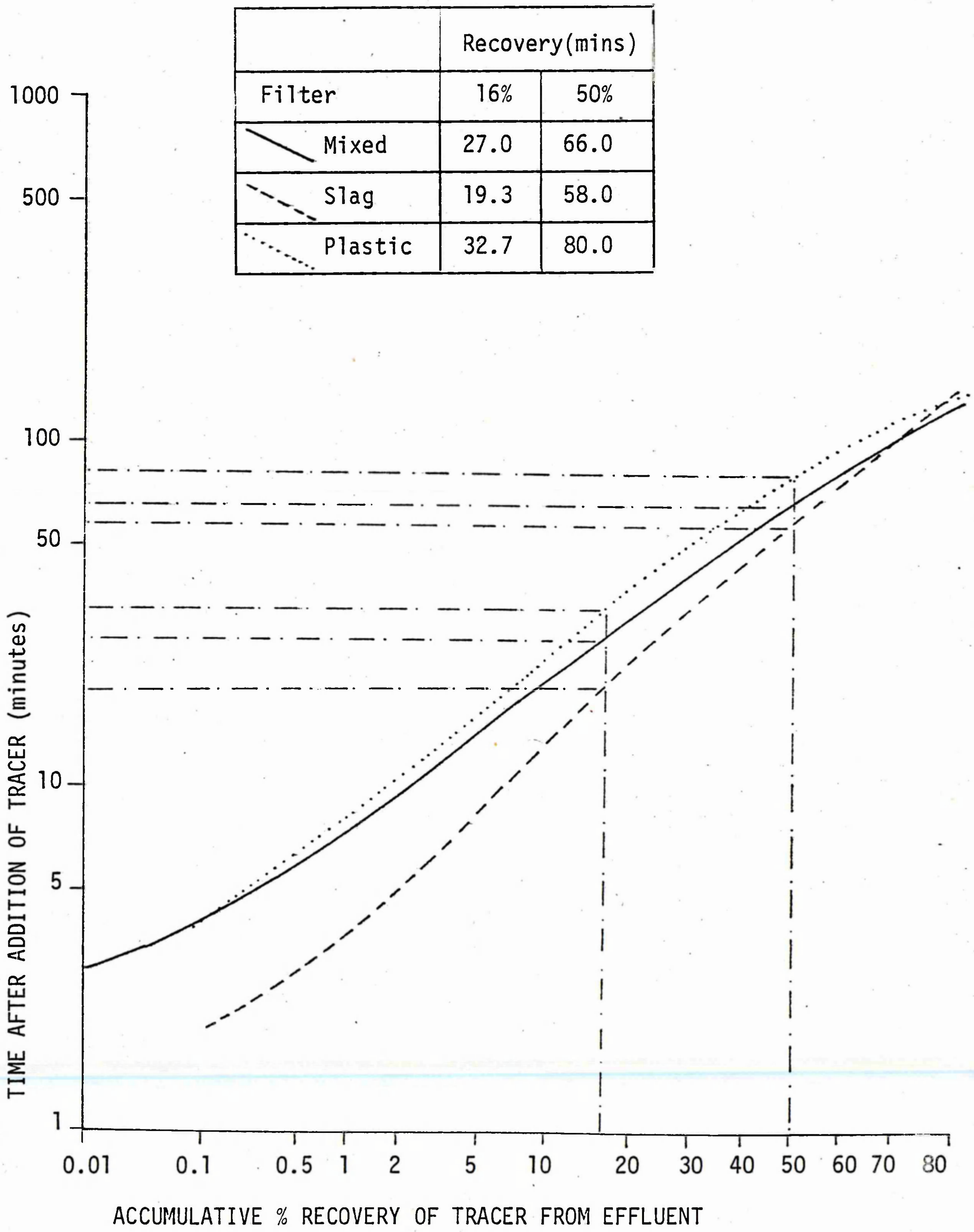
	Recovery(mins)	
Filter	16%	50%
— Mixed	34.5	95.0
- - Slag	41.0	130.0
··· Plastic	26.0	75.0

Figure 6.20: Retention test on low rate filters, 17th September, 1978.



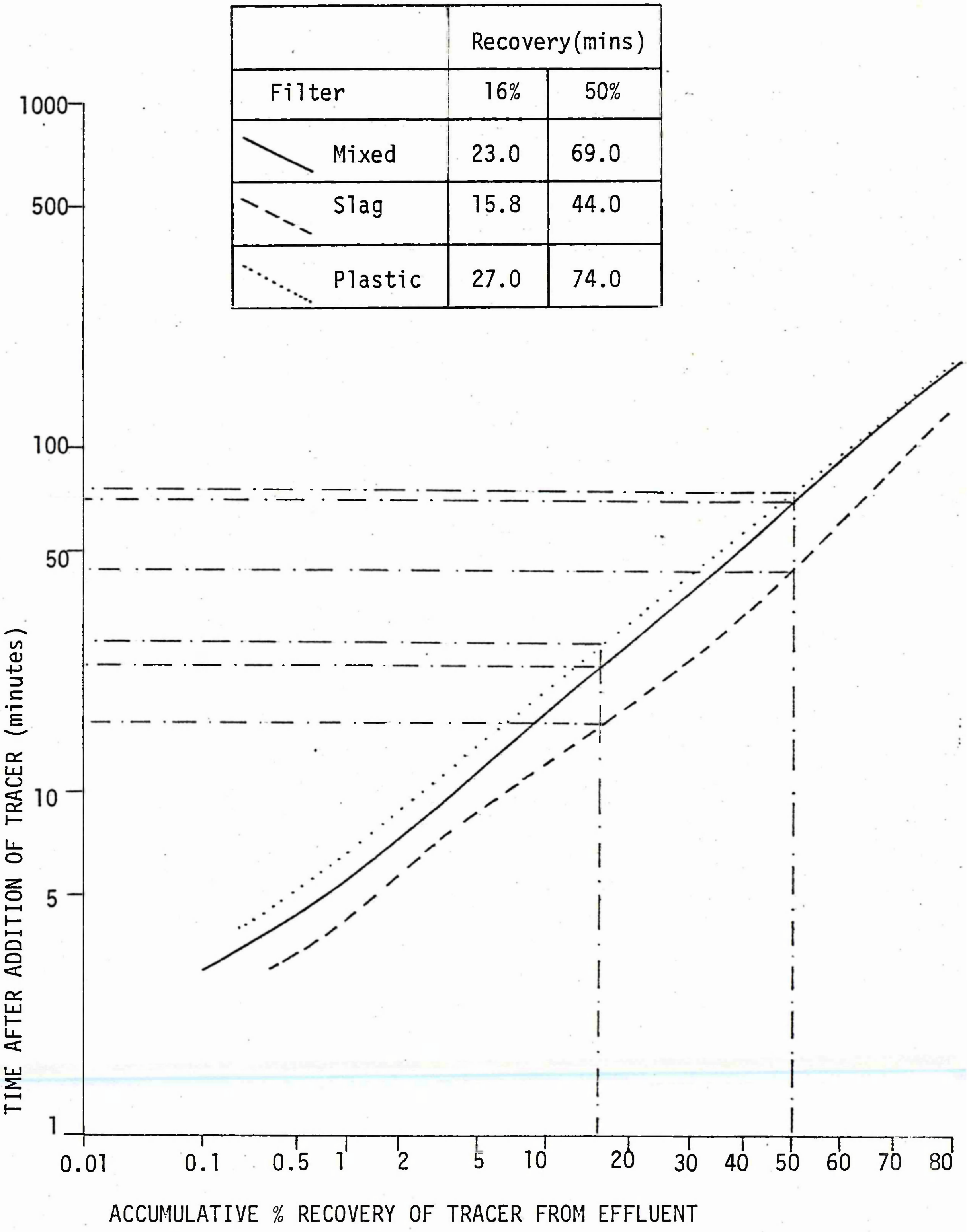
	Recovery(mins)	
Filter	16%	50%
— Mixed	25.3	76.0
– – Slag	21.5	90.0
··· Plastic	23.3	78.0

Figure 6.21: Retention test on high rate filters, 11th December 1978



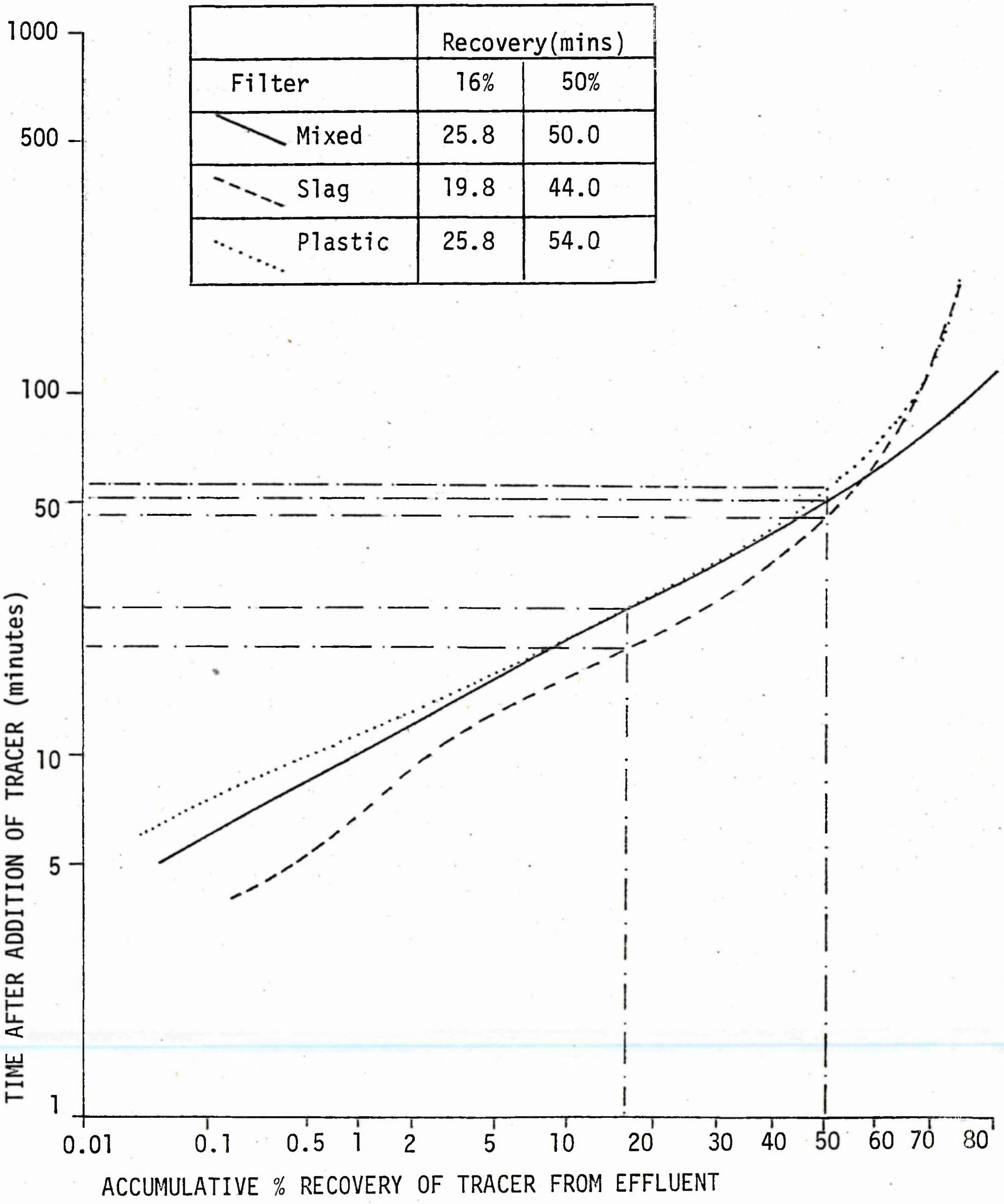
	Recovery(mins)	
Filter	16%	50%
— Mixed	27.0	66.0
- - Slag	19.3	58.0
··· Plastic	32.7	80.0

Figure 6.22: Retention test on high rate filters, 27 March 1979



	Recovery(mins)	
Filter	16%	50%
—— Mixed	23.0	69.0
– – Slag	15.8	44.0
····· Plastic	27.0	74.0

Figure 6.23: Retention test on high rate filters, 26th August 1979



Filter	Recovery(mins)	
	16%	50%
——— Mixed	25.8	50.0
- - - Slag	19.8	44.0
······ Plastic	25.8	54.0

Table 6.31: Summary of the retention times measured in the pilot filters, with the removal rates (in parenthesis) and film accumulation.

Flow Rate and Date	SLAG FILTER				MIXED FILTER				PLASTIC FILTER			
	Recovery of tracer		Ratio	Film	Recovery of tracer		Ratio	Film	Recovery of tracer		Ratio	Film
	16%	50%	t_{16}/t_{50}	kgm^{-3}	16%	50%	t_{16}/t_{50}	kgm^{-3}	16%	50%	t_{16}/t_{50}	kgm^{-3}
1.68 $m^3m^{-3}d^{-1}$												
5/78	41.0 (2.56)	130.0 (2.62)	0.31	8.32	34.5 (2.16)	95.0 (1.78)	0.36	3.22	26.0 (1.63)	75.0 (1.44)	0.35	2.33
9/78	21.5 (1.34)	90.0 (2.02)	0.24	4.03	23.3 (1.46)	78.0 (1.61)	0.32	2.72	25.3 (1.58)	76.0 (1.49)	0.32	4.71
3.37 $m^3m^{-3}d^{-1}$												
12/78	19.3 (1.21)	58.0 (1.14)	0.33	3.11	27.1 (1.69)	66.0 (1.15)	0.41	6.85	32.7 (2.04)	80.0 (1.39)	0.41	9.65
3/79	15.8 (0.99)	44.0 (0.83)	0.36	11.33	23.0 (1.44)	69.0 (1.35)	0.33	9.65	27.0 (1.69)	74.0 (1.38)	0.37	13.33
8/79	19.8 (1.24)	44.0 (0.71)	0.45	3.71	25.8 (1.61)	50.0 (0.71)	0.52	5.51	25.8 (1.61)	54.0 (0.83)	0.48	9.85

N.B. The retention times are expressed in minutes for 16 and 50% recovery of tracer. The rate of recovery (in parenthesis) is expressed as the time in minutes for 1% recovery of tracer over 0-16% and 16-50% ranges.

hence the MRT remains constant (Table 6.31). When the loading was increased, the MRT was reduced in both the slag and mixed filters, with the best MRT being achieved by the plastic filter due to better redistribution and utilisation of the greater surface area, a phenomenon also recorded in other experimental filters by Porter and Smith (1979).

At the lower loading an increase in film accumulation resulted in an increase in the MRT. This remained true at the higher loading up to an optimum film concentration, above which the interstices of the medium became blocked, channelling occurred and the influent sewage short-cut certain regions of the filter, thus reducing the MRT.

In similar pilot filter experiments, Wheatley (1976) using the same plastic medium, found greater median retention times at a hydraulic loading of 2.4 $m^3m^{-3}d^{-1}$ compared with those at a loading of 1.2 $m^3m^{-3}d^{-1}$. The retention time data were not directly related to performance, and he concluded that the increase in retention time was due to greater film accumulations at the higher loading rate. The median retention times recorded from the present investigation are much higher than those obtained by Wheatley. This is because of the greater dispersion of flow over the surface of the filter, effected by using the nozzle distributors, and therefore better distribution within the filter. Eden _et_ _al_. (1964) demonstrated that improved distribution of sewage and hence wetting of the medium improved filter efficiency. Bruce _et_ _al_. (1975) showed that the median retention time varied inversely with both the size of the medium and the hydraulic loading. The results obtained were shown to be due to the physical characteristics of the medium and to the film accumulation which was responsible for increasing the contact time of the sewage. Cook and Katzberger (1977) also observed that the film and humus had a pronounced effect on retention time. They found that large variations in retention time had little effect on organic removal efficiency in their low rate filters, but that small variations in retention time at higher rates of treatment had large effects on the removal efficiency. The results in the present investigation supports the conclusions of Cook and Katzberger (1977) that retention time has a greater effect on the removal efficiency of high rate filters than on that of low rate filters, and that retention time is not directly related to removal efficiency.

6.5.1 ESTIMATION OF FLOW PATTERN

The flow pattern of sewage within filters is tentatively predicted by using the ratio of the 16 percentile to the 50 percentile (t_{16}/t_{50}) of the retention time data, and also by comparing the initial rate of discharge of tracer (0 - 16%) to the median rate of discharge (16 - 50%) it was possible to assess the flow pattern within the filter.

When channels are present in filters owing to excessive film, then some of the tracer will pass through the filter extremely quickly, causing the rate of discharge to decrease after a short period, producing a ratio (t_{16}/t_{50}) of less than 0.32. Under thin film conditions and during periods of normal film accumulation, this ratio will gradually increase as the MRT and film accumulation increases. It is during this period that MRT is directly associated with the performance. When the ratio becomes excessively large, i.e. in the present investigation in excess of 0.48, this indicates that the influent is being retained in reservoirs formed by excessive film conditions. Although the MRT is longer it is not associated with increased performance. Because the influent is stored in the reservoirs only a very small amount of the liquid is in intimate contact with the film, thus nutrient transfer does not take place so efficiently. An increase in film accumulation either leads to the production of channels or if the excess film is not sloughed or removed by the grazing fauna, the filter becomes completely blocked. These processes are summarised in Figure 6.24.

Eden et al. (1964) observed that the MRT measured in small laboratory filters increased, as the film increased, up to certain heavy accumulation, before the MRT fell sharply back to a lower value (Figure 6.25). The peaks were usually associated with a reduction in the rate of accumulation of film and even with an actual loss in film weight. These results correspond to the phenomenon observed in the pilot filters and support the theory that above a certain weight of film there is a major redistribution of flow occurring within the filter. Work on the periodicity of dosing has shown previously that the retention time could be increased by large intermittent doses of influent (Shephard, 1967) due to storage of liquid in horizontal chambers within the filters. These reservoirs are found in filters at times of high accumulations of film, where the tracer enters quickly but is slowly

Figure 6.24: Summary of observed flow characteristics in relation to the ratio of the 16 percentile to the 50 percentile (t_{16}/t_{50}) of the retention time in the pilot filters.

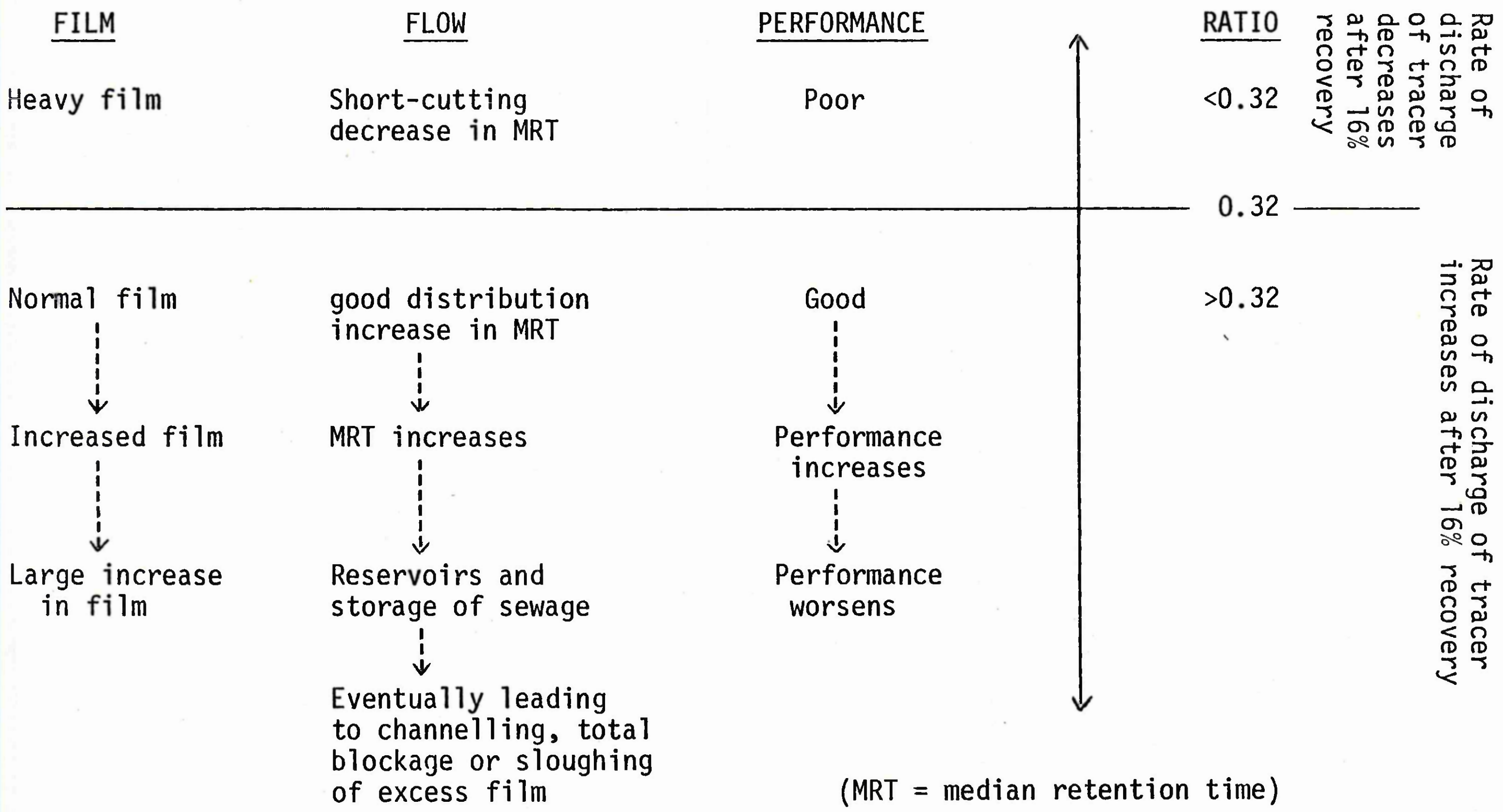
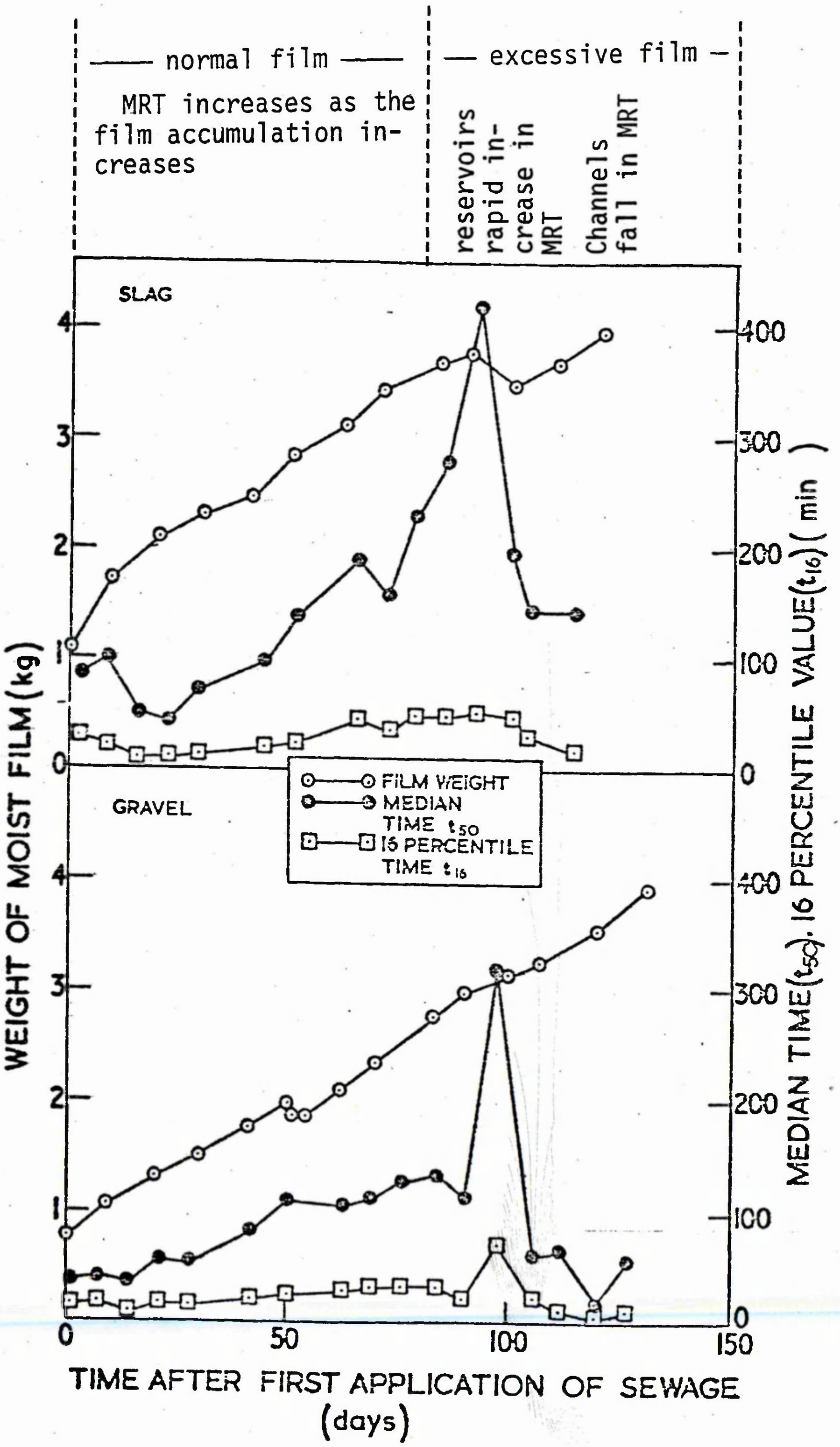


Figure 6.25: Relation between weight of film and retention characteristics of two small percolating filters.



(From: Eden, Brendish and Harvey, 1964).

discharged as more influent sewage replaces and dilutes it. This explains why the large increase in MRT recorded before the rapid decline in MRT is not directly associated with performance, as the sewage in the reservoirs is not in intimate contact with the film.

7.1 INTRODUCTION

The principal of the investigation was to determine if it was possible to increase the work done by a conventional mineral percolating filter by replacing the top 750mm with a random plastic filter medium, and to assess the changes, if any, in the ecology of the system.

Random plastic filter medium has a high surface area and is able to support more film than a conventional mineral medium of the same grade, and so increase the rate of adsorption of suspended material from the influent sewage. With larger interstices and a greater voidage than the slag, there is less chance of the plastic medium ponding during periods of heavy film accumulation and high loadings. The slag medium has a much lower voidage, and although there is an inverse relationship between the grade of medium and the surface area, the size of the interstices is directly related to medium grade. Therefore there is a greater possibility, when using medium of less than 50mm nominal grade, that the accumulated film will link across the interstices causing ponding, channelling and eventually the complete blockage of the filter. The neutron probe results indicated that there was always a risk of ponding in the slag filter during periods of maximum film accumulation in the months preceding sloughing. Recent workers have suggested that performance is linked directly with surface area, thus the plastic filter should have theoretically achieved a correspondingly better performance than either the mixed or slag filters at all the loadings studied (Hoyland and Harwood, 1979; Hemmings and Wheatley, 1979).

Most organic matter removal occurs in the top half of a percolating filter, ensuring that the lower portion rarely becomes blocked because of film accumulation. As mineral medium has a relatively high median retention time at the more conventional loadings, and is more able to remove the resistant portions of the organic matter than the plastic medium, it was proposed to use two types of medium in series. By replacing the surface layer of mineral medium with the random plastic medium, it was hoped to remove the maximum weight of organic matter and reduce the risk of ponding in the plastic section, while 'polishing' the sewage in the mineral section of the filter, thus producing a better quality final effluent than could be achieved by using a single medium filter at increased loading rates.

7.2 ECOLOGY

A wide variety of species was recorded from the pilot filters, some 69 species in all, including two unidentified species. Species richness was not significantly different in the pilot filters, although the mixed filter had 19.0 and 7.5% more species than the slag filter at the lower and higher loadings respectively. Species richness was possibly lower in the pilot filters because there was not the variety of niches available and the filter environment was more susceptible to environmental changes compared with full scale units. The extra sampling baskets showed that the horizontal distribution of both the film and fauna was even (with no significant differences between baskets at the 10% significance level ($P < 0.01$) being recorded), and that the results obtained from the sampling baskets were representative of the rest of the filter, at least in the top 300 mm.

The basic trophic level in the filters was represented by the autotrophic bacteria. Zoogloeal bacteria were recorded in similar abundances in all three pilot filters, although more of the filamentous bacteria Sphaerotilus natans was recorded in the mixed and plastic filters owing to the greater surface area. As seen in previous studies the nitrifying bacteria were restricted to the lower portion of the filters. In the slag and plastic filters, nitrification was poor and the nitrifying bacteria temporarily restricted in abundance and often eliminated at the higher loading rate of 3.37 $m^3m^{-3}d^{-1}$. Throughout the higher loading the mixed filter achieved a significantly greater degree of nitrification than either the other filters.

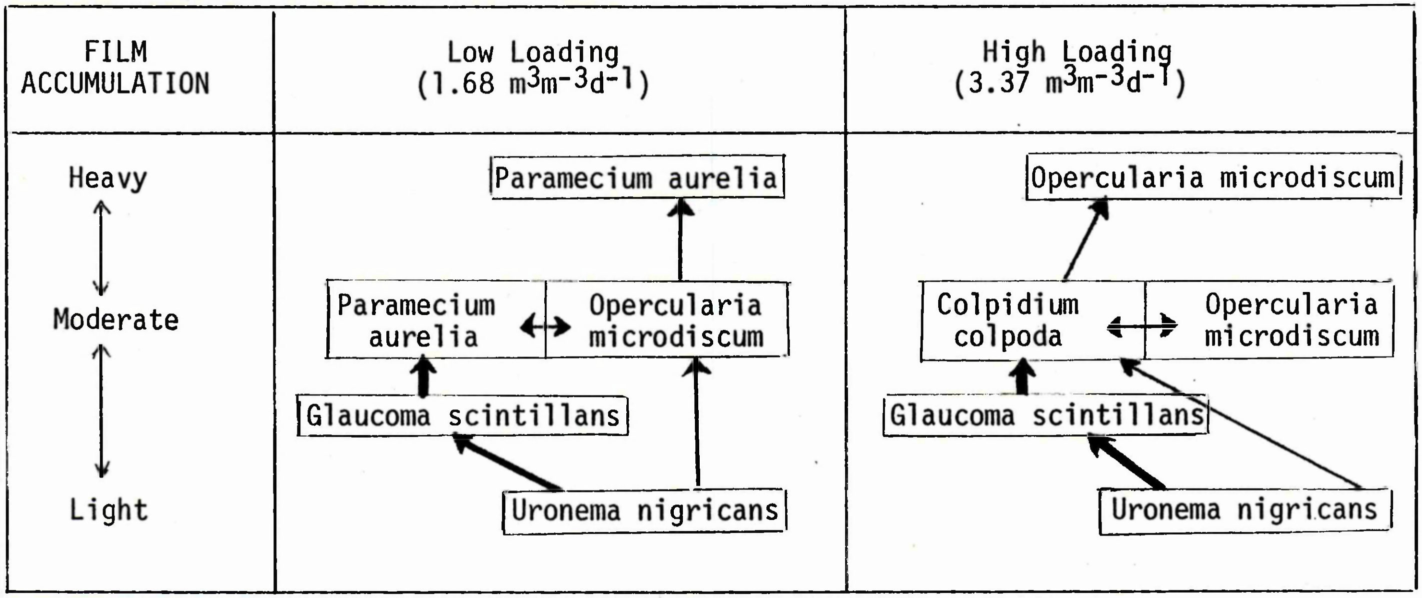
The success of the fungi Subbaromyces splendens in the pilot filters was due to the continuous dosing system used. It was more abundant in the mixed and plastic filters, clearly most successful in the plastic medium, being recorded in thick growths on the surface and throughout the depth of the filters. The algae were recorded in all the filters although they did not play an important role in the purification process.

The greatest species diversity of any faunal group observed in the filters was recorded for the Protozoa. Although the flagellates were numerically dominant over the ciliates, it was the latter which best reflected the environmental changes in the filters, for example increasing in abundance with the increase in loading. The mixed filter had the greatest species diversity of ciliate Protozoa which is advantageous in allowing the protozoan community to change rapidly in response to changes in the character of the influent settled sewage. It was observed however that whenever one species disappeared from a filter another usually took its place, usually occupying the same niche.

Five dominant protozoan species were recorded, one peritrich, *Opercularia microdiscum*, and the rest holotrichs. All these species were controlled either by the film accumulation or the temperature, and so the succession of species could be identified at both low and high rate loadings (Figure 7.1). The protozoan community structure recorded in the mixed filter was more stable and the population densities less variable than in the other filters. The mixed filter also retained individual ciliate species for longer periods than either the slag or plastic filters.

The Rotifera were found mainly in the lower sections of the slag and mixed filters. They were scarce in the plastic medium being more abundant in the slag. Perhaps the most important micrograzers were the Nematoda, which reached maximum population densities the same time as the enchytraeids. The nematodes were susceptible to being washed out of the filters, resulting in comparatively high abundances in the

Figure 7.1: Succession of dominant protozoan species with film accumulation at main loadings of 1.68 and 3.37 $m^3m^{-3}d^{-1}$.



slag filter and the slag portion of the mixed filter, due to the smaller voids and rough texture of the medium which reduced the rate of loss in this way.

The Enchytraeidae were found in maximum abundance in the slag portion of the mixed filter at the high loading rate. The greater abundance of adults in the slag medium corresponded to the greater retention of cocoons recorded in the slag and mixed filters. The enchytraeids and nematodes responded quickly to increases in film accumulation, because of the shorter life cycle of the nematodes and the large number of enchytraeid cocoons present in the film. The psychodid larvae always reached maximum abundance a month or two later. Although the Enchytraeidae and psychodid larvae were the most important grazers in terms of overall control of the film, the astigmatid mites were the most abundant grazers numerically.

Maximum population densities of psychodid larvae were recorded in the mixed and plastic filters at the higher loading owing to the greater accumulation of film. The abundance of _Psychoda_ spp. was also directly related to organic load and temperature. The lag phase between maximum film, i.e. maximum food availability, and maximum abundance was longer for _Psychoda_ than for the Enchytraeidae or the astigmatid mites.

The chironomids were an important group but were dominated in the pilot filters by the other grazers, and so took a secondary role in controlling film accumulation. The astigmatid mites were most abundant at the lower loading where they were important grazers, although they played a secondary role to the Enchytraeidae and the psychodid larvae at the higher loading rate. The mites, and Paracyclops sp., were not abundant in the mixed filter. The Acari, Collembola, spiders and all the adult dipterans, preferred the drier areas found in each module of the plastic medium.

The different characteristics of the media in the mixed filter does provide a wider variety of habitats for the flora and fauna, resulting in an increase in total species richness compared with the single medium filters. The slag portion of the mixed filter prevents rapid changes in population numbers and community structure, and reduces the total number of organisms washed out in the final effluent compared with the plastic filter. Seasonally occurring species remained for longer periods in the mixed filter than in either the slag or plastic filters, emphasising the way in which the two layers of medium provide a greater variety of habitats.

7.3 PERFORMANCE

At the lower loading of 1.68 $m^3m^{-3}d^{-1}$, all the pilot filters performed similarly although the slag filter produced a significantly better nitrified final effluent. With the increase in loading to 3.37 $m^3m^{-3}d^{-1}$ the performance of the slag filter deteriorated more rapidly than that of the mixed or plastic filters. The performance of the mixed filter was significantly better than that of the slag filter at this loading, in terms of BOD ($P < 0.01$), suspended solids ($P < 0.01$)

and ammonia removal ($P < 0.01$); also it was significantly more efficient than the plastic filter in removing ammonia ($P < 0.01$). At this loading the mixed filter produced a better quality final effluent than the slag filter for eleven out of thirteen months. The shorter experimental period at the very high loading of 5.72 $m^3m^{-3}d^{-1}$ indicated that the mixed filter was also well able to cope with the large increase in organic load, performing significantly better than either the plastic or slag filters.

Regression lines, using the data from the two main loadings and also all the data from the twenty-seven months of operation (Figure 6.9), showed that the mean predicted performance of the slag filter was better than the mixed filter at organic loadings of less than 0.2 kg BOD $m^{-3}d^{-1}$, and better than the plastic filter at loadings of less than 0.35 kg BOD $m^{-3}d^{-1}$. Above these respective loadings, the mixed and plastic filters produced increasingly better final effluents with increasing organic load than did the slag filter. From the regression plots the mixed filter produced a consistently better final BOD effluent than the plastic filter at all loadings.· The two regression lines had similar slopes which slightly converged with increased load. The similarity of these lines may well have been due to the surface layer of plastic medium where most organic matter is removed.

Linear regression between organic load and percentage removal of ammonia showed that the slag filter achieved better ammonia removals than the mixed filter at loadings below 0.4 kg BOD $m^{-3}d^{-1}$, while the mixed filter was far more efficient in the removal of ammonia at loadings in excess of this value.

The results indicated that there was not a direct relationship between the total surface area of the pilot filters and the performance at the loads tested. Clearly the utilisation of the plastic medium depended on the distribution and wetting of the medium within the filter, which was controlled by the hydraulic loadings and the distribution system used. It was shown that most organic matter was removed in the top 300 mm, and that up to 75% removal occurred in the top 900 mm. Therefore the removal efficiency was better related to the surface area of the top 900 mm of the filters than to the surface area of the whole filter.

Removal efficiency of BOD and suspended solids corresponded with the growth rate of the film. Seasonal variation in performance was inversely related to the seasonal pattern of film accumulation with maximum solids removal occurring when the film was thin and growing rapidly and the adsorption rate declining as the film reached maximum thickness prior to unloading, resulting in a reduction of final effluent quality. Temperature controlled the rate of film accumulation although the rate of adsorption was unaffected by temperature. The rate of accumulation depended directly on the rate of oxidation of the adsorbed material which was controlled by the temperature of the film, therefore when cold the film increased as the same amount of organic matter was adsorbed but less was absorbed.

The greater success of the mixed filter over both the slag and plastic filters can be attributed to its two different layers of medium. Both the mixed and plastic filters achieved higher removal efficiencies than the slag filter at the higher loadings because the top layer of plastic medium was able to remove the bulk of the organic matter present. This was due to the higher surface area of the medium and better redistribution of sewage within the filter with increased load. This produced greater film accumulation which was able to adsorb more of the suspended matter from the influent sewage. In the slag medium at these loadings, heavy film accumulation in the top 300mm led to surface ponding and subsequent channelling, resulting in a decrease in the median retention time and a final effluent containing a greater proportion of partially treated influent sewage.

The success of the fungus Subbaromyces splendens in the plastic medium of the mixed and plastic filters, although it was most abundant during low film conditions, accounted for the rapid recovery of the film and the rapid increase in adsorption rate after sloughing compared to the slag filter. The fungus was able to adsorb and physically trap solids, thus building up the film far more efficiently immediately after sloughing than the very low density of bacteria present.

Although some problems were encountered with excessive growths of Subbaromyces splendens, the high voidage of the plastic medium ensured that the risk of ponding was reduced and that no channelling occurred in either the mixed or plastic filters, ensuring that the maximum median retention times were obtained throughout the year.

The plastic medium caused better redistribution within the filter and this ensured better utilisation of the slag portion. It was probably due to the increased redistribution and also the reduced organic load of the sewage, that no film accumulation or ponding was observed at the interface with the slag medium. It is unlikely that the plastic layer of medium would remove enough organic matter to allow the rest of the filter, the slag portion, to act as a normal single-pass mineral filter at such increased organic loadings. The slag portion of the mixed filter was however achieving a greater removal of the more resistant BOD fraction, better solids removal and finally more efficient nitrification on an influent with most of the organic matter removed prior to this depth, compared with the same depth in the single medium filters.

At the lower loading, the slag filter had sufficient surface area to ensure that a good effluent was produced, even though the high film accumulation recorded within the filter showed that it was obviously working close to maximum capacity. Its success was primarily due to an ability to buffer the active film against sudden temperature changes. As the slag filter contained a greater proportion of solid material which adsorbed and retained heat, the filter was able to carry out biological oxidation at a faster rate than the other two filters. The central core of the filters also produced a constant amount of heat from biological oxidation, which was more efficiently retained within the slag filter.

The accumulation of film in both the mixed and plastic filters increased with the increase in loading but the slag filter retained the same weight of film, suggesting that no further voidage was available for film accumulation, therefore the rate of removal of organic matter was least efficient in the slag filter at the higher loading.

Higher rates of filtration are known to affect a number of processes, notably there is a change in sludge characteristics, a depression of nitrification and a more even BOD removal down the depth of the filter. These characteristics were all observed in the slag and plastic filters but were less obvious in the mixed filter. The slag portion of the mixed filter was able to retain some heat and so reduce the wide temperature variations recorded in the plastic filter. With less ventilation than the plastic filter, the slag portion buffered the temperature sufficiently well to reduce the film accumulation by greater biological oxidation at the warmer temperature. The slag portion also increased the median retention time, and with more carbonaceous matter removed in the upper plastic section, the concentration of organic matter was greatly reduced in the lower slag portion preventing inhibition of nitrification by hetertrophic competition as seen in the slag filter. The smaller fluctuation in film temperature also increased nitrification, as it has been shown that nitrification is inhibited by fluctuating and low temperatures.

There was more use made of the lower slag portion in the mixed filter than in the equivalent depth of the slag filter owing to better distribution of sewage within the filter, less channelling and less accumulation of humus and debris.

The mixed medium behaved as a high rate filter capable of some nitrification, producing a more stable and easily settled sludge compared with the slag filter. It offered advantages of increased capacity over the conventional filter, and the possibilities of increased performance in the ADF or recirculation processes, and a better final effluent quality over high rate plastic filters using random medium in treating loads in excess of 1.0 kg BOD $m^{-3}d^{-1}$.

The plastic filter failed to achieve the same rates of removal as the mixed filter, and although the top 900 mm of the plastic filter was achieving a good removal efficiency, the lower half did not enhance the overall quality of the effluent, and so offered no real advantages over the modular plastic medium. Surprisingly, the plastic filter was observed to be the least effective in treating sudden increases in organic loading, and the high voidage did not facilitate sloughing to any greater extent; unloading of the film took just as long in the plastic filter as in either of the others. The confidence limits for all the main performance parameters were wider in the plastic filter, suggesting that it was more susceptible to environmental variables such as ambient temperature. In fact, due to the higher constructional costs involved in using random plastic medium as compared with the modular medium, it appeared to have little advantage when used primarily as a roughing filter.

7.4 COST

The possible advantages of percolating filters over the activated sludge and other treatment processes have been the subject of much discussion especially in terms of cost. Most studies have clearly indicated that the activated sludge process is by far the most cost effective way of treating a domestic sewage from populations in excess of 100,000 (Bruce, 1969).

Treatment works using percolating filters are extremely common and are still being constructed. In a comparative study by Hambleton and Kirby (1974) it was found that a considerable saving was achieved if a high rate plastic filter was used in conjunction with low rate filtration instead of just low rate filters, but that it was still considerably more expensive than activated sludge. Up to quite recently the advantages of filtration, such as savings in energy, were offset by the cost of the area of ground required and the excessive construction costs (Clough, 1975). In a re-evaluation of the cost of sewage treatment, Clough (1979) states that the era of cheap energy has almost certainly passed and that current design and selection of plant should take into account the probable energy costs during the life of the plant, which are virtually certain to increase. He felt that this, coupled with the present reduction in anticipated real rate of return on capital, is likely to lead to a swing away from activated sludge towards low rate filtration where space was available, and towards the wider use of high rate plastic media filtration followed by low rate filtration using conventional mineral media.

It was originally thought that prefabricated units of similar design to those used to hold the modular type of plastic medium would also be of sufficient strength to house the random plastic medium. The potentially high bulk weights of the random plastic pilot filter recorded during the present investigation indicate that such structures may not be suitable. Recent research by Campbell (1979) has shown that the most economical system for containing such medium as Flocor RC are of sufficient strength to 'house' mineral media. Therefore percolating filters of identical dimensions will show no cost advantage for the civil engineering and construction work for filters using random plastic medium, and therefore savings must be related primarily to improvements in performance achieved per unit volume of medium installed.

The comparative cost of media indicates how expensive plastic medium has become due to increases in oil prices (Table 7.1). The price of an alternative plastic medium of similar dimensions, with a surface area of 124 m^2m^{-3}, Biopac 50E*, is included in Table 7.1 for comparison.

Because the pilot filters were run at much higher loadings than conventional plants, and produced good final effluents, it was not possible to estimate any advantage from the data directly. The conventional loading for a low rate filter producing a 20:30 standard effluent, highly nitrified, is in the order of 0.09 to 0.11 kg BOD $m^{-3}d^{-1}$ (Institution of Public Health Engineers, 1978). The range of loadings in the present

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*Manufactured by Hydronyl Ltd., Fenton, Stoke-on-Trent, Staffordshire, England.

Table 7.1: Comparative cost for 50mm filter medium. Price is given for the graded medium delived to the site and placed in the filter.

Medium	Cost(£m^3)
Blast furnace slag	20.00
Flocor RC	46.50
Biopac 50E	57.00

investigation were from 0.28 to 0.85 kg BOD $m^{-3}d^{-1}$.

From the regression analysis it was possible to predict the maximum organic load for each filter to achieve a 20 mgl^{-1} BOD final effluent. The mixed filter showed a 20% increase in efficiency over the slag filter in producing a final effluent of this quality. Therefore, using the figure of 20%, a cost benefit analysis of the new system was carried out. It was also assumed that the thickness of the replacement layer was 750mm as used in the pilot filter, although the removal efficiency of the plastic medium showed that removal decreased with depth and that the majority of removal occurred in the top 300mm. Therefore optimum thickness of the replacement medium would most likely be between these two depths.

Two systems for increasing the loading capacity (uprating) of the filters have been examined: i) by digging out the top layer of mineral medium from the filter and replacing it with the new medium, or ii) by raising the height of the distributor arm and inserting a collar, where there is sufficient hydraulic head, and stacking the plastic medium on top of the mineral medium either by constructing a simple prefabricated wall or by having the medium in nylon sacks or galvanised baskets or containers. The advantage of the latter method is that the overall capacity of the filter is extended even further and these filters should theoretically produce even better final effluents with a greater degree of nitrification.

The cost of uprating a large works using single filtration is probably totally prohibitive (Table 7.2), the cost of extending the works by the construction of new filters being three times cheaper. In normal circumstances the design of a sewage works allows for a certain amount of expansion, but if this required the costly acquisition of extra land or if the works was unable to expand by further building then the extra cost of uprating may be justified. As the main cost of uprating is due to the cost of plastic medium, research must be carried out to ascertain precise depths of medium to be replaced. If this optimum depth was 300mm for example, then the total cost of uprating the filters in Table 7.2 would be reduced by 51% to £111,720 which would make the possibility of uprating conventional filters a viable proposition.

Clearly the best advantage of uprating single-pass conventional filters is a) as a temporary measure, when there is a large transient population requiring extra treatment capacity at the local sewage works; b) in an emergency, when there is a failure in other filters or in a pretreatment system where extra capacity is required, or when an increase in performance is required during periods of environmental stress in the

TABLE 7.2: Comparative cost of increasing filter capacity of sewage treatment works by 2000 m^3 by
a) constructing new filters and
b) uprating existing filters.

a) Total cost of new filter (assuming no land cost-expansion allowed for in the original design)

Civils cost*	£34,997
Distribution system*	4,266
Media delivery and placement of 50mm blast furnace slag	40,000
TOTAL	£79,263

b) Total cost of uprating existing filters (cost of uprating 5 x 2000 m^3 filters which is equivalent to a total increase of 2000m^3 capacity)

Media removal	£33,600
Flocor R.C. media	195,300
TOTAL	£228,900

Each 1.8m deep filter had the top 750mm of mineral medium replaced with Flocor RC medium to give an equivalent increase in capacity of 2000m^3.

* calculated from tables in Water Research Centre (1977c).

receiving water body due to such factors as pollution or low flow; or c) in a small treatment works where the population is small and the construction of a small housing estate or a hotel could result in the overloading of the small treatment works (Table 7.3). In examples a) and b), the only way the capacity of the filters could be increased would be by either improved operational methods or by uprating by the surface bag technique, where the prepacked bags could be fitted in place and the distributor arm raised within hours (Tench, 1979). In example c) the construction of a new or an extension to an existing sewage works would probably not be justified, whereas the cost of uprating the filters would be acceptable (Table 7.4).

The system of uprating filters could be advantageous at higher rates of loading and benefits would be obtained when used with the ADF and recirculation processes. If a conventional single filtration plant was being improved to run on an ADF system, then the filters could possibly be uprated without having to replace all the mineral medium with a coarser grade. The advantages of the mixed medium at the organic loadings associated with ADF is that it can achieve far greater purification and nitrification than the normal mineral medium or plastic medium. At loadings in excess of 1.2 kg BOD $m^{-3}d^{-1}$ the filters are used as roughing filters, and the mixed media will be less effective than the plastic medium in treating such heavy organic loads.

Therefore mixed media has a role to play at those loadings in between low rate and truly high rate, and could well offer

Table 7.3: Theoretical increase in volume of filter, total organic load and increase in population served using uprated filters.

Standard rate percolating filters				Uprated percolating filters			
Volume of filter (m^3)	Total load kg BOD $m^{-3}d^{-1}$	Population served (P.H.E.)*	Population served (CP302)**	Theoretical volume of filter (m^3)	New load kg BOD $m^{-3}d^{-1}$	Extra people served by new filter (P.H.E.)*	Extra people served by new filter (CP302)**
100	10	167	193	120	12	33	38
200	20	333	455	240	24	66	91
300	30	500	755	360	36	100	151
400	40	667		480	48	133	
500	50	833		600	60	166	
600	60	1000		720	72	200	
700	70	1167		840	84	233	
800	80	1333		960	96	266	
900	90	1500		1080	108	300	
1000	100	1667		1200	120	333	

* P.H.E. Population estimated from the Institution of Public Health Engineers, 1978.

** CP302 Estimated from British Standards Institution, 1972 and Nicoll, 1974.

Table 7.4: Total cost of uprating small percolating filters by twenty percent.

Total volume of filter (m^3)	Total cost of replacement medium (£)	Cost of replacing medium (£)		Total cost of uprating filter (£)*	
		By medium replacement	By raising distributor**	By medium replacement	By raising distributor
100	1860	320	310	2180	2170
200	3720	640	520	4360	4240
300	5580	960	730	6540	6310
400	7440	1280	940	8720	8380
500	9300	1600	1150	10900	10450
600	11160	1920	1360	13080	12520
700	13020	2240	1570	15260	14590
800	14880	2560	1780	17440	16660
900	16740	2880	1990	19620	18730
1000	18600	3200	2200	21800	20800

* Price does not include cost of splash plates which are recommended.

**Price for the raising of the distributor and inclusion of new collar is calculated on a sliding scale from £100 to £200. The price for enclosing medium in either galvanised metal or nylon containers is estimated at £5 per m^3.

advantages in uprating small filters and as a temporary and emergency system for increasing the capacity of conventional plants. Surface replacement not only extends capacity but also prevents surface ponding, increases the distribution of sewage within the filter and increases the ventilation to the surface of the filter where maximum oxidation occurs.

7.5 CONCLUSION

Much research has been recently undertaken to improve the performance of percolating filters by better design (Oleszkiewicz, 1976; Sidwick, 1978), flow and load control (Young et al., 1978), better process control and automation (Water Research Centre, 1977d) and also by the addition of buffers to the influent (Neely, 1975; Shriver and Bowers, 1975; Barber, 1977). Even after eighty years of research into improving the system, it has largely remained unaltered (Thompson and Maguet, 1976; Sidwick, 1976).

The problem of uprating existing works has received less attention, and at present increasing capacity is limited to either the addition of roughing filters, modification of the process using ADF or recirculation or the construction of additional filters. Mann (1979) reported that the capacity of small percolating filters can be improved to a limited extent by adding extra layers of medium to the surface, thus increasing the overall depth of the filter. This is only possible if the existing medium is of suitable size and good quality and where hydraulic conditions permit. The depth of small filters can be profitably increased to about 2.5m by this method.

Experiments were carried out by the Anglian Water Authority to assess the effectiveness of uprating percolating filters by replacing the surface mineral medium with random plastic medium. A pilot filter at Burntwood and a full scale trial at Ruskington tested the mixed media. At Burntwood the filter was loaded at various loadings between 0.33 - 0.86 kg BOD m^{-3} d^{-1} while at Ruskington the filter was loaded at between 0.11 and 0.39 kg BOD $m^{-3}d^{-1}$. The plastic medium used in these experiments had a surface area 62% less than that recorded for Flocor RC. So the plastic layer offered no surface area advantage over the mineral medium used and was also less effective in redistributing the sewage within the filter, thus making maximum use of all the available medium. Both filters were loaded for very short periods varying from 2 to 10 weeks with one period in the pilot filter of 30 weeks duration at 0.75 kg BOD $m^{-3}d^{-1}$. The results in both cases show that at relatively low loadings, compared with the claimed loading for the plastic medium, there was no advantage to be gained in replacing the conventional medium (Pullen, 1977).

The results obtained in the present study do not support the results and conclusions obtained by Pullen, who was expecting a five-fold increase in performance. Although no information or data are available, it is clear that the poor results obtained at Ruskington and Burntwood were partly due to the simple 'flow on' distribution system employed which failed to take full advantage of the surface layer of plastic medium, as occurs when either nozzles or splash plates are used, and this resulted in a low retention time within the filters studied.

The advantages of continuous dosing using nozzles observed during the present investigation were: i) controlled fly emergence, ii) utilisation of all the surface layer of the filter, iii) maximum utilisation of available film, iv) maximum distribution, which reduced the risk of ponding and channelling, v) prevention of surface drying of medium in summer, and vi) reduction of heat loss from the filter in the winter. These observations indicate the need for more research into operational methods to optimise the performance of percolating filters.

8.1 ECOLOGY

a) The different characteristics of the media in the mixed filter provided a wider variety of niches for the flora and fauna, resulting in an increase in total species richness compared with the single medium filters. The variety of such niches were however limited by the small nature of the pilot filters which was more susceptible to environmental changes than the full scale units.

b) Seasonally occurring species remained for longer periods in the mixed filter than in either the slag or plastic filters emphasising the way in which the two layers of medium provided a greater variety of habitats.

c) The slag portion of the mixed filter prevented rapid changes in population densities and community structure, and also reduced the total number of organisms washed out in the final effluent compared with the plastic filter.

d) The greater surface area of the plastic medium resulted in larger population densities of many organisms being recorded, compared with the slag filter, especially during the higher loading (3.37 $m^3m^{-3}d^{-1}$) when maximum utilisation of the medium occurred. The greater voidage also ensured sufficient ventilation to support the increased population densities in the plastic medium. The anaerobic conditions in the slag filter during times of maximum film accumulation reduced the population densities of all the macroinvertebrates studied.

e) Heavy surface growths of the fungus Subbaromyces splendens occurred in the pilot filters due to the continuous dosing system used. The fungus grew more successfully on the plastic medium than on the slag medium.

f) Greater species diversity was recorded in the Protozoa, than in any other faunal group examined. The mixed filter had the largest diversity of protozoan species. It was observed that whenever one species disappeared from a filter another usually took its place, usually occupying the same niche.

g) The protozoan community structure was more stable in the mixed filter, with less variable population densities. The seasonally occurring species were recorded for longer periods in the mixed filter compared with either the other pilot filters.

h) The abundance of Psychoda spp. as larvae was directly related to organic loading and temperature. The psychodid larvae remained the dominant macrograzer in the filters for longer than either the Enchytraeidae or the astigmatid mites, the other main macrograzers.

i) The Enchytraeidae and psychodid larvae were never recorded together in large numbers, as the enchytraeids normally reached their maximum abundance before the larvae. As the psychodid larvae reached maximum abundance the population density of the enchytraeids declined rapidly. Although the larvae were the most important macrograzer in terms of film control, the Acari were the most abundant macrograzers numerically.

j) The Rotifera, Nematoda and the Enchytraeidae were most susceptible to being washed out of the filters, especially from the smooth surfaced plastic medium filter. The Acari, Collembola, Aranae, adult dipterans and the pupae of *Sylvicola fenestralis* were all found in greatest abundance in the drier areas of the plastic medium.

8.2 PERFORMANCE

a) At the lower loading (1.68 $m^3m^{-3}d^{-1}$) all the pilot filters performed similarly in terms of BOD and suspended solids removal, although the slag filter produced a significantly better nitrified final effluent than either the mixed or plastic filter.

b) The mixed filter performed significantly ($P < 0.01$) better than the slag filter at the higher loading (3.37 $m^3m^{-3}d^{-1}$) in terms of BOD, suspended solids and ammonia removal; producing a better final effluent than the slag filter during 11 out of 13 months sampled. The mixed filter also achieved significantly better ($P < 0.01$) ammonia removal than the plastic filter at this higher loading.

c) During the three months maturation period, when the filters were loaded at 5.72 $m^3m^{-3}d^{-1}$, the mixed media filter achieved a significantly better final effluent than either of the single medium filters.

d) At the higher loading (3.37 $m^3m^{-3}d^{-1}$) nitrification was poor and the nitrifying bacteria temporarily restricted in abundance and often eliminated in the plastic and slag filters. Throughout this loading the mixed filter achieved significantly better nitrification of the final effluent than either the other pilot filters.

e) Regression analysis showed the mixed media filter produced final effluents with lower BOD concentrations than the slag filter at loadings in excess of 0.2 kg BOD $m^{-3}d^{-1}$. Also the mixed filter achieved greater nitrification than the slag filter at organic loads in excess of 0.4 kg BOD $m^{-3}d^{-1}$.

f) Removal efficiencies of BOD and suspended solids correspond with the growth rate of film (i.e. the rate of adsorption).

g) The better removal of organic matter in the top layer of the mixed and plastic filters compared with the slag filter, was due to the plastic medium. The higher surface area, better ventilation and better redistribution of the sewage ensured maximum removal of organic matter, prevented ponding and channeling and a reduction in contact time between the film and sewage.

h) The rapid recovery of the film accumulation and resultant increase in the adsorption rate of organic matter recorded in the plastic medium after sloughing, was due to the extensive growth of the fungus Subbaromyces splendens. The fungus has the ability to adsorb and physically trap solids, thus building up the film far more efficiently than a 'bacteria-rich' film.

i) No build up of film or solids was recorded at the interface of the two medium layers in the mixed filter, due to the redistribution of sewage within the filter achieved by the plastic medium.

j) At the lower loading excessive film accumulation was recorded at various depths throughout the slag filter during the winter months and just prior to sloughing. Surface ponding and channelling were recorded during the colder months. At the higher loading the film accumulation was heavy in the slag filter and channelling occurred for most of the year.

k) The slag medium retained heat more efficiently than the plastic medium due to its greater bulk density. Therefore the temperature of the film in the plastic filter was affected more by changes in ambient temperature than in the other pilot filters.

l) The slag portion of the mixed filter increased the mean retention time, thus increasing the contact time between the sewage and film compared with the plastic filter, and so increasing the degree of nitrification achieved by the filter.

m) The continuous dosing system used produced better utilisation of the surface medium thus increasing the treatment capacity of all the filters.

n) Better redistribution ensured that the lower half of the mixed filter was utilised more than in the slag filter, thus the lower portion of the mixed filter achieved more organic removal than the same depth in the slag filter.

o) The plastic filter failed to achieve the same rates of removal as the mixed filter. Similar removal efficiencies were recorded in the top 900mm of both the mixed and plastic filters (same medium), but the lower half of the plastic filter did not enhance the overall quality of the final effluent and so offered no real advantages over the modular plastic media at these loadings.

p) Due to the excessive cost of plastic medium, the cost of uprating filters in this way is expensive. Although further research is required to establish the optimum depths of plastic and mineral medium, it is likely that the system will only be cost effective as a) a temporary or emergency system b) for use in small treatment works, and c) for uprating filters for the ADF system.

8.3 SUGGESTIONS FOR FURTHER WORK

8.3.1 PHYSICAL NATURE OF MEDIUM

a) In order for random plastic filter medium to be competitive with mineral medium it has to be cost effective. More research is required into cheaper methods of manufacture of random plastic filter, perhaps on-site processes, and also the development of alternative cheaper filter media processing high surface areas and large voidages.

b) Little is known about the effect of age on the mechanical strength of filter medium. Both mineral and plastic media should be examined at regular intervals during use, to test both their chemical and physical stability.

c) The cost of uprating filters using the layer of random plastic medium depends solely on the depth of plastic medium required. Qualitative studies to assess the optimum depth of plastic on mineral medium are required.

8.3.2 ECOLOGY

a) More intensive quantitative studies are required to

i) examine the role of the microfaula in controlling the film accumulation, and

ii) to measure energy flows through the filters, so that percolating filters can be run at maximum efficiency.

b) Longer term studies of filters at normal loadings are required so that the maturation of filters and the succession of dominant organisms can be studied in detail. Further details on seasonal variation in abundance and on intra- and inter-specific competition are needed before the optimum filter conditions can be identified.

c) Studies on individual organisms, both the microfauna and macrofauna are required in order that their roles within the filter system can be evaluated.

d) Large weights of organisms are continuously washed out of percolating filters. It has been proposed by other workers that these animals may be utilised as a source of food for intensive fish rearing. For this reason it is important to quantify the biomass production in relation to medium type and loading rate.

8.3.3 PERFORMANCE

a) Long term studies are required to determine the optimum operating conditions for maximum treatment efficiency not only for the mixed media but for all types of percolating filters.

b) More detailed analysis is required of the sludge produced by the mixed media filter, as the treatability of sludge is a major cost-factor in the treatment of sewage.

c) Further studies using mixed medium filters should be carried out to assess their potential use as nitrifying filters and in the ADF system.

d) More work on the nitrogen balance in filters is required in order to determine the important sources of nitrogen within filter and how these vary seasonally. The effect of temperature fluctuations on nitrification and the poor nitrification ability of plastic filters should be investigated.

e) More experience is required in relating the neutron scattering data to operating conditions. Close monitoring of the film accumulation linked with retention times studies should provide the basis for useful predictive models.

f) The continuous dosing method used during the study increased the performance of all the filters. A detailed study into the efficiency of the various distribution systems available should be carried out, and new methods of sewage application investigated.

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THE COMPARATIVE ECOLOGY OF HIGHRATE PLASTIC, CONVENTIONAL MINERAL AND MIXED PLASTIC/MINERAL MEDIA IN THE TREATMENT OF DOMESTIC SEWAGE IN PERCOLATING FILTERS.

VOLUME II : APPENDICES

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Doctor of Philosophy awarded by
the Council for National Academic
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CONTENTS

VOLUME II : APPENDICES

	Weight (g)	Volume of water displaced (cm^3)	Surface Area g 1 paint (2nd application)	Surface Area g 1 paint (3rd application)	Surface Area (m^2)
1	100.01	46.5	3.19	0.27	7.14×10^{-3}
2	77.86	47.5	5.27	2.72	2.00×10^{-2}
3	84.54	41.5	3.87	1.85	1.36×10^{-2}
4	103.63	56.0	6.78	3.25	2.39×10^{-2}
5	114.58	41.5	1.70	1.94	1.43×10^{-2}
6	74.07	44.0	5.25	2.80	2.06×10^{-2}
7	99.57	55.0	5.61	2.63	1.94×10^{-2}
8	95.86	55.0	5.79	2.64	1.94×10^{-2}
9	114.82	68.0	6.38	2.87	2.11×10^{-2}
10	126.22	74.5	7.30	3.30	2.43×10^{-2}
11	116.28	69.0	6.10	3.00	2.21×10^{-2}
12	111.43	64.0	7.02	2.73	2.01×10^{-2}
13	75.68	38.5	4.70	2.10	1.55×10^{-2}
14	114.34	60.0	5.61	3.74	2.76×10^{-2}
15	65.34	34.0	10.99	1.82	1.34×10^{-2}
16	114.30	67.0	6.77	2.48	1.83×10^{-2}
17	169.20	96.0	9.56	2.27	1.67×10^{-2}
18	77.36	37.5	3.31	1.62	1.19×10^{-2}
19	173.49	89.0	5.77	4.28	3.15×10^{-2}
20	69.12	44.0	5.99	2.37	1.75×10^{-2}
21	132.52	62.0	5.21	2.39	1.76×10^{-2}
22	92.57	50.0	5.00	1.48	1.09×10^{-2}
23	73.19	41.0	5.27	1.84	1.36×10^{-2}
24	92.95	58.5	6.42	2.16	1.59×10^{-2}
25	166.79	88.0	7.04	1.34	9.87×10^{-3}
26	194.69	106.0	8.69	3.03	2.23×10^{-2}
27	59.79	39.0	6.30	2.24	1.65×10^{-2}
28	82.57	46.0	5.49	2.44	1.80×10^{-2}
29	100.35	54.5	8.65	2.90	2.14×10^{-2}
30	93.08	53.5	8.12	3.33	2.45×10^{-2}
31	124.89	61.5	5.81	1.63	1.20×10^{-2}
32	120.59	72.5	7.95	2.59	1.91×10^{-2}
33	68.75	36.0	3.74	1.42	1.05×10^{-2}
34	134.03	72.0	5.70	2.35	1.73×10^{-2}
35	92.82	52.5	6.42	2.54	1.87×10^{-2}
36	87.21	57.5	8.93	3.09	2.28×10^{-2}
37	152.26	79.0	7.81	2.25	1.66×10^{-2}
38	69.87	46.0	5.57	1.87	1.38×10^{-2}
39	82.43	40.0	5.94	1.58	1.16×10^{-2}
40	53.60	33.0	4.52	2.22	1.64×10^{-2}

APPENDIX II. BIOLOGICAL RESULTS

October 1977 to August 1979

The microfauna, which include all the Bacteria, Fungi, Algae, Protozoa, Nematoda and Rotifera, are expressed as total number per 3.6×10^{-5} litre of medium.

The macrofauna are expressed as total number per litre of medium.

OCTOBER, 1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms					2	1	3	16	136	2	1	2				88	88	84	148	160	80				164	12	68	72	52	4
Sphaerotilus					47	41	279	253	140	110	79	81				20	16		P		6								8	
Leptothrix																														
FUNGI																														
Subbaromyces					3	2	8	5	52	3	6	14				20	12	12	8	16	5				84	32	18	19	32	12
Conidia of *Subbaromyces*						32	58	148	143	86	69	46				4	8	16	34	144	16				40	44	96	184	84	84
Sepedonium																														
Fusarium																									20					
ALGAE																														
Chlorella					104	P		P	28							384	96		24						96			144		
Scenedesmus																	4													
Stigeoclonium								4	4																					
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates								84											48		144				180	336		48		24
Amoebae																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum																														
Hemiophrys fusidens								4																						
H.pleurosigma																														
Chilodonella cucullulus																														
C.uncinata								12																						
Colpoda cucullus																														

OCTOBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
Uronema nigricans						2	11	9	4	2	6	12													34					
Glaucoma scintillans																														
Colpidium colpoda																												4		
Paramecium aurelia						2		4																						
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma																	2								4					
V. convallaria								2																						
V. vernalis																														
Vorticellid telotrochs								8																						
Opercularia minima																														
O. microdiscum							4	10	7	2	1							4	10		4				18		4	4	8	
O. coarctata																														
Opercularian zooids									8								6	16	20	32	10				18	8	14	24	8	2
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata								4																						
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

OCTOBER, 1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA							3	13	20	1	3	4				10	12			2								2		
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis								12	320																				480	
Cocoons of *L. rivalis*								2720																			160			
Immature White spp.																	160													
OLIGOCHAETA: Lumbricidae																														
Immature spp.																												4		
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae												800																		
pupae																														160
flies								4																						

OCTOBER, 1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				6568	2740	2368	920	1440	620	80	64				1600	2720	1120							13320	2720	640	280	160	160
	Pupae				760	1692	1000	680	480	432	120	12				1120	1920	1120	160	160					6240	3680	320	80	80	160
Psychoda alternata	Flies				108	276	260	72	32	68	19	8				80	160								640					
Psychoda severini	Flies										5																			
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae				40	40	100			40		160																		
	Pupae						20					120																		
	Flies																													
H. perennis	Larvae																													
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae																	160		240	800						160	40	640	40
	Pupae																												640	
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																								320					
	Pupae																													
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													
	Flies																													

OCTOBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA:</u> ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio								P																						
Histiostoma feroniarium							3600	2400		3600		10800					1200		1200		P						4800	320	1200	P
Rhizoglyphus echinopus								1200																						
ACARI: Mesostigmata																														
Platyseius italicus																														
<u>ARTHROPODA:</u> CHILOPODA																														
Lithobius forticatus																									4					
<u>ARTHROPODA:</u> CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni								800	160							160	160	1120	1920	640	640				320	320	640	1920	1280	1440
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus					4																					4				

NOVEMBER, 1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms		16	12	6	2			10	4			4	4	11	9	6	4	1			2	4	8	13	6	6	10			
Sphaerotilus			4			2	8	6		4			4		3	12	8	1	5	8			2	7	12		8	4		
Leptothrix																													4	4
FUNGI																														
Subbaromyces		5	1	10	16	12	7	4	2	4			4	3			2		2			8	4	1	10	4			2	
Conidia of *Subbaromyces*		12	12	16	18	38	76	108	72	44	36	52	4	4		2		4	14	4	4	8	36	4	8	36	12	2	16	4
Sepedonium																														
ALGAE																														
Chlorella																													4	
Scenedesmus																					2									
Stigeoclonium		4	4					2					8					2						4						
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates				422				4	100				20	196	900	100	112	56	88	12			52	64	252	152	8	18		56
Amoebae																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum																														
Hemiophrys fusidens		4												11	27		9													
H. pleurosigma												4								3			2				4			
Chilodonella cucullulus																														
C. uncinata									6						8					36										
Colpoda cucullus																														

NOVEMBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1548
Uronema nigricans													64							4							16	56		
Glaucoma scintillans												40																		
Colpidium colpoda																														
Paramecium aurelia		19	34	24		8	10	24				8	200			36	18	56	20	8	2		12	12	48		12	6	10	
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma				6										4	5	20						10								
V. convallaria																														
V. vernalis																									14	8				8
Vorticellid telotrochs			4					2						4		4					2	4			4		4	2		
Opercularia minima																														
O. microdiscum									4												2						4			
O. coarctata		2	4	8	2	2							12		3	2	6	2	12			4	8		2	4				
Opercularian zooids		6	4	4	6	4	2	2		4			4				2	10	4			8	2			24		8	12	
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli		6								4															2					
Aspidisca costata																	4				4									
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi								2																						
P. carchesii								2																						

NOVEMBER, 1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA		1	4			2	1	2		4	4		4	3		2	4	1	18		2	2	2	4	4	4		2	2	2
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																			4											
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis		P	480	640	644	1444	1542	484	324	504	61	80	80	160	480	480	1124	3040	4968	1280	213			P	80	2960	1120	640	160	160
Cocoons of *L. rivalis*		P	1440	850		320	80	320	400	320	160		640	160	160	160	400	320		240		160		160	80		480			320
Immature White spp.																					80									160
OLIGOCHAETA: Lumbricidae																														
Immature spp.								P													P					P			P	
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																	4								20	8	60	20		20
COLEOPTERA																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis	Larvae															4	4	8												
	pupae						P	4	4	16	20	12								4	4						4	4	8	
	flies																													

NOVEMBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	320	492	6256	1120	960	260	484	160	640	213	40	1520	640	1764	5444	1924	480	·	80	53	1760	755	964	596	400	164	160	p	
	Pupae	800	1120	2400	1280	1612	450	480	484	480	107		1440	964	480	1604	1452	320	320	240		160	853	1440	720	484	340	564	160	
Psychoda alternata	Flies	32	88	16	24	32	32	8	16	4			40	24	16	140	132	6			53	20	92	200	168	188	36	4		4
Psychoda severini	Flies																8													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																												4	
	Pupae																													
	Flies																													
H. perennis	Larvae																												160	4
	Pupae																								4					
	Flies																								4		4	4	4	24
Metriocnemus hygropetricus																														
	Larvae						p	160		160	57	600			640					400	53									
	Pupae															4				80	106									
	Flies						4				8	4								8	4									
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae	36	12					4		4													4							
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																	p	p											
	Flies																													

NOVEMBER, 1977.

	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
SPECIES	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA</u>: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium						7200	14400			36000	10800	3600					3600		3600		7200				7200	18000	7200		14400	7200
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																														
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni			400	240			480	1280	320	2880	3360	2720	240		160	320	400	320	2400	800	960		320		160		320	560	480	3200

DECEMBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms					3	20	3	4	18	3	6	1				12	18	16	16	6	4				10	26	16	3	2	5
Sphaerotilus					4	100										14		22	27	20					32	16	16	12		14
Leptothrix																														
FUNGI																														
Subbaromyces					9	1	3		2	9							2	2	6	4					10	6				
Conidia of *Subbaromyces*					12	3		4	12	8	28	7						12	4	24	6				12	10	8	24		4
Sepedonium																											16			
ALGAE																														
Chlorella																														
Scenedesmus																														
Stigeoclonium					2	1					4																			1
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates					48	348	184	308	156		32	198				108	204		36	180	24				144		36		48	72
Amoebae																														
PROTOZOA: CILIOPHORA HOLOTRICHIA																														
Trachelophyllum pusillum																					4									
Hemiophrys fusidens																10	4	4									2			1
H.pleurosigma																1													2	
Chilodonella cucullulus																	2	2	8										4	
C.uncinata																1														
Colpoda cucullus																														

DECEMBER, 1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
Uronema nigricans																29	12									2				
Glaucoma scintillans																1	10	2												
Colpidium colpoda																														
Paramecium aurelia												8				4	22	18	8	20	4				32	8	14	15	20	4
P. caudatum												1																		
PERITRICHIA																														
Vorticella microstoma									2		4						4	2								4			4	
V. convallaria																				2										
V. vernalis																														
Vorticellid telotrochs						8		4	2									2								4				
Opercularia minima																														
O. microdiscum					1	10	12	3	8	8	4					9				4						4				
O. coarctata					3			4										4							4					
Opercularian zooids					7	8	19	5	18	11	4	3				3	8	2	3	4						8	4	5		
Epistylis rotans					2	5			2																					
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata																	4	2												
Tachysoma pellionella																3					4									
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi										3																				
P. carchesii																														

DECEMBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA					3		1	2		3	8	9				7	4	12	20	24	7				2	6	6	8	26	5
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					644	4	160	220	60	276	1764	1104				328	480	400	172	1536	1556				320	800	160	480	640	640
Cocoons of *L. rivalis*						640	320	240	1600	1120	1440	240						640	480	480					160	1120	480	640	160	160
Immature White spp.					4				160																		P	160	4	160
OLIGOCHAETA: Lumbricidae																														
Immature spp.																										P	P			
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																										12	24	28	56	40
COLEOPTERA																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis	Larvae									320								8												
	pupae						8	8	4	P							P									P			4	164
	flies																													

DECEMBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				6404	11368	5280	4738	5764	6420	1840	560				1296	1764	648	320	4	P				164	1120	320		160	
	Pupae				3044	3056	1604	2892	2424	2404	800	80				3108	3540	1960	804	160	160				646	2080	800	160	160	
Psychoda alternata	Flies				104	356	436	132	20	20		4				104	212	60	44						56	100	64	16	8	4
Psychoda severini	Flies																												8	
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																										4			
H. perennis	Larvae											80									P				160					P
	Pupae																													160
	Flies					4															4									
Metriocnemus hygropetricus																														
	Larvae						P					4									8								P	P
	Pupae																													
	Flies																				4									4
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae				164	36	8																		8	16				
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae					4																								
	Flies																													

DECEMBER,1977.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA		▨	▨	▨									▨	▨	▨							▨	▨	▨						
ACARI: Astigmata		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Histiogaster carpio		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Histiostoma feroniarium		▨	▨	▨	3600	3600		14400	1800	2400	P	10800	▨	▨	▨		P	P	P	3600	3600	▨	▨	▨		10800	1440	3600	P	3600
Rhizoglyphus echinopus		▨	▨	▨									▨	▨	▨							▨	▨	▨						
ACARI: Mesostigmata		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Platyseius italicus		▨	▨	▨									▨	▨	▨							▨	▨	▨						
ARTHROPODA: CHILOPODA		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Lithobius forticatus		▨	▨	▨									▨	▨	▨							▨	▨	▨						
ARTHROPODA: CRUSTACEA		▨	▨	▨									▨	▨	▨							▨	▨	▨						
COPEPODA: Cyclopoida		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Paracyclops fimbriatus chiltoni		▨	▨	▨	P		320	240	320	160	240	400	▨	▨	▨	640	960	480	960	1280	960	▨	▨	▨	160	1120	320	800	1920	1600

JANUARY, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms		8	12	14	8	4	5						8	6	6	16	18					8	8	12	12	6	5	2	3	
Sphaerotilus		4	32	4		6		6		2			6	10	12	2	14			8	4	4	2		16	4				4
Leptothrix																														
FUNGI																														
Subbaromyces		10	10	8	36	2	8			1			8		4	2				2	4	8	10	8	8	4	1		3	6
Conidia of *Subbaromyces*			2		6		P				2				8			4	6	12	24	4	2		2	2	4		14	6
Sepedonium																														
ALGAE																														
Chlorella																		2												
Scenedesmus																														
Stigeoclonium				4																8										
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates		252	156	224	144	420	52	16	136	56	28	64	168	168	168	264	48	80	84	20	72	63	252	432	48	120	432	36	1104	32
Amoebae											4																			
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum					6																									
Hemiophrys fusidens		4	4	20				4	8	5	6	6		2										4	6					
H. pleurosigma																														
Chilodonella cucullulus																														
C. uncinata		8			2					2											4	1			24	6	7			
Colpoda cucullus																														

JANUARY, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans							2	42	4	38	6	44														12		4		
Glaucoma scintillans																														
Colpidium colpoda																														
Paramecium aurelia		50		10			2	6	6	5		2	2		4		48	10	14	8		2	14	20	12		7	10	3	2
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma																														
V. convallaria												5				2														
V. vernalis																	10					1		2	16	4	6			
Vorticellid telotrochs		4												6								4								2
Opercularia minima																														
O. microdiscum		10	2	10	4	18	38	30	32	48	4	6	6	2	10	4						2				6	4	4	8	
O. coarctata																														
Opercularian zooids		2	8	14	14	72	50	34	22	10	4	8	2	8	10	6	10	8	12	8	8	8	38		4	8	2	8	14	2
Epistylis rotans							2																							
SPIROTRICHIA																														
Stentor roeseli			2							2																				
Aspidisca costata								4		6																				
Tachysoma pellionella										2	2	4											2		2					
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi									2	6																				
P. carchesii																														

JANUARY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA					4	4			1			3	6		20	4		26	12	14		15	20	2		4	9	12	17	26
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola											4	2																		
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis		320	P	P	640	640	160	3944	4200	2476	1176	4888	P	188	972	808	496	3672	1488	1248	5028	P	160	480	P	880	1120	7528	1604	6092
Cocoons of *L. rivalis*		320	160		160	160	640	168	880	720	640	480	160	480	1280		640	960		640	1920			160	160	800	1920	1920	160	160
Immature White spp.									4		240						12				640							8		
OLIGOCHAETA: Lumbricidae																														
Immature spp.														4																
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																											4	8	8	4
COLEOPTERA *Staphylinidae*																								4						
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																														
pupae											8	80														4	P	8		
flies																														

JANUARY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	3520	640	2564	1440	2408	4160	832	700	436	88	176	1788	804	1120	812	1772	80	960	160	P	800	640	1444	1440	3760	4000	640	480	P
	Pupae	1120	800	968	2404	1600	6568	1520	1140	488	160	160	504	644	164	164	4	1280	160	160	P	160	320	804	800	800	480	P		
Psychoda alternata	Flies		24	12		116	600	112	48	8	76	16	8		4	20	8	52	176	12	4	8		4	4	20		4	4	
Psychoda severini	Flies																													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae																			P										
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae															P														
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae	4	216			12	4	4	4	4													24		52	16	12			
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																	8												
	Flies																													

JANUARY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA:</u> ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium			P		3600	P	10800	7200	5400	2400	7200	5400	P	P	P	1200	P	1800	1200	P	6000	3600	1800	1800		3600	5400	4800	5400	5400
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																														
<u>ARTHROPODA:</u> CHILOPODA																														
Lithobius forticatus																									4					
<u>ARTHROPODA:</u> CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni				640	P	120	P	80	160	540	480	480			320	320	160	320	320	480	1600		160		960	960	1280	1120	320	2240

FEBRUARY, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>BACTERIA</u>																														
<u>Zoogloeal forms</u>					28	48	10	2			2	2				20	4				2				12	14	2			
Sphaerctilus							8									8	8		28	8					8	6	4			
Leptothrix																														
<u>FUNGI</u>																														
Subbaromyces																	4										2			2
Conidia of *Subbaromyces*																					2				4			4		2
Sepedonium					8		2	4								4			4						16					
<u>ALGAE</u>																														
Chlorella																														
Scenedesmus																									4					
Stigeoclonium																														
<u>PROTOZOA</u>: SARCOMASTIGOPHORA																														
Flagellates					192	96	276	96	36	96	60	126				264	96	48	12	36	24				816	312	96	6	60	24
Amoebae																				4										
<u>PROTOZOA</u>: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum																														2
Hemiophrys fusidens										2															11					
H.pleurosigma																														
Chilodonella cucullulus																											4			
C.uncinata												2															4		4	
Colpoda cucullus																														

FEBRUARY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans								4		4	2																8	8		
Glaucoma scintillans																														
Colpidium colpoda																														
Paramecium aurelia					8		8	2	8		2							8	4		6						14		8	
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma					8	4		2																			4			
V. convallaria																									12					
V. vernalis																														
Vorticellid telotrochs					4					2																				
Opercularia minima											2																			
O. microdiscum						8	8	4	20		4	4				P	4	8	48	P	2				4	16	4	4		4
O. coarctata																														
Opercularian zooids					52	84	30	10	8	8	2	2				4	8	12	4	4	4				32	20	12	4	4	12
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata								2	4																					
Tachysoma pellionella									4	2	6	10																		
SUCTORIA																														
Acineta cuspidata												2					4	4												
A. foetida																		4										4		2
Podophrya maupasi								2																						
P. carchesii																														

FEBRUARY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA					20	40	14	6	36	8	10	16				12	24	44	48	40	36				P	20	16	16	8	12
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola										2		4									2							4		
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					960	160	4644	2264	2228	3632	4916	3164				780	208	2400	648	1672	1080				4	P	4008	4800	11520	2880
Cocoons of *L. rivalis*					320	2560	3360	1800	1200	720	480	480				640	5600	1920	2240	1600	1280				320	800	2560	960	800	2080
Immature White spp.								160	8	480	640	640								160								800	1600	
OLIGOCHAETA: Lumbricidae																														
Immature spp.																	P	4												
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea										8																		8	4	4
COLEOPTERA																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																														
pupae									P	8	4								4								P	8		P
flies																														

FEBRUARY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				320	480	800	400	80	P	4	4					480	800		320					324	2568	1440	1920	320	320
	Pupae				160	4008	1608	1848	240	400		80				160	160	320	P	P	160				164	160	1124	P	P	160
Psychoda alternata	Flies				32	372	428	432	144	172	52	300				12	112	180	76	8	24				4	140	316	120	116	52
Psychoda severini	Flies																													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae										160	20						160	168	164	172									
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae																		4											
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae						8			4									4						4	16	8	4		
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													
	Flies																													

FEBRUARY, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA:</u> ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium					2400	9600	2400	7200	7200	3600	7200	3600				2400		1200	P	P	5400				1200	8400	14400	10800	3600	7200
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																													1600	
<u>ARTHROPODA:</u> CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA:</u> CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni						160	800	160	320	240	480	960				480	480	960	587	960	640				160	640	320	560	960	320

MARCH, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>BACTERIA</u>																														
<u>Zoogloeal forms</u>		8	10	12	8	14	10	36	8	10	4	2	8	8	8	32	8	12	4	4	8	44	12	20	6	4	12			8
Sphaerotilus		4	2	8	4	14	20	24	10	18	32	12	12		12	4	20	20	24	36	24	4	4		P	4	8	12	4	
Leptothrix					2																									
<u>FUNGI</u>																														
Subbaromyces		2			4		16					2																		
Conidia of *Subbaromyces*		2							4																			4		
Sepedonium		2				4					2																			
<u>ALGAE</u>																														
Chlorella		140	360													516				48			528	144	4					2
Scenedesmus		68	168	4	8			4		P						72		4		16			16	24		4		4		
Stigeoclonium																														
<u>PROTOZOA:</u> SARCOMASTIGOPHORA																														
Flagellates		44	300	480	72	168	240	348	64	180	138	162	240	552	132	108	60	84	168	36	96	144	432	252	108	204	108	180	36	36
Amoebae																														20
<u>PROTOZOA:</u> CILIOPHORA HOLOTRICHIA																														
Trachelophyllum pusillum				2	4		6	8		2	2		4		4				4				4	4					4	P
Hemiophrys fusidens		4														4						4			4			4		
H. pleurosigma																														
Chilodonella cucullulus								4			2																			
C. uncinata												4					16				4				4		32		4	
Colpoda cucullus			42	136																										

MARCH, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
Uronema nigricans																										16				4
Glaucoma scintillans											4						4	4			20						4		20	18
Colpidium colpoda					6	6	6						76		4	28						12	4	184	88	36		28		
Paramecium aurelia				4		26	24	12	12		10	26			12	4	12	52	68	24	12	8	4		4			4	20	
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma				2							4	2		8	4										72					
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs								8							4							16	16		12					
Opercularia minima																														
O. microdiscum		2	10	2	4	12	28	4	6	10	6	6	4	4	4		2					8	8		4		4	20	4	4
O. coarctata					2																									
Opercularian zooids		16	28	22	12	18	22	24	22	16	16	14	16	4	12		4	8	12	8	4	8	8	8	4	4	16	20	8	18
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata											2																		4	24
Tachysoma pellionella											2								4			4								
SUCTORIA																														
Acineta cuspidata																														
A. foetida											2																			
Podophrya maupasi								4																						
P. carchesii																														

MARCH,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA		10	8	2	8	30	16	20	36	12	26	26	12	20		32	4	4	4	28		12						20	4	30
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola									2	2										4									8	
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis		P	640	1120	320	324	160	364	512	1280	1040	548	388	464	152	344	216	564	264	896	692	P	P	P	480	480	2080	320	960	1600
Cocoons of *L. rivalis*		1120	960	160		1920	2720	4008	2880	3200	1120	2080	1760	1308	160	1440	2240	2080	1760	800	1120	640	1600	800	480	2720	3040	3040	2400	1120
Immature White spp.														4				4									160			640
OLIGOCHAETA: Lumbricidae																														
Immature spp.																		4												
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																												4		4
COLEOPTERA																														
Staphylinidae			4																											
Cercyon ustulatus			4																											
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																														
pupae											P	P							P					P			P	8	160	
flies																														

MARCH,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	1120	1440	800	1920	640	480	480	160	640	80	484	1792	968	2560	480	320	320	P	4		1120	3520	2560	1920	3040	2884	1440	800	160
	Pupae	1120	160	160	P	640	480	320	320	640	P	P	8	P	320	P	320	160	P	P	P	160	1760	2400	808	640	960	1280	320	P
Psychoda alternata	Flies	44	36	168	4	28		20	8	20						12						12	20	P	12	28	560	576	28	12
Psychoda severini	Flies		P																											
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae			4														320	160	480	480					P		160	P	P
	Pupae			P																										
	Flies																													
Metriocnemus hygropetricus																														
	Larvae																													
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae	16	12					8	4	4												4	4		180	4	4		160	
	Flies																					4								
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae												4																	
	Flies																													

MARCH,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA</u>: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium		9600	16200	7200	7200	9600	18000	3600	12600	9600	18000	14400						1200			3600		3600	2400	5400	27600	19800	12000	2400	18000
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																														
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus		4											4												4					
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni		1120	1440	480	320	160	160	480	160	320	800	320	P	P	160	160	640	160	160	480	P	320	320	960	1600	1280	480	640	800	160

APRIL, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3H	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms					12	52	24	24	16	8							20	8		12	40				8		4	12		
Sphaerotilus					2	4	20	12	4	36	16	20					36	22	36	64	48				8		4			
Leptothrix									4																			12	4	
FUNGI																														
Subbaromyces					2					2	4																			
Conidia of *Subbaromyces*								4		4	4										4									
Sepedonium																												4		
ALGAE																														
Chlorella					72											288					24				312					
Scenedesmus					4	4										4					8				12				4	
Stigeoclonium																4														
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates						132	84	18		72	96	132				120	84	120	432	48	12				348	288	348	120	240	1620
Amoebae																														4
PROTOZOA: CILIOPHORA **HOLOTRICHIA**																														
Trachelophyllum pusillum					8							8				4			4		4									
Hemiophrys fusidens																														
H.pleurosigma																														
Chilodonella cucullulus								4	8																					
C.uncinata									4	4																		2		
Colpoda cucullus																														

APRIL,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	N1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans																										24	12	12	32	8
Glaucoma scintillans											4	8						4			32									
Colpidium colpoda																									48					
Paramecium aurelia							14	10	4	24	8	8					12	4	12	14	22									4
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma																										2	4			
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs											4	4													8					
Opercularia minima																														
O. microdiscum					4	2	8	8	6	16	12	20				8		8	6						8		0	12		4
O. coarctata																														
Opercularian zooids					2	8	8	8	2	24	24	20				8	4	12	2	2	4				12	4	4	8	20	8
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata							4	20	12	8	8	4																4	4	
Tachysoma pellionella																														4
SUCTORIA																														
Acineta cuspidata								2																						
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

APRIL,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA					2	16	24	12	4	28	20	64				16	8	8	8	4	4					10	20	4	16	20
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					640	P	1124	2312	2392	436	1784	2836				120	40	72	276	212	900				P	160		P	2880	2240
Cocoons of *L. rivalis*					480	1920	3520	3200	1920	5120	8160	3200				640	2240	520	640	1120	1760				640	1120	640	4160	3680	3840
Immature White spp.							484	160	320		168	960				8				8	12								640	1440
OLIGOCHAETA: Lumbricidae																														
Immature spp.																												4		
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																												P		8
COLEOPTERA																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																														
pupae						160					8	4															P			12
flies																														

APRIL,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				160	320	1120	160	164	320	160	P				4	324		320	320	160				2084	4960	5920	960	960	
	Pupae				800	640	480	640	484	P	320	160				320	488	320	320	P					960	960	640	960	160	160
Psychoda alternata	Flies				120	144	204	288	36	24	16	4				4	48	8	72	16	8				36	196	676	212	384	24
Psychoda severini	Flies																													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupaa																													
	Flies																													4
H. perennis	Larvae								4			4									160									
	Pupae																													
	Flies																												8	16
Metriocnemus hygropetricus																														
	Larvae																								4					
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae									160																				
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae								4																24		4	8		
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae									4	4										4									
	Flies																													

APRIL, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1548
<u>ARTHROPODA</u>: ARACHNIDA																														
<u>ACARI</u>: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium					P	27720	15600	4800	9000	14400	7200	19800					2400	P		P	2400				1200	61200	40800	43200	25200	21600
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																														
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni					P	960	480	160	800	320	160	480						P	320	160	320				P	160	160	320	960	160

MAY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA									
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms		16	28	44	16	20	4						40	16	12	8				12	8	28	10	20	32	4				
Sphaerotilus																														
Leptothrix																										4				
FUNGI																														
Subbaromyces			8	4	12								8																	
Conidia of *Subbaromyces*											2	4																		
Sepedonium																								2						
ALGAE																														
Chlorella		336	2832	2592	6720	24		112	156		96		2496	9312	912	4896			36			9120	6912	23040	464					
Scenedesmus		4	36	36	96								P	96	8							8	432	192	272					
Stigeoclonium															4															
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates		120	24	40	36	420	120	96	12	12	348	60	24	4	16	60	60	156	24	60	528	36	4	156	52	768	40	84	756	84
Amoebae						4																								
Euglena																							4							
PROTOZOA: CILIOPHORA HOLOTRICHIA																														
Trachelophyllum pusillum																					4									
Hemiophrys fusidens																														
H.pleurosigma																														
Chilodonella cucullulus																														
C.uncinata					4			4		2	4						6										2	4	24	6
Colpoda cucullus																														

MAY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
Uronema nigricans								20	28	48	16	20					2	20	16								216	72	80	40
Glaucoma scintillans										4																				
Colpidium colopoda																														
Paramecium aurelia																														
P. caudatum																														
Colpidium campylum									32																					
PERITRICHIA																														
Vorticella microstoma								2																				4		2
V. convallaria									2																					
V. vernalis										2																				
Vorticellid telotrochs							2																							
Opercularia minima																														
O. microdiscum							6	3					4				4	2		2		16			4					
O. coarctata																														
Opercularian zooids		8	4	6			P	2			4		8	4	8		2	4		P	12	16		16					2	2
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata							2		8	22							12	4	2											4
Tachysoma pellionella								2	4	24	2						2		4											
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi								2	2																					
P. carchesii																														

MAY, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA		6	8	12	8				4		2		16	16	2				2		4	4	10	14	4		2	4		
ROTIFERA																														
BDELLOIDEA/*Philodina roseola*																														
MONOGONONTA/*Lecanidae sp.*																														
MONOGONONTA/*Dicranophorus Sp.*																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					P		160	1452	2552	2008	2084	2788				136	448	3228	5328	40	32					P	960	640	1280	3200
Cocoons of *L. rivalis*			160	320	640	160	800	960	1760	2080	5600	2880		160	480		1760	3360	5120	2080	320	160		160		160	320	960	4160	4480
Immature White spp.								160	160	800	1308	1760						320	160										160	160
OLIGOCHAETA: Lumbricidae																														
Immature spp.																		4	P											
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														8
COLEOPTERA *Staphylinidae*		4														12							4							
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae			40	P									40	160		4						4								
pupae		8										4												4					4	
flies																														

MAY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3N	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
DIPTERA: Psychodidae																														
(*Psychoda (all species)*	Larvae	6880	9280	8800	10560	7680	8640	3524	1784	11484	12	800	5764	5604	5760	9100	2224	1984	176	1808	336	4800	4320	2560	12480	11360	6240	5604	11200	4640
	Pupae	1440	2080	480	1120	2080	1920	962	972	1332	1448	644	5124	3200	2720	652	1772	2268	480	1628	2084	1600	320	640	320	2560	960	1920	2400	480
Psychoda alternata	Flies	28	0	8	104	280	244	8	1425	172	8	4	84	64	96	36	224	108	532	60	456	28	8	4	72	760	220	76	60	
Psychoda severini	Flies	476	68					104			64	48		16	36							188	176	32						
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae						P			4	P	P				P		8								P				P
	Pupae																													
	Flies				4	P				8	16			4				12										P		
H. perennis	Larvae						160	12	80	320	1128	648					P	80	160	480	P								160	320
	Pupae							4																						
	Flies										8	8							4	4							4			
Metriocnemus hygropetricus																														
	Larvae											4				8									320					
	Pupae																								P					
	Flies										P																			
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae				24	40					4	4											40	4				4	4	4
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																											4	4	
	Flies																													

MAY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio										1200																			120	
Histiostoma feroniarium		18000	23400	P	2400	31200	22800	13200	25200	15600	23400	14400	·	·	·	1200	1200	6000	13200	·	·	4800	8400	3600	6000	12000	19800	19200	20400	20400
Rhizoglyphus echinopus										1200		1200							1200							1200		1200		2400
ACARI: Mesostigmata																														
Platyseius italicus																										P		1200		
ARTHROPODA: CHILOPODA																														
Lithobius forticatus																								4						
ARTHROPODA: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni		160	160	480	320	··	·	·	240	640	640	1120	·	160	160	P	1920	1600	960	·	·	·	160	·	P	·	·	160	640	160

JUNE,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms						12	4	4	4	2	4					4			P		4					12				
Sphaerotilus																														
Leptothrix																														
FUNGI *Fusarium*					6	4																								
Subbaromyces									4		4					8	40	2	12								4	2	2	
Conidia of *Subbaromyces*						4										56	56	32	24		6				8		4			
Sepadonium																														
ALGAE																														
Chlorella					72		P																		11568		P			
Scenedesmus																	4													
Stigeoclonium																									528				2	
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates					48	420	24	36	12	24	12	30				12	8	12	16	24	84					120		120	18	120
Amoebae																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum							4																							
Hemiophrys fusidens																														
H. pleurosigma																														
Chilodonella cucullulus																														
C. uncinata																														
Colpoda cucullus																														

JUNE,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans						220	56	88	192	148	60	116					8	24	12		8					416		112	28	10
Glaucoma scintillans										4		6								6										2
Colpidium colpoda								6	4	68	10	16																		
Paramecium aurelia																														
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma										2										2								P		
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs										2	P																			
Opercularia minima																													4	2
O. microdiscum					4		8	4	16	4							32	24	6	34						24	4	4	36	2
O. coarctata																														
Opercularian zooids					8		4		2	2	2	4				8		2	8	6	4				20	28	4	8	20	6
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata											12							12	2		P							4		
Tachysoma pellionella											P	4						8	6	2										
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

JUNE,1970.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA					4												4				2				2			2	4	
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis						P	640	876	1284	1284	1200	716					264	3232	2728	1492	1388					320		480	1280	480
Cocoons of *L. rivalis*							160	160	160	1120	160						320	800	160	320	640					P	P	160	800	2720
Immature White spp.								160									8	160										160		
OLIGOCHAETA: Lumbricidae																														
Immature spp.																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*								4																					4	
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae					76	8		4								264	348	4							220	8	4	4		
pupae					4	56	4	P									528	16	8	4						76	4		8	
flies																	12	8								4				

JUNE,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				12968	16964	5124	5096	18044	18264	8604	4 024				7548	10036	5316	6752	2416	1128				9924	16000	8640	7680	7040	6240
	Pupae				480	4800	320	1120	2132	324	160	P				4196	4044	1280	648	480	160				960	2400	160	1280	800	160
Psychoda alternata	Flies				243	681	285	187	112	50	17	11				375	2082	172	50	8	14				100	512	362	354	36	72
Psychoda severini	Flies				9	575	427	221		62	23	53				21	34	48	46	36	50				8	44	210	254	44	52
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae											4									4									
	Pupae																													
	Flies											P									12									4
H. perennis	Larvae				8	84		8	4											160	16								8	
	Pupae																													
	Flies																				4				4					
Metriocnemus hygropetricus																														
	Larvae				196					4	8										4				160					
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																160													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae					4			4		40														8	48	172	20	8	P
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae											4																	4	4
	Flies																													

JUNE,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA</u>: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio						2400			1200		1200																			
Histiostoma feroniarium						13200	12000	1200	4800		3600					1200		1200							1200	9600	19800	12000	4800	6000
Rhizoglyphus echinopus									1200																				1200	1200
ACARI: Mesostigmata																														
Platyseius italicus																										1200				
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni								320	80	320	P	P						320	160	480	640								320	P

JULY, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms		4	4	2	76	12		4	2				30	24	40	8	20							4	10					
Sphaerotilus																														
Leptothrix																														
FUNGI *Fusarium*					8																									
Subbaromyces		48	12	16	68	4	P					2	42	92	44	96	2		8	P	4	36	24	16	22	6				
Conidia of *Subbaromyces*		232	88	40	156	8		12	4	12	6	10	124	184	12	200	20		36	28	8	68	144	156	116	20		8		4
Sepedonium							4		2	P																				
ALGAE																														
Chlorella		P	72	16									6768	384	72	288	144					P	12	36						
Scenedesmus																													24	
Stigeoclonium																								12						
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates		648	324	264	456	120	60	312	84	504	288	72	1008	864	2064	144	224		24	48	48	336	672	1008	384	96	456	168	84	180
Amoebae																			4	4							4	4	2	
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum																				4	4									
Hemiophrys fusidens																														
H. pleurosigma																														
Chilodonella cucullulus					4																									
C. uncinata					32	P		4		4							32		4								4			8
Colpoda cucullus																														

JULY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans					80	120	124	44		52	4						20		12		4					36		24	2	12
Glaucoma scintillans										2	4																			
Colpidium colpoda																														
Paramecium aurelia																														
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma				12								4												54						p
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs				36																				6						
Opercularia minima																														
O. microdiscum		18	4	20	18	12	4	4	4		2		6		2	8	32		40	4		8	4	4	14	12		4	8	24
O. coarctata																														
Opercularian zooids		14	92	28	12	4	8	4		p	2		122	4	2	16	8					36	16	10	16		4	4	4	
Epistylis rotans								4																						
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata								4	2	p											6									
Tachysoma pellionella												4									4									
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

JULY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA			8	2	4					2			10	8	2				4	4	4		8	4	4	2				2
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola												2																		
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis		P			P	P	480	224	224	484	284	872	164	16	8	4	320		448	52	660			4		480	80		320	
Cocoons of *L. rivalis*		480				640	480	640	1920			2560	160	160	320	320	2624		160	1440	2240	160		480		800	480	640	P	1600
Immature White spp.																														160
OLIGOCHAETA: Lumbricidae																														
Immature spp.																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*																														
DIPTERA: Aniscopodidae																														
Sylvicola fenestralis Larvae					4				4					48		368						4	4							
pupae				12	136			4					P	4	4	8	120		P			4			8	4				
flies																						4								

JULY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	3360	3200	6240	3840	640	2000	928	980	976	800	164	2084	1600	1284	4368	4564		164	4	320	6400	4640	3360	7840	1124	160	320	480	160
	Pupae	1280	800	1280	800	1760	640	1168	968	972	484	P	644	1604	1464	2888	1620		484	P	160	2240	1124	1600	2720	1608	P	160	160	320
Psychoda alternata	Flies	436	148	16	333	148	80	49	26	5	6	13		4		36	485		12		12	8	88	80	441	48	51		18	43
Psychoda severini	Flies				123	208	112	59	94	71	6	7					179		8						27	36	13	28	18	29
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies							4	4																					
H. perennis	Larvae																				244									
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae	160					4			4		8							160		4			4						
	Pupae																													
	Flies								8	4	4					4				16										
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																164													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae				4	160													4											
	Pupae				44	12	4					4														164	56	4		160
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae												4								4			4			4		160	4
	Flies																													

JULY,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	ŚC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA</u>: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																			P											
Histiostoma feroniarium		6000	1200		10800	6000	P		4800	4800	1200	3600							9600	2400		1200	2400	2400		4800	1200		1200	
Rhizoglyphus echinopus			1200																											
ACARI: Mesostigmata																														
Platyseius italicus																										2400	2400	1200	1200	
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus						960	160	1440	1280	1280	1120	2880	160	120			320		4480	1280	2880				320	P	320	P	P	160
chiltoni																														

AUGUST, 1978.

SPECIES / Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																													
Zoogloeal forms				12	28	12			8						4	4	4	4	8					76	8				
Sphaerotilus				12		4									8									12				4	
Leptothrix																													
FUNGI																													
Subbaromyces				40	16	16		2	4						148	12	8							72	4				4
Conidia of *Subbaromyces*				96	36	12	20	12	2	16	2				212	32	84	24	64	20				52	12	4	4	8	14
Sepedonium																													
ALGAE																													
Chlorella				600	P	24		36										12	36					12					
Scenedesmus				60		96																		12					
Stigeoclonium				12	4																								
PROTOZOA: SARCOMASTIGOPHORA																													
Flagellates				384	48	84	108	48	240	36	12				108	60	252	120	108	24				84	24	48	36	36	48
Amoebae									6																				6
PROTOZOA: CILIOPHORA HOLOTRICHIA																													
Trachelophyllum pusillum						2			8																				
Hemiophrys fusidens																													
H.pleurosigma																													
Chilodonella cucullulus																													
C.uncinata					4	P	4		6									8							4	4			2
Colpoda cucullus																													

AUGUST,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans						4											8	12									8	4		2
Glaucoma scintillans																					4									14
Colpidium colpoda																														
Paramecium aurelia					24																									
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma																										12	4			6
V. convallaria						p		12	p	2																				
V. vernalis																														
Vorticellid telotrochs								8		2	4																2			
Opercularia minima																														
O. microdiscum						28	10	p	p			2				40	4								16	4	2			
O. coarctata																														
Opercularian zooids					8	16	8			2	4	2				60	28	8							14	4	2		4	
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata						4																				8				
Tachysoma pellionella																					12									
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																											2	4	4	
P. carchesii																														
Sphaerophrya magna								4																						

AUGUST,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA						4	4	2								4	4								8	4				
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					P	53	1280	272	16	92	548	132				644	1328	1716	976	28	652				P	P	P	P	P	
Cocoons of *L. rivalis*					2240	2220	1600	640	640	160	480	640				1120	1600	320	640	320	160				1760	800		960	640	360
Immature White spp.																														
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																									4	4				
Eiseniella tetraedra																			4	8										
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA																														
Staphylinidae					4																									
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																4											P			
pupae						8										116	432	532	48	8							4			
flies																	8			4							4		164	

AUGUST,1970.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				480	110	P	16	P	P						4804	484	P							1120					12
	Pupae				1120	53	160	124	8	320						2732	160	P		4					1440	8		4	P	172
Psychoda alternata	Flies				76	92	32	8	8	8						180	800								116	4	53			164
Psychoda severini	Flies					4			4								160													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae				160				4							960									160					
	Pupae						8																							
	Flies																									4				
H. perennis	Larvae										4	12								160	4									
	Pupae																													
	Flies										4																			16
Metriocnemus hygropetricus																														
	Larvae										12	4									4									4
	Pupae									4																				
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies										160						4	324												
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae						160	160	4																4	4	8	4	4	
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																		4											
	Flies																													

AUGUST,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																				2400							1200	P	P	
Histiostoma feroniarium					1200	2400		3600									7200	6000	1200	1200					4800	3600	4800	4800	4800	1200
Rhizoglyphus echinopus																		1200												
ACARI: Mesostigmata																														
Platyseius italicus																										P	1200	P		1200
ARANEAE: Linyphiidae																													8	
ARTHROPODA: CHILOPODA																														
Lithobius forticatus																														
ARTHROPODA: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni					160	7840	6080	2720	1760	4000	2080	320				480	4480	3040	2560	2400	160				160	1280	1440	P	P	1120
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																										4	4			

SEPTEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA										PLASTIC MEDIA									
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1548
<u>BACTERIA</u>																														
Zoogloeal forms		24	20	26	24	2		8	4			2	24	28	24	32	16	14	8	4		40	16	16	70	20	16	44		
Sphaerotilus							8	8			4			8		8	4	12	4			4				6	80	40	16	
Leptothrix																														
<u>FUNGI</u>																														
Subbaromyces		12	8	4	40	4	16	12			4		32	24	20	30	16	12	8	8		8	12	32	6					
Conidia of *Subbaromyces*		28	8	4	32	12	8	20	4	8	12		24	24	8	20	20	8	16		16	12	12	4	2	4	16	16	4	4
Sepedonium																														
<u>ALGAE</u>																														
Chlorella			60				48						768	5760	720	3816	240					96	144	24	1272	96				
Scenedesmus														24		120					12	12	12		12					
Stigeoclonium							12														12						4			
<u>PROTOZOA: SARCOMASTIGOPHORA</u>																														
Flagellates		204	264	36	528	48	72	144	20	36	168	54	216	84	96	312	144	36	24	48	48	180	24	180	492	60	24	12	48	
Amoebae						4	8		2										4			4						8	12	4
Euglena															72	84									2					
<u>PROTOZOA: CILIOPHORA</u> <u>HOLOTRICHIA</u>																														
Trachelophyllum pusillum			8						14	4							4		4	8										8
Hemiophrys fusidens																														
H.pleurosigma																														
Chilodonella cucullulus						8		8	2																					
C.uncinata												2							4	2	4				4	8				
Colpoda cucullus																														

SEPTEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans				8		40	12	4									28									52	4			
Glaucoma scintillans									2							4				4					20			2	16	
Colpidium colpoda																														
Paramecium aurelia																									4	4	28	24	14	4
P. caudatum																														
PERITRICHIA																														
Vorticella microstoma									2	2		P								4					2					
V. convallaria																														
V. varnalis																														
Vorticellid telotrochs				4	2																				2		6	2		
Opercularia minima																														
O. microdiscum		14	8		8	8	12	8	14				12	4	4	6				4		36	4		2	8		2		
O. coarctata																														
Opercularian zooids		24	8	12	12	16	10	8	2	8			28	28	4	10	4	4	4	4		4	40	8	2	4	8	2	8	
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata			2			16		4									12										8			
Tachysoma pellionella												2							12											10
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																				8										
P. carchesii																														

SEPTEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA		4	6	10	4	2	6	16	2	4			6	12	8	8	8	4	12	4		8	8	8	6	16	8	12	12	8
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																													P	4
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis		640	960	320	P	1440	4320	988	2684	3768	428	416	104	24	36	800	2620	2800	1716	2160	960	P	P		P	2240	3040	800	320	P
Cocoons of *L. rivalis*		640	320	1280	160	800	2400	640	1440	1120		160		480	160			800	800	640	160	160	320	480	1440	800	4000	1440	1440	160
Immature White spp.		480				320	320				4							320		160						4				
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																			4		4									
Eiseniella tetraedra																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*																							4							
Cercyon ustulatus																							4							
DIPTERA: Anisopodidae																														
Sylvicola fenescralis Larvae														4		8		4						4			4			
pupae						96	160						8	4	8	40	112	P	4	16	8	P			164		160	4	4	
flies																						4								

SEPTEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	800	1600	2720	4480	480	960	160		8	8		3056	1936	1280	2752	480	320	4			1440	1604	2080	2560	1120	164			
	Pupae	320	480	3200	1600	320	960	P		4	P		4488	1452	964	3360	1608	160				480	1600	480	2720	4000	160	P	4	176
Psychoda alternata	Flies	44	72	64	12	172	48	24	4	8	8	4	48	180		16	156	28	24			60	264	1196	476	248	88	20	8	60
Psychoda severini	Flies																													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae									4	4	4										164								
	Pupae																					160								
	Flies										4	8																	4	
H. perennis	Larvae	160																						160						
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae															4							160		640					4
	Pupae																								320					
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae													4	4															
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae	184	40	12																			112	111	1547	136				
	Flies											4																		
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae		4			40								160		4		40						107						
	Flies																													

SEPTEMBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA:</u> ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																		1200					1200		P	1200	1200		1200	
Histiostoma feroniarium		9600	1200	7200	2400	6000	3600	6000	13200	3600	1800	3600		2400	3600		8400	2400		3600	1200	3600	7200	10800	12000	8400	2400	1200	3600	1200
Rhizoglyphus echinopus		2400																					2400			1200		2400		
ACARI: Mesostigmata																														
Platyseius italicus						P																				2400	120	2400	200	1200
ARANEAE: Linyphiidae																				4										
<u>ARTHROPODA:</u> CHILOPODA																														
Lithobius forticatus													4																	
<u>ARTHROPODA:</u> CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni		1920	2400	2560	P	480	1280	2080	2240	2240	3680	800	P	P	320	160	960	1600	2080	3840	1760	160	320	160	960	1440	320	160	960	800
<u>MOLLUSCA</u>																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																													4	

OCTOBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1548
BACTERIA																														
Zoogloeal forms					52	36	20		44	18	8					154	44	70	24	60	24				40	44	6	2	4	16
Sphaerotilus					4	92	248		144	252	204					20	P				10				4	40	232	144	36	12
Leptothrix							16																							
FUNGI																														
Subbaromyces					4	8										22	2	4		8	2				68	28	2	4		4
Conidia of *Subbaromyces*					4		4			4	4							8	4	4					12		4		4	
Sepedonium																														
Fusarium																2														
ALGAE																														
Chlorella					504											16416									24					
Scenedesmus									12							48			12						4					
Stigeoclonium																														
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates					288	576	108		72	96	84	24				252	564	108	60	24	24				72	84	48	P	12	
Amoebae											4	6								4	4									
Euglena											4	2									4							2		
PROTOZOA: CILIOPHORA HOLOTRICHIA																														
Trachelophyllum pusillum									4	2	4	2						4	4	8	6							8		
Hemiophrys fusidens										2									8											
H.pleurosigma												8																	4	
Chilodonella cucullulus																														
C.uncinata							16		2	2	4							12		4										
Colpoda cucullus																														

OCTOBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans									8	2		2							4											
Glaucoma scintillans									4		4	14							28	18	4							4	8	28
Colpidium colpoda																														
Paramecium aurelia									6		14							14	10	6								24	48	20
P. caudatum											4									4								2	4	
PERITRICHIA																														
Vorticella microstoma																		4										2		
V. convallaria							2																							
V. vernalis																														
Vorticellid telotrochs							28										4	2		8						4	2			
Opercularia minima																														
O. microdiscum						2	2		4							18	22	132			2				4	4	2		4	
O. coarctata																														
Opercularian zooids						4			2							16	26	4	4	4					4	12			4	
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata											4	12							16		4							2		
Tachysoma pellionella																													4	
Oxytricha ludibunda																					2									4
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

OCTOBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA		▨	▨	▨		2	4		8	8	12	P	▨	▨	▨			4		12	12	▨	▨	▨	4	6	6	6		6
ROTIFERA		▨	▨	▨									▨	▨	▨							▨	▨	▨						
BDELLOIDEA/*Philodina roseola*		▨	▨	▨									▨	▨	▨							▨	▨	▨						
MONOGONONTA/*Lecanidae sp.*		▨	▨	▨							4		▨	▨	▨							▨	▨	▨						
Dicranophorus Sp.		▨	▨	▨								6	▨	▨	▨							▨	▨	▨						
ANNELIDA OLIGOCHAETA: Enchytraeidae		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Lumbricillus rivalis		▨	▨	▨	P	P			3172	576	996	360	▨	▨	▨	12	72	44	1804	48	2120	▨	▨	▨	8	P	P	2240	5760	1600
Cocoons of *L. rivalis*		▨	▨	▨	160	800	960		960	800	640	160	▨	▨	▨		160	480	960	1120	160	▨	▨	▨	P	1120	960	1440	160	480
Immature White spp.		▨	▨	▨					80	4			▨	▨	▨				160	4	320	▨	▨	▨				160	320	160
OLIGOCHAETA: Lumbricidae		▨	▨	▨									▨	▨	▨		24		68	16		▨	▨	▨						
Dendrobaena subrubicunda		▨	▨	▨	4	4	4			8	8	8	▨	▨	▨							▨	▨	▨						
Eiseniella tetraedra		▨	▨	▨						64			▨	▨	▨						168	▨	▨	▨		16	52	12	4	
ARTHROPODA: INSECTA COLLEMBOLA		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Isotoma olivacea-violacea		▨	▨	▨									▨	▨	▨							▨	▨	▨						32
COLEOPTERA		▨	▨	▨									▨	▨	▨							▨	▨	▨						
DIPTERA: Anisopodidae		▨	▨	▨									▨	▨	▨							▨	▨	▨						
Sylvicola fenestralis Larvae		▨	▨	▨						P			▨	▨	▨				40	4	4	▨	▨	▨	8	4				12
pupae		▨	▨	▨						4			▨	▨	▨		4	164	128	4	8	▨	▨	▨						160
flies		▨	▨	▨									▨	▨	▨							▨	▨	▨						

OCTOBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				1440		160		P	4	160	164				1284	1152	3212	1120	480					2092	960	480	160	P	
	Pupae				320	320	640		640	P	160	4				2720	5152	2096	968	800	320				808	640	80	P	P	P
Psychoda alternata	**Flies**				24	80	128		52	8	P	12					248	1100	48	28	44				36	28	8	8		914
Psychoda severini	Flies																													366
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae									4	160							4												160
	Pupae																													
	Flies																													
H. perennis	Larvae																										160			160
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae				4																									
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies Pupae																									4				
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae						120																							
	Pupae				100	12	8				4															12	24	4		P
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae				4																									
	Flies																													

OCTOBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio						1200													P							1200	P		2400	
Histiostoma feroniarium					2400	1200	2400		4800	7200	1200	2400					1200	2400	4800	2400	4800				P	1200	3600	2400	3600	1200
Rhizoglyphus echinopus									P	1200	P										1200							1200	1200	4800
ACARI: Mesostigmata																														
Platyseius italicus																P	1200									1200	P	160	2400	1200
ARANEAE: Linyphiidae																											8			4
ARTHROPODA: CHILOPODA																														
Lithobius forticatus																														
ARTHROPODA: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni					480	P	160		800	1920	3200	2400				P	160	P	1120	800	320				480	P	P	640	160	320
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus					4																				4					

NOVEMBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms		24	32	20	28	104	40	68	72	46	18	60	24	18	40	28	68	56	56	32	16	24	40	36	48	128	40	60	32	90
Sphaerotilus			36		12	72	20	28	52	24	24	52	16	36	28	52	76	60	100	80	48	8		28	64	92	12	24	32	76
Leptothrix											4							8		8										
FUNGI																														
Subbaromyces		28	28	4	36	48	12	48	44	66	58	68	12	8		4	16	12				100	40	28	24	52	12		52	12
Conidia of *Subbaromyces*		8	20	4		8		4	8	4	10		4	4		12			8		8	8	4		40	8	8	12	12	8
Sepedonium																														
Fusarium		8	4					12	20	10			24	12	12	8				4							10		4	
ALGAE																														
Chlorella		624	432	384	144		12						4800	816	552	1824						264	1200	480	960					
Scenedesmus																			P				2		24					
Stigeoclonium														4																
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates		120	348	108	360	84	72	48	72	8	108	324	48	144	96	108	24	36	24	24	64	84	72	60	144	132	12		144	24
Amoebae																					4									
Euglena				4									4	8	4	12							8	4						
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum											4										P								4	
Hemiophrys fusidens												4								8	4						4			4
H.pleurosigma																														
Chilodonella cucullulus																														
C.uncinata									4	6								8	8									12	4	
Colpoda cucullus																														

NOVEMBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans																											208	4		
Glaucoma scintillans																														
Colpidium colpoda																36	52													
Paramecium aurelia								20	52	134	32	6					16	38	24	32	22						4	14	16	36
P. caudatum											3	8							2								4		4	4
Colpidium campylum																4														
PERITRICHIA																														
Vorticella microstoma							P	8			4	4																		
V. convallaria																														
V. vernalis									14																					
Vorticellid telotrochs									2																					
Opercularia minima																														
O. microdiscum		8	12	4	32	40	12	84	48	64	24	100		8			8					2	2	4		8	56	4		20
O. coarctata																														
Opercularian zooids		12	8	4	8	12	60	48	36	32	18	44	4	12	4	12		4	12	12			10	4	32	16	24	8	4	
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata										8	36	4					8	16										20	20	8
Tachysoma pellionella																												4	4	
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

NOVEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA		14	8		12	8	6	18	2	12	6	32	4	8	10		4	18	26	12	20	8	4	10	12		4	4	8	8
ROTIFERA																														
BDELLOIDEA/*Philodina roseola*																														
MONOGONONTA/*Lecanidae sp.*																														
MONOGONONTA/*Dicranophorus Sp.*																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis						P	P	40	88	2400	4260	116	4		16	24	372	960	864	32	928					P	640	480	4	P
Cocoons of *L. rivalis*		160			160	P	320	640	320	960	800	640					320	1600	480	480	1928					160	160	320	1280	480
Immature White spp.																														
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra										4		4							20	P	4									
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*																														
Cercyon ustulatus																4														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae			4										8		4								4	8	4	4	4	4		P
pupae			4				8		8		4	40		4				64	40	184	24	40					8	12	8	160
flies																									4					

NOVEMBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	4984	7380	2576	3204	3680	5780	5148	5544	4972	1944	1928	684	972	1760	1288	1968	1444	1128	320	160	3576	4176	4660	8804	12648	7684	1120	164	640
	Pupae	3204	3360	1280	3368	1760	1920	3064	3056	1920	160	960	168	664	1284	1440	1296	812	960	320	P	1924	1600	3364	1280	1600	800	160	1120	964
Psychoda alternata	**Flies**				20	P	140	32	24	12	12					24	104	332	16	8	4			8	8	356	88	36	12	12
Psychoda severini	Flies																													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																								4					
	Pupae																													
	Flies																													
H. perennis	Larvae																			160										
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae																										160			
	Pupae																				160									
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																												4	
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae	160			4																	160				4	160	4		
	Pupae				44	44	52												4							P	4	48	20	480
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae									4		40				4					4									
	Flies																													

NOVEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA:</u> ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio											P								P											
Histiostoma feroniarium					1200	1200	4800	P	1200	4800	1200	2400					1200	P	1200		1200			120	P	1200	1200	3600	1200	
Rhizoglyphus echinopus						1200	3600			1200							1200			1200						2400	1200	P		1200
ACARI: Mesostigmata																														
Platyseius italicus						P									P			1200							1200	1200	1200			P
ARANEAE: Linyphiidae					4																									
<u>ARTHROPODA:</u> CHILOPODA																														
Lithobius forticatus					4																									
<u>ARTHROPODA:</u> CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni		160	160	P	P	P	160	P	320	640	640	P	160		160	P	160	480	160	P	320			P	160	P	P		160	P
<u>MOLLUSCA</u>																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																			4											

DECEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
BACTERIA																														
Zoogloeal forms					136	120	104	100	56	28	88	32				80	44	80	28	60	4				92	108	100	100	72	80
Sphaerotilus					32	28	28	20		28	8	16				16	12	8							12	92	68	52	28	40
Leptothrix																									4					
FUNGI																														
Subbaromyces					28	24	18	12	12	48	22	8				8	8	4	8		2				24	48	52	36	8	36
Conidia of *Subbaromyces*							4	16	4	8		4				12			4		4				12		8	8	16	12
Sepedonium																														
Fusarium					4																				12					
ALGAE																														
Chlorella					108	192		12								6096	448	288	96	P	P				1872	336	720	432	576	24
Scenedesmus					24	12													4								48			
Stigeoclonium					24	4	4										8				4				P					
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates					24	36	528	348	528	204	12	112				P	48	192	84	108	264				336	168	60	36	84	36
Amoebae							4																		4					
Euglena																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum																														
Hemiophrys fusidens							4														4									
H. pleurosigma																														
Chilodonella cucullulus																														
C. uncinata																			4	8	4									
Colpoda cucullus																														

DECEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans							P	4	176									4	28	28	44									
Glaucoma scintillans							4				8									4	36									
Colpidium colpoda					4	4	136	66		12									8	4	4					76				
Paramecium aurelia									4		32	14									8					12				
P. caudatum																														
Colpidium campylum																														
PERITRICHIA																														
Vorticella microstoma								8	4																	2				
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs																									4					
Opercularia minima																														
O. microdiscum						4	12	20	P	6	16	P				16	24	12	56		12					18	4	8	4	8
O. coarctata																														
Opercularian zooids						16	8	56	76	30	18	20				18	88	232	112	36	10				16	24	28	16	32	32
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata									4												4					1				
Tachysoma pellionella									4			2									4									
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

DECEMBER,1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA						8	4	10		2	12	8				14		4			8					4	4	4	8	16
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis							P	96	676	228	140	6124				12	72	248	868	1956	2548				P	8	P	4	P	8
Cocoons of *L. rivalis*					160	960	2240	800	1440	480	960	1280				160		320	640	1600	2240				320	1760	1920	1120	3360	2240
Immature White spp.										12	8	320									480									
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra								2		4	4								4		4								4	
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																													4	
COLEOPTERA ***Staphylinidae***																									4					
Cercyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																4	4	4							12					
pupae					4			4		4	P							P		4					8	4		4		4
flies																														

DECEMBER, 1978.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3N	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				1120	320	328	1292	1288	1928	480	8				1668	3232	3400	2320	484	640				1120	2884	644	P	484	960
	Pupae				960	1444	1284	800	1296	808	640	320				1308	1808	4496	4852	2572	640				964	1600	2568	1280	800	320
Psychoda alternata	Flies				28	48	96	88	368	24	8						28	32	636	1032	8					4	24	36	80	4
Psychoda severini	Flies																													
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae																													
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae																													
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																				44									
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																			160										
	Pupae				44	48		4	20	172	4	44													4	8	40		28	328
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae										P																			
	Flies																													

DECEMBER, 1978.

SPECIES Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																													
ACARI: Astigmata																													
Histiogaster carpio								1200																				1200	
Histiostoma feroniarium				P	1200	1200	2400	2400	1200	2400	2400						2400	3600	2400	P				1200	3600	2400	1200	P	P
Rhizoglyphus echinopus						1200			2400	2400	1200													1200		1200			
ACARI: Mesostigmata																													
Platyseius italicus					P	P												1200						1200	1200	1200	1200	P	1200
ARANEAE: Linyphiidae							160																						
ARTHROPODA: CHILOPODA																													
Lithobius forticatus																													
ARTHROPODA: CRUSTACEA																													
COPEPODA: Cyclopoida																													
Paracyclops fimbriatus chiltoni						320	320	160		1440	1120							160	160										P
MOLLUSCA																													
GASTROPODA: Limacidae																													
Agriolimax reticulatus				4																									

JANUARY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>BACTERIA</u>																														
Zoogloeal forms		32	40	20	52	60	64	12	12	8	36	20	36	28	84	76	44	48	32	36	64	32	36	72	112	56	68	42	6	28
Sphaerotilus		36	68	32	76	36	16	8	4	8	28	60	32	44	56	32	36	36	20	4	24	32	20	4	32	56	54	26	4	
Leptothrix																														
Beggiatoa														4	8					20	12									2
<u>FUNGI</u>																														
Subbaromyces		12	16	16	20	13	16	P	4	8	6	52		8	4	4		6	8		8	12	20	40	16	20	28	22	6	6
Conidia of *Subbaromyces*																							98			4				2
Sepedonium																														
Fusarium		4	4			4																8		4		4	2	2		
<u>ALGAE</u>																														
Chlorella		912	432	720	864	48	96	72					720	1488	10032	240	816	96			288	1224	336	48	976	P	96	48		480
Scenedesmus																														
Stigeoclonium													4												4					
																												48		
<u>PROTOZOA:</u> SARCOMASTIGOPHORA																														
Flagellates		96	180	28	168	18	132	240	252	84	240	24	276	96	384	60	96	72	168	204	132	36	108	72	48	48	36	12	624	P
Amoebae																														
Euglena																														
<u>PROTOZOA:</u> CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum																														
Hemiophrys fusidens		4									2		4		8															
H.pleurosigma																														
Chilodonella cucullulus												2																		
C.uncinata									8	22		48							4											
Colpoda cucullus																												2		

JANUARY, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3N	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans								4	8			12																		
Glaucoma scintillans										40		52																		
Colpidium colpoda		336	328	154	104			118	102	12				38	26				56			112	64	32	222	36	110	92		
Paramecium aurelia		4							8	2			4	4					P			8								
P. caudatum																			2											
Colpidium campylum																														
PERITRICHIA																														
Vorticella microstoma		6	8	2					4											4										
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs		4							4																					
Opercularia minima																														
O. microdiscum		8	36	20	8	28	40	12	20	16	6	200			8				16		12	20	32	32	8	24	98	48	22	20
O. coarctata																														
Opercularian zooids		24	48	20	28	32	44	60	64	36	6		4	12	4	4	16	12	20	16	8	36	40	40	32	40	38	80	32	32
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata									24	8		10																	4	
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														4

JANUARY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA		4	4			4	12	4	16	10	10	8	12	12		4	4			4		16	4	6	6	4	6	4	16	8
																					2									2
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis ·		P	P	80	P	P	4	628	316	2308	1192	3352	344	88	P	168	196	448	1112	368	1240		P	172	P	4	80	4	184	1440
Cocoons of *L. rivalis*			800	1920	1600	1760	2240	3592	2240	4480	3040	960	1600	800	800	160	960	640	3840	4320	6880	640	160	1280	960	2720	1600	1920	2080	1120
Immature White spp.								160		160																				
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*																														
Corcyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae			4													28								4	52	4	80			
pupae		160					4		P				4							320	12							P	12	
flies																														

JANUARY, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	2400	4508	4640	5448	3200	3360	3212	4064	4164	3368	1776	1608	1448	976	992	5124	7540	5524	8008	5604	3204	5120	1764	5940	5616	3684	4160	3536	7844
	Pupae	1280	1120	1604	80	1920	1280	1444	644	488	1292	800	968	480	160	160	488	640	804	484	680	1120	320	1440	1760	1120	1120	1120	1600	800
Psychoda alternata	Flies					4	320	516	16	12	12	12	8					164	12				8						168	8
Psychoda severini	Flies																												24	
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae																													4
	Pupae																													
	Flies																		P										4	
Metriocnemus hygropetricus																														
	Larvae				160																									
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																												4	
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae				4																									
	Pupae							4			4									4	4					4		4	8	12
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																												4	
	Flies																													

JANUARY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA</u>: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio								320		1200																1200	480	P	480	160
Histiostoma feroniarium					1200	4800	8400	3600	6000	12000	6000	13200					1200		1200	1200	3600			P	1200	3600	1200	7200	8400	12000
Rhizoglyphus echinopus																													320	
ACARI: Mesostigmata																														
Platyseius italicus															P										640	1200		320	3600	
ARANEAE: Linyphiidae																														
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni		P	P	80		160	P	320	160	480	160	320	P	P	P	P	P	P	P	P	P	P	80		P		P	P	P	P
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																						8								

FEBRUARY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms					168	100	296	212	164	76	220	156				100	116	84	120	92	68				108	88	36	136	112	64
Sphaerotilus					44	72	52	112	176	52	12	24				56	56	20	24	4	4				24	60	64	156	88	56
Leptothrix																			4											
Beggiatoa							4		4								4										4			
FUNGI																														
Subbaromyces					20	4	16	6	32	12	26	12				22	2				4				16	2	4	36	52	60
Conidia of *Subbaromyces*																					P									
Sepedonium							4																		12	4				
Fusarium																														
ALGAE																														
Chlorella					144	528	240	144	336	336	96	144				240	192	96	96	864	96				240	144	96			
Scenedesmus																48									P		P			
Stigeoclonium																									24		2	4		
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates					36	48	24	36	168	144	408	192				204	396	180	360	312	516				24	96	336	600	264	192
Amoebae																														
Euglena																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum																														
Hemiophrys fusidens												4																		
H. pleurosigma																														
Chilodonella cucullulus																			12		4									
C. uncinata												4									8								12	12
Colpoda cucullus																														

FEBRUARY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans																														
Glaucoma scintillans																														
Colpidium colpoda																														
Paramecium aurelia						4	4		4			10																12		
P. caudatum																														
Colpidium campylum								4											44	2						4	4	52		
PERITRICHIA																														
Vorticella microstoma									P			6															8	2	4	4
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs																											8	12		
Opercularia minima																														
O. microdiscum					36		58	8	10	2	92	32				18	16	52	24	12						12	88	156	168	344
O. coarctata																														
Opercularian zooids					16	16	22	32	6	10		12				28	20	52	52	92	20				12	12	68	48	16	64
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata																														
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida												4																	4	32
Podophrya maupasi								4				4																		44
P. carchesii																														

FEBRUARY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA					4	4		4		4	8	14						2	4						4		8	12	6	24
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola										2		2								8										
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					160	640	P	260	228	1324	1516	2520				480	204	40	424	524	264				320	160	P	4	4	P
Cocoons of *L. rivalis*					1120	320	3520	1120	640	3680	1120	8480				960	320	800	2720	4800	2240				1600	1440	1920	2560	1440	1600
Immature White spp.												P									320									
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra									4																			4	4	
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA																														
Staphylinidae																														
Cercyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																									4				4	
pupae						4				4	4																			
flies																														

FEBRUARY, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				3364	1124	2720	1288	480	3208	972	1124				2720	4820	5628	5324	3244	536				5292	4324	2740	5608	6256	4000
	Pupae				1760	800	480	640	484	1124	480	640				328	168	804	1452	1120	372				2080	480	3520	1600	480	320
Psychoda alternata	Flies									160	P	4								132	348						12		36	57
Psychoda severini	Flies																			44									4	115
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae				160							324					4				160								8	8
	Pupae																													
	Flies											4																		
Metriocnemus hygropetricus																														
	Larvae																													
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae								P	4		4																40	40	4
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													
	Flies																													

FEBRUARY, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio												160																		
Histiostoma feroniarium					P	.	P	.	P	.	2400	2400				.	.	.	P	3600	4800				.	P	1200	2400	8400	3600
Rhizoglyphus echinopus																														3600
ACARI: Mesostigmata																														
Platyseius italicus											1200															1200			320	1200
ARANEAE: Linyphiidae																														
ARTHROPODA: CHILOPODA																														
Lithobius forticatus																														
ARTHROPODA: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus *chiltoni*					P	.	P	P	P	P	320	160				.	.	P	P	P	320				P	160	P	P	P	320
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																														

MARCH,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms		96	60	32	148	196	68	92	140	60	56	48	44	68	84	48	48	24	108	108	80	60	48	80	40	48	120	52	68	32
Sphaerotilus		20	48	16	52	136	32	48	16	20	4	8	16	24	20	28	12	20	64		12	20	44	28	40	56	20	20	20	16
Leptothrix												12								4	4									
Beggiatoa																4			4				12							
FUNGI																														
Subbaromyces			4	4	44	72	12	16	4	2							6		8			12								
Conidia of *Subbaromyces*											4							4												
Sepedonium																														
Fusarium		4		4		4									4									12	4					
ALGAE																														
Chlorella		1248	432	336	48	48	48	624	96	24			960	1680	18576	96	144	24	144	120	96	672	1248	960	960	336	288	192	48	144
Scenedesmus														48						24	4									
Stigeoclonium															4		4						8							
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates		216	396	192	156	564	156	288	252	48	228	72	120	360	24	36	264	444	348	432	132	156	564	132	12	48	24	108	120	288
Amoebae											4																			
Euglena																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum		4	8	4	4	8	4	4					4	4	8	8	8					4			16	6	4			
Hemiophrys fusidens								1																						
H.pleurosigma																														
Chilodonella cucullulus								4							2															
C.uncinata								1			8	4																		
Colpoda cucullus																														

MARCH,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans																														
Glaucoma scintillans																														
Colpidium colpoda		14	4										22	26	4							10	16							
Paramecium aurelia								16	5	4		6							2											
P. caudatum																														
Colpidium campylum										4																				
PERITRICHIA																														
Vorticella microstoma									3												2									
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs		4						18	P				4																	
Opercularia minima																														
O. microdiscum		16	4	8	38	24	20	12	8	14	4	4	4	12	8			4	36	4		12	4		4	8	16	20	36	8
O. coarctata																														
Opercularian zooids		8	28	24	4	16	16	20	28	16	20	14	16	16	4	8		16	12	8	4	8	16	8	8	56	28	16	20	16
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata																														
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																			4									4	4	
A. foetida												4																		
Podophrya maupasi							4				8	10									4								12	12
P. carchesii																														

MARCH,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA		18	4	4	8	28	10		12	20	16	28	18	34			14	6	48	16	30							16	12	20
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola									1		4								6	6									2	4
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis		16	136	P	640	P	P	524	776	576	3100	1628	268	532	164	1064	340	P	1540	1108	3980	8	P	P	2080	160	4	P	P	P
Cocoons of *L. rivalis*		320	2720	480	2560	4160	6080	3200	4000	2880	4320	3680	1440	2400	160	P	1120	3520	1760	4160	2560		480	960	P	2080	5600	2080	3040	4480
Immature White spp.																														
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*																														
Cercyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae			4		66																									
pupae					4								4								P						8	8	8	8
flies																														

MARCH, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1548
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	800	4	320	160	960	320	808	800	640	160	160	640	480	80	324	160	640	320	640	160	480	160	160		P	640	640	640	480
	Pupae	644	1124	960	960	2400	1284	2896	960	800	160	4	160	964	P	320	164	1120	960	1200	480	640	480	640	320	1120	800	1120	480	320
Psychoda alternata	Flies					21	64	95		20	12			4					8	96	84	4				8	48	36	12	28
Psychoda severini	Flies					7	16	17		8									4											
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae											160																		160
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae											12																	4	
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae						P		4																					
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													
	Flies																													

MARCH, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA</u>: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium						P		P	1200	P	7200	3600								1200	2400						3600	13200	18000	19200
Rhizoglyphus echinopus								1200				900																		
ACARI: Mesostigmata																														
Platyseius italicus																													160	
ARANEAE: Linyphiidae																														
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni		P			P	P	P	P	P	P	P	160	P	P				P	160	P	160	P	P	160	P	P	P	P	P	P
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																														

APRIL, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms					44	28	24	8	20	20	8	8				64	16	32	8	12	12				84	60	104	80	60	80
Sphaerotilus					40	12	4			4	12	24					8								64	12	20	8		8
Leptothrix																														
Beggiatoa																									p	4			4	10
FUNGI																														
Subbaromyces								p			4	8					4	4		4									4	
Conidia of *Subbaromyces*																														
Sepedonium																														
Fusarium																														
ALGAE																														
Chlorella					2736	336		96	96	96		4				15984	672	240	192	192	96				336	96	48	192	264	432
Scenedesmus										48						144									8					
Stigeoclonium																8														
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates					204	36	136	48	60	132	36	48				384	40	60	180	60	144				36	48	132	48	42	180
Amoebae																														
Euglena																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum					4																				4		12	4		
Hemiophrys fusidans																														
H. pleurosigma																														
Chilodonella cucullulus																														
C. uncinata						6	4																			4	4			
Colpoda cucullus																			4								8			

APRIL,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
Uronema nigricans																														
Glaucoma scintillans																														
Colpidium colpoda					122	12										44	4								196	60	16			
Paramecium aurelia					4																				8	4				
P. caudatum																														
Colpidium campylum																														
PERITRICHIA																														
Vorticella microstoma						8										4			P								6			
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs																											4			
Opercularia minima																														
O. microdiscum						4	2	4	24	4	12	20				12	44	10	12	16	8						12	2	8	12
O. coarctata																														
Opercularian zooids					16	28	16		8	20	4					32	36	52	8	12	8					24	16	24	16	20
Epistylis rotans							2				6																			
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata																					4									
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida																											4			
Podophrya maupasi							4	4			4	8									4				4			6	4	8
P. carchesii																														
P. mollis							12	8													8									

APRIL, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA					4	4	6	6	6			8				28	44	26	18	16	4					4	2	8	16	18
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola									2		6							4	4	14	12									4
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					1284	2	80	692	1980	1380	5336	504				6592	13036	2416	16336	1704	13512				160	3624	960	960	320	480
Cocoons of *L. rivalis*					6240	12320	8800	16800	8000	6880	3360	5120				5280	5760	16000	8960	11040	6560				480	1920	2080	3040	4160	2560
Immature White spp.																					160									
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra																											P			
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*																									P					
Cercyon ustulatus																									P					
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																														
pupae									4		4							160										4		4
flies						40																				4		4		

APRIL, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				640	640	960	1144	324	P	160	480					80	1360		480	320				160	800	2240	2560	1920	640
	Pupae				960	800	40	648	164	160	P	320					160	320	P	640	P				P	800	960	960	320	640
Psychoda alternata	Flies					4	40	8		168		P						4								4				4
Psychoda severini	Flies																									12		12		12
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae										P																			
	Pupae																													
	Flies																													
H. perennis	Larvae											160					160			8										4
	Pupae																													
	Flies																													
Matriocnemus hygropetricus																														
	Larvae																													
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae						P			4																			4	4
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													4
	Flies																													

APRIL, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio						1200															1200									
Histiostoma feroniarium					2400	2400	1200	2400	2400	2400	P	2400								P	4800					1200	6000	1200	3600	7200
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																									P		P			
ARANEAE: Linyphiidae																													P	164
ARTHROPODA: CHILOPODA																														
Lithobius forticatus					P																				P					
ARTHROPODA: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni					P	P	P	320	160	160	P	160				P		P		160					P	P	P	P	160	
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus.																														

MAY, 1979.

SPECIES Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
BACTERIA																													
Zoogloeal forms	84	56	100	120	76	144	48	96	56	52	32	68	116	92	40	92	56	72	40	88	76	72	120	124	124	208	144	48	108
Sphaerotilus	24	24	32	28	20	52	8	28	4	4		20	16	12	20	16			8	20	12	24	28	32	40	76	36	16	12
Leptothrix																													
Beggiatoa					4		4						4	4	4		4					4			4	12			
FUNGI																													
Subbaromyces	4			6									8						4		4				12	4	6		4
Conidia of *Subbaromyces*																													
Sepedonium																													
Fusarium													4		4	8						4							
ALGAE																													
Chlorella	432	2112	7392	480	192	72	48	24	12	120	24	74304	50112	59328	23328	96	96	96	336	528	1872	2160	10368	5088	288	336	192	48	48
Scenedesmus	12	12	384	48	P		12					96	24	96	144	48				96		48							
Stigeoclonium																													
PROTOZOA: SARCOMASTIGOPHORA																													
Flagellates	64	132	96	60	84	120	36	72	60	48	84	912	192	60	324	48	240	132	48	432	336	180	84	84	192	48	144	444	204
Amoebae																													
Euglena																													
PROTOZOA: CILIOPHORA																													
HOLOTRICHIA																													
Trachelophyllum pusillum													4		4								4	8				2	
Hemiophrys fusidens																													
H. pleurosigma																													
Chilodonella cucullulus																				4									
C. uncinata																	4	4	16	8									
Colpoda cucullus																								4		8			

MAY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans																				4	4									
Glaucoma scintillans																														
Colpidium colpoda				10	4																4		8	14	4	6	16	32	6	4
Paramecium aurelia																														
P. caudatum																														
Colpidium campylum																														
PERITRICHIA																														
Vorticella microstoma																	2		4											
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs																														
Opercularia minima																														
O. microdiscum		8	8		16	8	4	8	24	20	36	16	4	12	4	4	8	16	16	28	4	4	8	12	4	20	24	18	14	24
O. coarctata																														
Opercularian zooids		16	12	8	88	44	28	16	36	36	16	28	8	8	12	10	40	20	4	20	44	6		36	4	16	32	26	16	32
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata																														
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														
P. mollis																														

MAY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
NEMATODA		8	8	16	8	8	26	12	4	12	10	14	4	12		2	28	8	4	44	24	2	14	11	12	8	12	4	16	12
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola											4	8							2	2	2									2
MONOGONONTA/*Lecanidae sp.* *Dicranophorus Sp.*																				2										
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis		7060	10724	12808	15864	16024	4640	3952	4708	4884	1752	2084	11696	8320	7076	8824	11540	2256	2480	1668	2324	4968	5920	8008	9136	800	3684	1768	160	4
Eggs of *L. rivalis*		1280	320	160	960	480	1120	800	800	800	640	2080	2880	800	320	3040	5920	4720	9760	8000	3360	960	960	320	1280	2080	960	320	640	1920
Immature White spp.																														
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA *Staphylinidae*																														
Cercyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae																			44		160					4		4		4
pupae																									12	160	16	4		
flies																8						4	4		8					

MAY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	1600	1440	320	320	1920	4160	1920	480	4488	3040	3060			P	480	480	648	1760	484	800	1764	160	160		3360	1920	1600	3684	5600
	Pupae	160	1280			320	800	320	168	1124	800	4				324	800	976	3520	808	160	960	640	800	160	640	484	496	800	480
Psychoda alternata	Flies		160					12			4	4						276	364	200	172		8			160	16	8		36
Psychoda severini	Flies																													144
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae											160								164	52								44	176
	Pupae																													
	Flies																											4		
Metriocnemus hygropetricus																														
	Larvae											4									8		160				160			
	Pupae																													
	Flies																		4	8	8									
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae													40																
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae										4																			4
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													
	Flies																													

MAY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
<u>ARTHROPODA</u>: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium											3200	1200								320	1200						1200	12000	9600	28800
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																														
ARANEAE: Linyphiidae																													4	164
<u>ARTHROPODA</u>: CHILOPODA																														
Lithobius forticatus																4														
<u>ARTHROPODA</u>: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni					P	P	P	160	160	P	320	160					160	P	P		320	P	P	P	P	P	P	P	P	160
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																														

JUNE, 1979.

SPECIES / Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																													
Zoogloeal forms				48	8	2		4	4						120	96	28	68	8	2				10	32	16	8	12	
Sphaerotilus															72	112	4												
Leptothrix																													
Beggiatoa															8														
FUNGI																													
Subbaromyces				6	20	10	24	4	4	4					4	16	10	8		2					6				
Conidia of *Subbaromyces*					4	8	8				2				4			4											
Sepedonium																													
Fusarium															8	20													
ALGAE																													
Chlorella				9936	432	96		120		12					8928	900	336	1680	144	120				6912	336	144		24	
Scenedesmus				144																				24					
Stigeoclonium																													
PHOTOZOA: SARCOMASTIGOPHORA																													
Flagellates				72	12	24	84	24	36	12	24				84	36	312	264	72	84				228	48	576	48	204	504
Amoebae																													
Euglena																													
PROTOZOA: CILIOPHORA																													
HOLOTRICHIA																													
Trachelophyllum pusillum															4	8													
Hemiophrys fusidens																													
H.pleurosigma																													
Chilodonella cucullulus																													
C.uncinata																													
Colpoda cucullus																													8

JUNE, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
Uronema nigricans							44	128	324	136	22	36								8	20					84	56	148	56	56
Glaucoma scintillans																														
Colpidium colpoda									4												4								4	
Paramecium aurelia									2	2																				
P. caudatum																														
Colpidium campylum																														
PERITRICHIA																														
Vorticella microstoma												12																		
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs																													4	
Opercularia minima																														
O. microdiscum						12	4	4	4	16	4	28				8	52	28	24	28	12					16	8	4	4	26
O. coarctata																														
Opercularian zooids						6	16	4		4						12	64	36	12	20	4				8	28	24	8	12	12
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata									4			2																		
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														
P. mollis																														

JUNE, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA					4												4		4	2										
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola												4					4	4	4	4	8									
MONOGONONTA/*Lecanidae sp.*							4					4																		
Dicranophorus Sp.																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					328	160	320	2044	6524	10528	7272	6024				8	160	112	920	4408	3216				80	4	320	812	640	1600
Cocoons of *L. rivalis*					160											160	480	960	640		320				320	320	160	160	40	320
Immature White spp.																				160									160	
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA																														
Staphylinidae																														
Cercyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae					764	132	24	172		4	324					172	52	73	16	2408					276	252	4	4		4
pupae					172																				84	96	16	8		
flies																									8			4		

JUNE, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				38884	50880	40004	45936	43388	30772	24064	13468				960	9284	8972	10916	15556	11492				39812	44004	43560	17600	10724	7200
	Pupae				5120	2560	7040	2576	3528	2248	1152	712				640	2240	4992	9488	2420	824				3204	4000	2720	960	3360	2244
Psychoda alternata	Flies				1498	469	813	185	310	84	133	96					320	320	608	432	38				1276	580	81	597		187
Psychoda severini	Flies				86	139	739	195	526	68	99	32									22				32	472	539	199	20	449
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae						84	12	80	36	444	572							52	723	328								56	168
	Pupae																				8									
	Flies																													
Metriocnemus hygropetricus																														
	Larvae															4														
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae										12																			
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													
	Flies																													

JUNE, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium						1200	3600	2400	3600																1200	P	1200	2400		P
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																											8			
ARANEAE: Linyphiidae																													4	
ARTHROPODA: CHILOPODA																														
Lithobius forticatus																														
ARTHROPODA: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni					160	320	160	P	320	160	480	480				P	40		P	P	P				160	P	P	320	P	80
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																														

JULY,1979.

Medium	MIXED MEDIA										
SPECIES Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6
Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18
BACTERIA											
Zoogloeal forms	84	132	36	52	24	164	104	88	96	24	20
Sphaerotilus	20		12	64	16			8	24	12	4
Leptothrix											
Beggiatoa	4		4								
FUNGI											
Subbaromyces	34	44	12	102	120	200	44	62	74	32	32
Conidia of *Subbaromyces*	4				72	164	92	80	600	44	4
Sepedonium											
Fusarium	28	22	8	8				4			
ALGAE											
Chlorella	144	336	6528	576	240	240	48	P	48	48	
Scenedesmus			72								
Stigeoclonium											
PROTOZOA: SARCOMASTIGOPHORA											
Flagellates	120	72	12	552	60	144	288	120	156	168	36
Amoebae											
Euglena											
PROTOZOA: CILIOPHORA											
HOLOTRICHIA											
Trachelophyllum pusillum											
Hemiophrys fusidens											
H.pleurosigma											
Chilodonella cucullulus											
C.uncinata											
Colpoda cucullus											

Medium	SLAG MEDIA								
SPECIES Basket code	SR	SC	SL	S1	S2	S3	S4	S5	S6
Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA									
Zoogloeal forms	56	140	88	60	52	68	32	96	4
Sphaerotilus	12	12	44	24	20	8		8	
Leptothrix									
Beggiatoa	20	4	4		12				
FUNGI									
Subbaromyces		4	4	4	4	4	12	24	
Conidia of *Subbaromyces*					8	16	20	14	4
Sepedonium									
Fusarium	10	4	4	12	84	20	4		
ALGAE									
Chlorella	4224	26928	15552	2016	816	336	360	288	48
Scenedesmus	P	192	4	12					
Stigeoclonium									
PROTOZOA: SARCOMASTIGOPHORA									
Flagellates	240	48	108	84	180	120	180	636	12
Amoebae									
Euglena									
PROTOZOA: CILIOPHORA									
HOLOTRICHIA									
Trachelophyllum pusillum									
Hemiophrys fusidens									
H.pleurosigma									
Chilodonella cucullulus									
C.uncinata									2
Colpoda cucullus									

Medium	PLASTIC MEDIA								
SPECIES Basket code	PR	PC	PL	P1	P2	P3	P4	P5	P6
Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-1
BACTERIA									
Zoogloeal forms	92	76	16	140	88	16	36	22	12
Sphaerotilus		20		40	16	8			
Leptothrix									4
Beggiatoa			12		12				
FUNGI									
Subbaromyces	62	14	132	32	50	128	94	106	101
Conidia of *Subbaromyces*	20		20		12	44	308	140	152
Sepedonium									
Fusarium	24		4	12	48		2	26	
ALGAE									
Chlorella	384	576	96	1440	156	384	240	240	36
Scenedesmus		12							
Stigeoclonium									
PROTOZOA: SARCOMASTIGOPHORA									
Flagellates	144	60		396	24	24	36	24	12
Amoebae									
Euglena									
PROTOZOA: CILIOPHORA									
HOLOTRICHIA									
Trachelophyllum pusillum									
Hemiophrys fusidens									
H.pleurosigma									
Chilodonella cucullulus									
C.uncinata									
Colpoda cucullus									

JULY, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
Uronema nigricans											48	12									32									
Glaucoma scintillans																					10									
Colpidium colpoda		4									4	1																		
Paramecium aurelia																														
P. caudatum																														
Colpidium campylum																														
PERITRICHIA																														
Vorticella microstoma																					4									
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs																														
Opercularia minima																														
O. microdiscum			4	4				4	100	212	156	34	4		5	8	4	36	20	40	84							74	24	160
O. coarctata																														
Opercularian zooids		8		4		8	28	48	80	20	40	18	16	16	32	4	36	124	120	52	8	20	8	8	4	6	12	46	76	60
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata																					4									
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														
A. foetida																														
Podophrya maupasi																														
P. carchesii																														

JULY, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA										PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA					4								4	8	4				2						4	2		2		
ROTIFERA																														
BDELLOIDEA																														
Philodina roseola												1	2				4			8										
MONOGONONTA/*Lecanidae sp.* *Dicranophorus Sp.*																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis			P		P		P	213	88	592	2172	780	624	240	18240	324	460	788	804	1324	2360	P	.	P	P	164			640	P
Cocoons of *L. rivalis*					160	160		160		160	320	160	320				160	800	960	480	160									
Immature White spp.																														
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA																														
Staphylinidae																														
Cercyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis	Larvae	192	128	12	252	176	260	148	132	4	8		4	4	120	452	208	380	56	160	16	228	428	96	64	160	212	96	52	52
	pupae		64			328	436	320	304	108	64	212		4	84		12	120	248	504	152	52	48	24		4	120	240	592	132
	flies				8															4										

JULY, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae	18092	4656	21168	25100	23712	21300	21416	25680	23792	17540	27308	5444	2088	2736	6764	10756	9144	5788	5936	2592	18560	29452	5620	10404	22812	19580	31244	20480	24020
	Pupae	1760	4648	2240	172	5136	8648	4648	492	1620	2260	1132	512	320	1132	1936	4968	6620	3248	1340	332	4000	3200	14560	640	2400	4480	3360	5284	2080
Psychoda alternata	Flies		172		8	8	24	40		237	162	4			1074	12	8	820	124	580	4	P	160	80	340	20	160	96	123	53
Psychoda severini	Flies									119	54				269														5	23
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae		160						80	12	64	4								208	328									
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae	160														124						40			20					
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae																													
	Pupae																													
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae									4																				
	Flies																													

JULY,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4'	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
<u>ARTHROPODA:</u> ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium																			1200											
Rhizoglyphus echinopus								4																						
ACARI: Mesostigmata																														
Platyseius italicus																												1204		
ARANEAE: Linyphiidae																														
<u>ARTHROPODA:</u> CHILOPODA																														
Lithobius forticatus																														
<u>ARTHROPODA:</u> CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni			P	160	P	P	P	.	.	P	P	P	P	P	320	P	P	P	160	160	160	P	.	P	40	P	P	P	P	P
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																														

AUGUST,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
BACTERIA																														
Zoogloeal forms					164	128	112	128	56	60	64	8				80	224	96	48	116	8				84	212	312	124	36	8
Sphaerotilus					136	28	4		20		12					4	180		24	40	12				204	236	28	8	44	
Leptothrix																											4			
Beggiatoa						52													4						20					
FUNGI																														
Subbaromyces					68	64	36	60	4	16	16	4				20	64	28		24	4				44	152	80	76	60	4
Conidia of *Subbaromyces*					4	16	32	32	24	40	44	12				4	12	8	4	4					4		32	44	16	4
Sepedonium																														
Fusarium																														
ALGAE																														
Chlorella					48		96	144	336	48	96					672		144	192	144					1104	240	192	144	240	384
Scenedesmus																192									240					
Stigeoclonium																														
PROTOZOA: SARCOMASTIGOPHORA																														
Flagellates					48	192	240	240	324	168	24	60				88	108	320	144	24	72				36	12	48	12	32	108
Amoebae																														
PROTOZOA: CILIOPHORA																														
HOLOTRICHIA																														
Trachelophyllum pusillum											6	8																		
Hemiophrys fusidens																														
H.pleurosigma																														
Chilodonella cucullulus																														
C.uncinata									2	4	2	8				4		4		4										10
Colpoda cucullus																														

AUGUST, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
Uronema nigricans							8		32	4		6							56	8	4							4	12	8
Glaucoma scintillans									4		2								4											
Colpidium colpoda						36	8		2							2										32				
Paramecium aurelia																														
P. caudatum																														
Colpidium campylum																														
PERITRICHIA																														
Vorticella microstoma							2																							
V. convallaria																														
V. vernalis																														
Vorticellid telotrochs																														
Opercularia minima																														
O. microdiscum					2	·	24	8	60	56	96	8					12	196	268	144	16						36	24	88	16
O. coarctata																														
Opercularian zooids					8	·	24	48	72	60	28	8					2	76	12	40	4				4	24	48	96	52	20
Epistylis rotans																														
SPIROTRICHIA																														
Stentor roeseli																														
Aspidisca costata										12	6	10																	4	
Tachysoma pellionella																														
SUCTORIA																														
Acineta cuspidata																														4
A. foetida																														
Podophrya maupasi																														
P. carchesii																														
P. mollis												4																		

AUGUST,1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	1518
NEMATODA						4	8		10	8		4							4								4	8	2	
ROTIFERA																														
EDELLOIDEA																														
Philodina roseola									2	4	2	8						8	4	12	8									
MONOGONONTA/*Lecanidae sp.* *Dicranophorus Sp.*																														
ANNELIDA																														
OLIGOCHAETA: Enchytraeidae																														
Lumbricillus rivalis					P	P	P	1116	1100	1876	3244	2260				332	212	376	1144	56	340					P		P	1440	280
Cocoons of *L. rivalis*								480		160	160					160	160		960	640	320					160		640		
Immature White spp.											160																			
OLIGOCHAETA: Lumbricidae																														
Dendrobaena subrubicunda																														
Eiseniella tetraedra																														
ARTHROPODA: INSECTA																														
COLLEMBOLA																														
Isotoma olivacea-violacea																														
COLEOPTERA																														
Staphylinidae																														
Cercyon ustulatus																														
DIPTERA: Anisopodidae																														
Sylvicola fenestralis Larvae					52	132		44	8	8		84				4	12	24	56	52	12				132	184	72	20	4	4
pupae					216	356	256	692	232	96	32	20					172	48	100	416	236				144	1264	1436	924	204	28
flies								8				4																	4	4

AUGUST, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3N	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
DIPTERA: Psychodidae																														
Psychoda (all species)	Larvae				2404	2728	4800	2412	3396	496	1124	964				8980	14120	13340	14628	6208	6024				5138	3040	3188	4330	3520	800
	Pupae				640	644	1440	3044	1292	960	484					320	3856	2452	2940	3528	P				2252	1600	1760	1920	320	480
Psychoda alternata	Flies				324	36	20	108	162	21	16	4				164	1360	752	808	104	108				328		28	44	P	16
Psychoda severini	Flies								54	7	24																			
DIPTERA: Chironomidae																														
Hydrobaenus minimus	Larvae																													
	Pupae																													
	Flies																													
H. perennis	Larvae										42	56								4	168									
	Pupae																													
	Flies																													
Metriocnemus hygropetricus																														
	Larvae																													
	Pupae																													
	Flies																													
DIPTERA: Ephydridae																														
Scatella silacea	Flies																													
	Pupae																													
DIPTERA: Sphaeroceridae																														
Leptocera Spp	Larvae								160								40		160											
	Pupae							4																						
	Flies																													
DIPTERA: Cordyluridae																														
Spathiophora hydromyzina																														
	Larvae																													
	Pupae																													
	Flies																													

AUGUST, 1979.

SPECIES	Medium	MIXED MEDIA											SLAG MEDIA									PLASTIC MEDIA								
	Basket code	MR	MC	ML	M1	M2	M3T	M3M	M3L	M4	M5	M6	SR	SC	SL	S1	S2	S3	S4	S5	S6	PR	PC	PL	P1	P2	P3	P4	P5	P6
	Depth (dm)	0-3	0-3	0-3	0-3	3-6	6-7	7-8	8-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18	0-3	0-3	0-3	0-3	3-6	6-9	9-12	12-15	15-18
ARTHROPODA: ARACHNIDA																														
ACARI: Astigmata																														
Histiogaster carpio																														
Histiostoma feroniarium					2400	7200	13228	1200	4800	1200	4	P														12		4800		
Rhizoglyphus echinopus																														
ACARI: Mesostigmata																														
Platyseius italicus																													4	4
ARANEAE: Linyphiidae																														
ARTHROPODA: CHILOPODA																														
Lithobius forticatus																														
ARTHROPODA: CRUSTACEA																														
COPEPODA: Cyclopoida																														
Paracyclops fimbriatus chiltoni					160	P	320	P	640	960	2240	2720					160			480	1120					P	P	320	P	P
MOLLUSCA																														
GASTROPODA: Limacidae																														
Agriolimax reticulatus																									4					

APPENDIX III : CHEMICAL RESULTS

August 1977 to September 1979

LOADING ($m^3m^{-3}d^{-1}$)	FLOW ($l\ min^{-1}$)	Results commence		Results end	
		Sheet	date	Sheet	date
5.72	8.5	1	5.8.77	14	9.9.77
1.68	2.5	15	14.9.77	86	13.9.77
3.37	5.0	87	20.9.78	123	5.9.79

KEY TO PARAMETERS:

	Prefix:	Suffix:
Ref:	INF: influent	1: Port sewage sample at 0.3m depth
	S: slag filter	2: " " " " 0.9m "
	M: mixed filter	3: " " " " 1.5m "
	P: plastic filter	4: Final effluent at 1.8m

Flow : hydraulic loading ($l\ min^{-1}$)

BOD : biochemical oxygen demand (mgl^{-1})

S/S : suspended solids (mgl^{-1})

PV : permanganate value (mgl^{-1})

COD : chemical oxygen demand (mgl^{-1})

Amm : ammonical nitrogen (mgl^{-1})

TON : total oxidised nitrogen (mgl^{-1})

Sludge : sludge production (cm^{-3})

pH : pH

Turbid : turbidity (FTU)

Conduct : conductivity ($mm\ S\ cm^{-1}$)

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 1

Date 05087

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Co
7	10		20		30		40		50		60		70		80	
INF			165·0													
S1																
S2																
S3																
S4		8·5	72·0	56·4												
M1																
M2																
M3																
M4		8·5	73·0	55·8												
P1																
P2																
P3																
P4		8·5	88·0	46·7												

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 2

Date 1 100877 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7 10			20	30			40		50		60		70		80	
INF			117·1		168					39·2		0·8		7·7		
S1			121·1	0·0	152	9·5								7·9		
S2			117·4	0·0	148	11·9				36·2	7·7	0·0		7·9		
S3																
S4		8·5	81·6	30·3	142	15·5				34·0	13·3	2·0		7·9		
M1																
M2			68·6	41·4	94	44·1								7·8		
M3					182	0·0								7·8		
M4		8·5	70·6	39·7	130	22·6				35·2	10·2	1·6		7·8		
P1			143·6	0·0	162	3·6								7·5		
P2																
P3			92·6	20·9	158	6·0				27·6	29·6	0·2		7·8		
P4		8·5	75·1	35·9	114	32·1				35·4	9·7	0·2		7·9		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 3

Date 1 129877 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
1NF			164.7		174									7.3		
S1																
S2																
S3																
S4	8.5		74.7	54.7	116	33.3								8.2		
M1																
M2																
M3																
M4	8.5		57.4	65.2	106	39.1								8.2		
P1																
P2																
P3																
P4	8.5		64.2	61.0	114	34.5								8.2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 4

Date 1 6
150877

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF					328									7·2		
S1																
S2																
S3																
S4	8·5				180	45·1								8·2		
M1																
M2																
M3																
M4	8·5				122	62·8								8·3		
P1																
P2																
P3																
P4	8·5				130	60·4								8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 5

Date 1 6
170877

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			182.5		144		34.0							7.2		
S1					130	9.7	32.0	5.9						7.7		
S2					126	12.5	31.0	8.8						7.8		
S3																
S4		8.5	103.5	43.3	126	12.5	21.0	38.2						8.0		
M1					140	2.8	25.0	26.5						7.5		
M2			116.3	36.3	126	12.5	25.0	26.5						7.8		
M3			75.5	58.6	114	20.8	17.0	50.0						7.8		
M4		8.5	50.3	72.5	118	18.1	18.0	47.1						8.0		
P1					136	5.6	33.0	2.9						7.7		
P2																
P3																
P4		8.5	74.4	59.2	122	15.3	25.0	26.5						8.0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 6

Date 1 9 0 8 7 7 (1–6)

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			85·0		88									7·7		
S1																
S2																
S3																
S4		8·5	45·8	46·1	72	18·2								8·2		
M1																
M2																
M3																
M4		8·5	19·2	77·4	64	27·3								8·2		
P1																
P2																
P3																
P4		8·5	19·5	77·1	50	43·2								8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 7

Date 1 220877 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF					118									7·3		
S1																
S2																
S3																
S4		8·5			76	35·6								8·4		
M1																
M2																
M3																
M4		8·5			68	42·4								8·4		
P1																
P2																
P3																
P4		8·5			64	45·8								8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 8

Date 1 240877 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Condu
INF			168·8		126		52·0			40·8		0·6		7·4		
S1			147·5	12·6	134	0·0				40·6	0·5			7·8		
S2			108·8	35·6	96	23·8	34·6	33·5						7·9		
S3			95·0	43·7	124	11·6								8·0		
S4		8·5	78·8	53·3	92	27·0	29·6	43·1		33·6	17·7			8·1		
M1			145·0	14·1	110	12·7								7·8		
M2			116·3	31·1	64	49·2	31·0	40·4						7·9		
M3			40·0	76·3	54	57·1								8·1		
M4		8·5	58·8	65·2	86	31·8	28·0	46·2		31·2	23·5			8·2		
P1			137·5	18·5	126	0·0								7·9		
P2			90·0	46·7	140	0·0	34·6	33·5						8·0		
P3			73·8	56·3	124	11·6								8·2		
P4		8·5	77·5	54·1	110	12·7	34·4	33·9		31·4	23·0			8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 9

1 6
Date 260877

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			168·8		82									7·2		
S1																
S2																
S3																
S4		8·5	27·5	83·7	92	0·0								7·9		
M1																
M2																
M3																
M4		8·5	30·0	82·2	88	0·0								8·0		
P1																
P2																
P3																
P4		8·5	12·5	92·6	88	0·0								8·0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 10

Date 290877

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF					110									7·4		
S1																
S2																
S3																
S4		8·5			64	41·8								8·2		
M1																
M2																
M3																
M4		8·5			88	20·0								8·2		
P1																
P2																
P3																
P4		8·5			80	27·3								8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 11

Date 310877

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			170.0		114		53.2							7.5		
S1			141.3	16.9	144	0.0	52.4	1.5						8.0		
S2			83.8	50.7	134	0.0	46.8	12.0						8.3		
S3			56.3	66.9	130	0.0	43.2	18.8						8.2		
S4	8.5		85.0	50.0	82	28.1	34.8	34.6						8.2		
M1			147.5	13.2	116	0.0	45.2	15.0						7.9		
M2			112.5	33.8	86	24.6	42.2	20.7						8.0		
M3			85.0	50.0	102	10.5	40.6	23.7						8.2		
M4	8.5		60.0	70.6	72	36.8	27.4	48.5						8.2		
P1			142.5	16.2	106	7.0	50.4	5.3						7.9		
P2			107.5	36.8	100	12.3	40.6	23.7						8.0		
P3			42.5	75.0	46	59.7	30.8	42.1						8.2		
P4	8.5		55.0	67.7	66	42.1	26.6	50.0						8.2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 12

Date 1 020977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			135·0		144									7·5		
S1																
S2																
S3																
S4		8·5														
M1																
M2																
M3																
M4		8·5	47·5	64·8	84	41·7								8·2		
P1																
P2																
P3																
P4		8·5	65·0	51·9	84	41·7								8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 13

Date 1 070977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			158·8		96		46·8									
S1			122·5	22·9	188	0·0	53·2	0·0								
S2			80·0	49·6	74	22·9	37·2	20·5								
S3			28·8	81·9	20	79·2	20·0	57·3								
S4		8·5	63·8	59·8	102	0·0	25·2	46·2								
M1			102·5	35·5	106	0·0	46·4	0·9								
M2			90·0	43·3	48	50·0	31·2	33·3								
M3			76·3	52·0	34	64·6	28·8	38·5								
M4		8·5	47·5	70·1	48	50·0	25·2	46·2								
P1																
P2			165·0	0·0	104	0·0	46·8	0·0								
P3			32·5	79·5	18	81·3	20·4	56·4								
P4		8·5	92·5	41·8	88	8·3	32·4	30·8								

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 14

Date 1 6 090977

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			143·8		104									7·6		
S1																
S2																
S3																
S4		8·5	88·8	38·3	96	7·7								8·1		
M1																
M2																
M3																
M4		8·5	67·5	53·1	66	36·5								8·2		
P1																
P2																
P3																
P4		8·5	82·5	42·6	88	15·4								8·2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 15

Date 1 6
140977

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7 10			20		30		40		50		60		70		80	
INF			172·5		166		59·6			40·5		0·0		7·5		
S1			96·3	44·2	124	25·3	36·8	38·3						8·2		
S2			51·3	70·3	92	44·6	24·8	58·4						8·3		
S3			40·0	76·8	92	44·6	31·2	47·7						8·2		
S4		2·5	71·3	58·7	152	8·4	33·2	44·3		23·3	42·5	18·5		8·1		
M1			83·8	51·4	130	21·7	41·2	30·9						8·3		
M2			41·3	76·1	48	71·1	25·6	57·1						8·3		
M3			41·3	76·1	56	66·3	28·0	53·0						8·3		
M4		2·5	23·8	86·2	76	54·2	22·8	61·8		38·5	4·9	4·0		8·3		
P1			101·3	41·3	122	26·5	41·2	30·9						8·2		
P2			70·0	59·4	156	6·0	43·6	26·9						8·2		
P3			42·5	75·4	94	43·4	35·2	40·9						8·3		
P4		2·5	36·3	79·0	88	47·0	30·0	49·7		38·0	6·2	5·5		8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 16

Date 160977

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			168·8		128									7·6		
S1																
S2																
S3																
S4		2·5	27·5	83·7	60	53·0								8·1		
M1																
M2																
M3																
M4		2·5	41·3	75·5	70	45·3								8·2		
P1																
P2																
P3																
P4		2·5	33·8	80·0	82	35·9								8·2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 17

Date 1 210977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			156·3		146		52·0	·		38·0		0·15		7·3		
S1			80·0	48·8	42	71·2	38·0	26·9						7·9		
S2			40·0	74·4	114	21·9	32·6	37·3						7·9		
·S3			7·5	95·2	92	37·0	11·2	78·5						7·9		
S4		2·5	27·5	82·4	60	58·9	22·0	57·7		27·0	29·0	13·0		7·9		
M1			61·3	60·8	34	76·7	33·2	36·2						8·0		
M2			25·0	84·0	28	80·8	17·2	66·9						8·0		
M3			7·5	95·2	64	56·2	22·4	56·9						8·1		
M4		2·5	26·3	83·2	80	45·2	20·0	61·5		34·5	9·2	6·0		7·9		
P1			102·5	34·4	154	0·0	48·4	6·9						8·0		
P2			57·5	63·2	196	0·0	44·4	14·6						8·0		
P3			32·5	79·2	54	63·0	24·8	52·3						8·1		
P4		2·5	38·8	75·2	94	35·6	25·2	51·5		34·5	9·2	5·0		8·0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 18

1 6
Date 230979

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20	30			40		50		60		70		80	
INF			158·8		116									7·7		
S1																
S2																
S3																
S4		2·5	35·0	78·0	70	39·7								8·5		
M1																
M2																
M3																
M4		2·5	35·0	78·0	88	24·1								8·6		
P1																
P2																
P3																
P4		2·5	26·3	83·4	110	5·2								8·5		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 19

Date 1 280977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			171·3		126		60·0			34·5		11·0		7·4		
S1			56·3	67·1	94	25·4	36·8	38·7						8·2		
S2			46·3	73·0	146	0·0	32·0	46·7						8·2		
S3			26·3	84·7	90	28·6	24·0	60·0						7·9		
S4		2·5	48·8	71·5	180	0·0	35·2	43·0		14·0	59·4	18·0		7·8		
M1			102·5	40·2	596	0·0	30·8	48·7						8·2		
M2			25·0	85·4	90	28·6	26·4	56·0						8·4		
M3			40·0	76·7	108	14·3	26·4	56·0						8·2		
M4		2·5	38·8	77·4	132	0·0	26·0	56·7		23·0	33·3	11·5		8·1		
P1			98·8	42·3	148	0·0	42·8	28·7						8·3		
P2			17·5	89·8	78	38·1	27·6	54·0						8·4		
P3			43·8	74·4	170	0·0	37·2	38·0						8·2		
P4		2·5	38·8	77·4	138	0·0	31·0	48·3		22·0	36·2	11·0		8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 20

1 6
Date 300977

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			183·8		138									6·8		
S1																
S2																
S3																
S4		2·5	27·5	85·0	88	36·2								7·4		
M1																
M2																
M3														7·3		
M4		2·5	48·8	73·5	126	8·7								7·3		
P1																
P2																
P3																
P4		2·5	15·0	91·8	72	47·8								7·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 21

Date 1 051077 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			163·8		124		52·4			36·0		0·0		7·5		
S1			71·3	56·5	64	48·4	26·8	48·9						8·2		
S2			27·5	83·2	100	19·4	25·2	51·9						8·0		
S3			22·5	86·3	74	40·3	17·6	66·4						7·8		
S4		2·5	25·0	84·7	122	1·6	29·2	44·3		20·0	44·4	14·0		8·0		
M1			71·3	56·5	288	0·0	42·0	19·9						7·5		
M2			18·8	88·5	52	58·1	16·0	70·0						7·9		
M3			17·5	89·3	76	38·1	18·6	64·5						7·5		
M4		2·5	28·8	82·4	96	22·6	25·2	51·9		21·0	41·7	10·0		7·9		
P1			101·3	38·2	146	0·0	43·6	16·8						8·0		
P2			21·3	87·0	64	56·5	20·4	61·1						8·0		
P3			17·3	89·4	82	33·9	20·8	60·3						8·2		
P4		2·5	27·5	83·2	80	35·5	16·4	68·7		19·5	45·8	10·0		7·9		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 22

Date 1 071077 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			165·3		148									8·8		
S1																
S2																
S3																
S4		2·5	49·3	70·2	126	14·9								8·2		
M1																
M2																
M3																
M4		2·5	52·5	68·2	92	37·8								8·1		
P1																
P2																
P3																
P4		2·5	35·0	78·8	102	31·1								8·0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 23

Date 1 121077 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Condu
INF			177·3		136		56·6			39·0		0·0		6·8		
S1			201·3	0·0	440	0·0	88·8	0·0						7·4		1
S2			61·5	65·3	84	38·2	28·0	50·5						7·4		
S3			26·3	85·2	40	70·6	13·4	76·3						7·0		
S4		2·5	21·3	88·0	80	41·2	22·4	60·4		13·0	66·7	18·0		7·0		
M1			125·8	29·1	186	0·0	51·6	8·8						7·4		
M2			52·8	70·2	84	38·2	28·4	49·8						7·5		
M3			50·3	71·6	76	44·1	25·2	55·5						7·4		
M4		2·5	49·8	71·9	104	23·5	28·8	49·1		22·0	43·6	9·0		7·2		
P1			94·5	46·7	128	5·9	41·2	27·2						7·5		
P2			47·3	73·3	108	20·6	43·6	23·0						7·6		1
P3			130·0	26·7	290	0·0	62·4	0·0						7·3		
P4		2·5	109·3	38·4	206	0·0	52·0	8·1		22·8	41·5	13·6		7·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 24

Date 1 141077 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	14·0		178·0		122									7·6		
S1																
S2																
S3																
S4	11·0	2·5	34·5	80·6	80	34·4								8·0		
M1																
M2																
M3																
M4	11·0	2·5	37·5	78·9	84	31·2								8·2		
P1																
P2																
P3																
P4	10·0	2·5	34·5	80·6	68	44·3								8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 25

Date 1 6 191077

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	14·5		188·5		146		69·9			53·2		0·00		7·8		
S1																
S2			26·0	86·2	60	58·9	14·9	78·7						8·4		
S3			26·5	85·9	72	50·7	15·0	78·5						8·3		
S4	13·2	2·5	37·5	80·1	130	11·0	24·5	65·6		17·8	66·5	14·0		8·2		
M1			61·5	67·4	58	60·3	27·8	60·2						8·5		
M2			78·5	58·4	84	42·5	27·3	60·9		41·0	22·9	1·8		8·5		
M3			36·5	80·6	78	46·6	22·1	68·4		31·0	41·7			8·3		
M4	13·0	2·5	39·5	79·1	116	20·6	25·8	63·1		23·0	56·8	14·6		8·3		
P1			69·5	63·1	78	46·6	36·8	47·4						8·4		
P2			12·0	93·6	48	67·1	24·0	65·7						8·5		
P3			21·5	88·6	56	61·6	17·1	75·5						8·3		
P4	12·8	2·5	37·0	80·4	84	42·5	22·3	68·1		21·6	59·4	13·0		8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 26

Date 211077

1 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	15·3		173·8		134									7·8		
S1																
S2																
S3																
S4	15·6	2·5	34·0	80·4	110	17·9								8·1		
M1																
M2																
M3																
M4	15·4	2·5	35·0	79·9	84	37·3								8·2		
P1																
P2																
P3																
P4	15·1	2·5	31·0	82·2	76	43·3								8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 27

1 6
Date 261077

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	14·5		178·0		132		58·5			39·4		0·00		7·7		
S1			64·5	63·8	74	43·9	29·0	50·4						8·5		
S2			47·0	73·6	88	33·3	26·5	54·7						8·4		
S3			36·0	79·8	108	18·2	24·5	58·1						8·2		
S4	10·6	2·5	46·5	73·9	116	12·1	25·5	56·4		17·0	56·9	19·0		8·2		
M1			159·5	10·4	314	0·0	48·5	17·1						8·4		
M2			53·0	70·2	78	40·9	19·0	67·5						8·5		
M3			33·5	81·2	62	53·0	19·5	66·7						8·4		
M4	10·2	2·5	55·0	69·1	98	25·8	21·0	64·1		25·8	34·5	8·2		8·4		
P1			85·0	52·3	100	24·2	84·0	0·0						8·5		
P2			19·5	89·1	50	62·1	27·3	53·3						8·5		
P3			38·5	78·4	40	69·7	20·5	65·0						8·4		
P4	10·0	2·5	32·5	81·7	146	0·0	28·0	52·1		23·2	41·1	14·0		8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 28

Date 1 281077 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	14.0		180.5		138											
S1																
S2																
S3																
S4	9.0	2.5	36.5	79.8	94	31.9										
M1																
M2																
M3																
M4	9.2	2.5	42.5	76.5	82	40.6										
P1																
P2																
P3																
P4	8.8	2.5	52.0	71.2	68	50.7										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 29

1 6
Date 071177

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	12·2		40·5		140									7·7		
S1																
S2																
S3																
S4	10·3	2·5	23·0	43·2	86	38·6								8·0		
M1																
M2																
M3																
M4	9·8	2·5	25·5	37·0	74	47·1								7·9		
P1																
P2																
P3																
P4	10·2	2·5	24·5	39·5	62	55·7								7·8		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 30

Date 1 181177 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	11·4		139·5		138									8·4		
S1																
S2																
S3																
S4	4·1	2·5	57·5	58·8	76	44·9								8·5		
M1																
M2																
M3																
M4	5·2	2·5	34·5	75·3	88	36·2								8·6		
P1																
P2																
P3																
P4	5·2	2·5	41·5	70·3	72	47·8								8·5		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 31

Date 021277

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	10·2		98·5		112									7·7		
S1																
S2																
S3																
S4	6·3	2·5	33·5	66·0	82	26·8								7·9		
M1																
M2																
M3																
M4	6·1	2·5	39·0	60·4	88	21·4								8·0		
P1																
P2																
P3																
P4	5·8	2·5	46·0	53·3	88	21·4								8·0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 32

1 6
Date 161277

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	10·8		109·5		94									8·0		
S1																
S2																
S3																
S4	9·0	2·5	36·5	66·7	90	4·3								7·8		
M1																
M2																
M3																
M4	8·8	2·5	54·8	50·0	180	0·0								7·9		
P1																
P2																
P3																
P4	8·4	2·5	52·0	52·5	118	0·0								7·9		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 33

Date 1 3 0 1 7 8

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	8·0		158·0		90											
S1																
S2																
S3																
S4	2·6	2·5	40·5	74·4	32	64·4										
M1																
M2																
M3																
M4	3·1	2·5	36·9	76·7	50	44·4										
P1																
P2																
P3																
P4	3·0	2·5	40·8	74·2	54	40·0										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 34

Date 1 180179 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	8·2		110·5		110									7·8		
S1																
S2																
S3																
S4	4·0	2·5	32·3	70·8	60	45·5								7·9		
M1																
M2																
M3																
M4	2·5	2·5	21·8	80·3	70	36·4								7·9		
P1																
P2																
P3																
P4	2·1	2·5	36·3	67·2	74	32·7								7·9		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 35

Date 1 010278 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	7·8				44									7·8		
S1																
S2																
S3																
S4	4·8	2·5			42	4·6								7·8		
M1																
M2																
M3																
M4	4·6	2·5			56	0·0								7·8		
P1																
P2																
P3																
P4	4·9	2·5			100	0·0								7·7		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 36

Date 100278

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
1NF	8·1		118·5		102									7·9		
S1																
S2																
S3																
S4	3·7	2·5	18·5	84·4	72	29·4								8·2		
M1																
M2																
M3																
M4	3·2	2·5	12·5	89·6	70	31·4								8·3		
P1																
P2																
P3																
P4	3·2	2·5	17·4	85·3	94	7·8								8·3		

CHEMICAL ANALYSIS

(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 37

Date 1 240278 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	9·5		32·3		60									7·8		
S1																
S2																
S3																
S4	8·0	2·5	8·9	72·5	54	10·0								8·0		
M1																
M2																
M3																
M4	7·8	2·5	17·7	45·2	98	0·0								7·9		
P1																
P2																
P3																
P4	7·7	2·5	26·4	18·3	110	0·0								7·8		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

SHAKEN SAMPLES ONLY

Sheet No. 38

Date 1 6 100378

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF					112									8·1		
S1																
S2																
S3																
S4	9·4	2·5			26	76·8								7·8		
M1																
M2																
M3																
M4	9·1	2·5			20	82·1								7·8		
P1																
P2																
P3																
P4	9·3	2·5			24	78·6								7·8		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 39

1 6
Date 12087

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Con
7	10		20		30		40		50		60		70		80	
INF			164·7		174									7·3		
S1																
S2																
S3																
S4		8·5	49·8	69·8	44	74·7								8·2		
M1																
M2																
M3																
M4		8·5	40·8	75·2	52	70·1								8·2		
P1																
P2																
P3																
P4		8·5	42·8	7[illegible]·0	6[illegible]	64·4								8·2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 40

Date 1 6
190877

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF			85·0		88									7·7		
S1																
S2																
S3																
S4			19·5	77·1	20	77·3								8·2		
M1																
M2																
M3																
M4			12·0	85·9	12	86·4								8·2		
P1																
P2																
P3																
P4			12·0	85·9	12	86·4								8·3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 41

Date 1 260877 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			168.8		82									7.2		
S1																
S2																
S3																
S4		8.5	15.0	91.1	36	56.1								7.9		
M1																
M2																
M3																
M4		8.5	9.75	94.2	34	58.5								8.0		
P1																
P2																
P3																
P4		8.5	11.25	93.3	20	75.6								8.0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 42

Date 1 020977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			135·0		144									7·5		
S1																
S2																
S3																
S4		8·5														
M1																
M2																
M3																
M4		8·5	23·25	82·8	30	79·2								8·2		
P1																
P2																
P3																
P4		8·	3·	[illegible]	5	2·								8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 43

Date 1 090977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			150·8		104									7·6		
S1																
S2																
S3																
S4		8·5	47·3	68·6	44	57·7								8·1		
M1																
M2																
M3																
M4		8·5	39·8	73·6	32	69·2								8·2		
P1																
P2																
P3																
P4		8·5	49·5	67·2	26	75·0								8·2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 44

Date 1 6 160977

Ref. 7 10	Temp.	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF			168·8		128									7·6		
S1																
S2																
S3																
S4		2·5	17·8	89·5	8	93·8								8·1		
M1																
M2																
M3																
M4		2·5	17·5	89·6	16	87·5								8·2		
P1																
P2																
P3																
P4		2·5	21·2	87·4	12	90·6								8·2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 45

Date 1 230977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7 10			20		30		40		50		60		70		80	
INF			158.8		116									7.7		
S1																
S2																
S3																
S4		2.5	10.5	93.4	22	81.0								8.5		
M1																
M2																
M3																
M4		2.5	16.5	89.6	10	91.4								8.6		
P1																
P2																
P3																
P4		2.5	15.6	90.1	14	87.9								8.5		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 46

Date 1 300977 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			183·8		138									6·8		
S1																
S2																
S3																
S4		2·5	8·3	95·5	34	75·4								7·4		
M1																
M2																
M3																
M4		2·5	30·0	83·7	32	76·8								7·3		
P1																
P2																
P3																
P4		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								7·2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 47

Date 1 071077 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			165.3		148									8.8		
S1																
S2																
S3																
S4		2.5	6.0	96.4	18	87.8								8.2		
M1																
M2																
M3																
M4		2.5	9.75	94.1	22	85.1								8.1		
P1																
P2																
P3																
P4		2.5	10.07	93.9	26	82.4								8.0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 48

1 6
Date 141077

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	14·0		178·0		122									7·6		
S1																
S2																
S3																
S4	11·0	2·5	15·0	91·6	10	91·8								8·1		
M1																
M2																
M3																
M4	11·0	2·5	12·6	92·9	14	88·5								8·2		
P1																
P2																
P3																
P4	10·0	2·5	4·5	97·5	2	98·4								8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 49

1 6
Date 211077

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	15·3		173·8		134									7·8		
S1																
S2																
S3																
S4	15·6	2·5	7·5	95·7	20	85·1								8·1		
M1																
M2																
M3																
M4	15·4	2·5	14·1	91·9	20	85·1								8·2		
P1																
P2																
P3																
P4	15·1	2·5	10·7	93·8	16	88·1								8·1		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 50

Date 281077

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	14·0		180·5		138									7·8		
S1																
S2																
S3																
S4	9·0	2·5	18·3	89·9	18	87·0								8·4		
M1																
M2																
M3																
M4	9·2	2·5	26·6	85·3	20	85·5								8·5		
P1																
P2																
P3																
P4	8·8	2·5	39·6	78·1	32	78·2								8·5		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 51

Date 1 071177 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	12·2		40·6		140									7·7		
S1																
S2																
S3																
S4	10·3	1·8	5·55	86·3	16	88·6								8·0		
M1																
M2																
M3																
M4	9·8	2·8	1·95	95·2	4	97·1								7·9		
P1																
P2																
P3																
P4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]								7·8		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 52

Date 1 091177 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7 10			20	30			40		50		60		70		80	
INF	13.6		107.8		86		50.0			35.0		0.0		8.2		
S1			32.8	69.6	65	24.4	21.0	58.0						8.6		
S2			15.0	86.1	36	58.1	19.0	62.0						8.5		
S3			8.8	91.8	22	74.4	21.0	58.0						8.4		
S4	10.3	2.2	2.3	97.7	16	81.4	10.0	80.0		17.0	51.4	18.5		8.3		
M1			44.3	58.9	62	27.9	32.5	35.0						8.5		
M2			9.3	91.4	26	69.8	20.5	59.0						8.6		
M3			6.3	94.2	20	76.7	19.0	62.0						8.4		
M4	10.3	2.7	12.3	88.6	22	74.4	17.0	66.0		23.0	34.3	11.1		8.5		
P1			39.8	63.1	70	18.6	13.0	74.0						8.6		
P2			11.8	89.1	40	53.5	15.0	70.0						8.6		
P3			17.0	84.2	30	65.1	9.5	81.0						8.5		
P4	10.5	2.6	14.0	87.0	118	79.1	10.0	80.0		16.0	54.3	18.5		8.4		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 53

Date 181177

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20	30			40		50		60		70		80	
INF	11·4		150·0		138									8·4		
S1																
S2																
S3																
S4	4·1	2·6	21·0	86·0	40	71·0								8·5		
M1																
M2																
M3																
M4	5·2	2·8	27·3	81·8	42	69·6								8·6		
P1																
P2																
P3																
P4	5·2	2·4	32·9	77·4	48	65·2								8·5		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 54

Date 281177

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF			195·9		84											
S1																
S2																
S3																
S4		2·0	36·8	81·2	22	73·8										
M1																
M2																
M3																
M4		2·8	36·5	81·4	22	73·8										
P1																
P2																
P3																
P4		2·8	41·7	6[illegible]·[illegible]	[illegible]	64·2										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 55

Date 1 021277 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	10·2		98·5		112									7·7		
S1																
S2																
S3																
S4	6·3	2·8	17·4	82·3	32	71·4								8·0		
M1																
M2																
M3																
M4	6·1	2·8	17·7	82·0	28	75·0								8·0		
P1																
P2																
P3																
P4														8·0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 56

Date 1 071277 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20	30			40		50		60		70		80	
INF	9.3		105.0		98	.	31.0							7.7		
S1			73.5	30.0	78	20.4	12.8	58.7						8.0		
S2			65.5	47.1	60	38.8	12.8	58.7						8.1		
S3			26.7	74.6	36	63.3	11.8	61.9						7.9		
S4	4.4	2.2	22.2	78.9	40	59.2	10.0	67.7						7.9		
M1			76.8	26.9	84	14.3	15.9	48.7						8.0		
M2			60.6	42.3	68	30.6	12.4	60.0						8.0		
M3			29.4	72.0	40	59.2	15.3	50.7						8.0		
M4	5.4	2.8	33.9	67.7	48	51.0	11.5	62.9						8.0		
P1			73.5	30.0	92	6.1	17.5	43.6						8.0		
P2			45.0	57.1	58	40.8	8.0	74.2						8.1		
P3			27.9	73.4	58	40.8	15.6	49.7						7.9		
P4	3.[illegible]	[illegible].9	3[illegible].7	[illegible]6.[illegible]	[illegible]6	[illegible]3.1	11.[illegible]	65.5						8.0		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 57

Date 1 21277 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF														7·9		
S1																
S2																
S3																
S4		2·5												8·1		
M1																
M2																
M3																
M4		2·5												8·2		
P1																
P2																
P3																
P4		2·5												8·2		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 58

Date 1 6 1 2 7 7

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7 10			20		30		40		50		60		70		80	
INF	10·8		109·5		94									8·0		
S1																
S2																
S3																
S4	9·0	2·8	6·3	94·3	20	78·7								7·8		
M1																
M2																
M3																
M4	8·8	2·1	4·5	95·9	10	89·4								7·9		
P1																
P2																
P3																
P4	8·1	[illegible]	15·0	86·3	26	72·3								7·9		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 59

Date 1 040178 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	9·2		88·5		108		29·3			28·2		11·6		7·7		
S1			70·25	20·6	94	13·0	17·8	39·3						8·0		
S2			15·75	82·2	34	68·5	9·8	66·6						8·0		
S3			4·95	94·4	20	81·5	3·8	87·0						7·6		
S4	5·5	2·6	7·95	91·0	20	81·5	6·3	78·5		4·0	85·8	19·0		7·7		
M1			53·1	40·0	76	30·0										
M2			12·30	86·1	18	83·3	12·3	58·0						8·1		
M3			12·30	86·1	28	74·1	29·3	0·0						8·0		
M4	4·4	3·5	9·3	89·5	18	83·3	16·8	42·7		14·2	49·7	14·2		7·9		
P1			46·5	47·5	86	20·2	14·8	49·5								
P2			6·3	92·9	32	70·4	40·3	0·0						8·0		
P3			3·0	96·6	20	81·5	14·3	51·2						7·6		
P4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10·	[illegible]		10·8	61·7	13·0		·7		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 60

Date 1 3 0 1 7 8 (1–6)

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	8.0		158.0		90											
S1																
S2																
S3																
S4	2.6	2.8	11.3	92.9	10	88.9										
M1																
M2																
M3																
M4	3.1	2.8	2.6	98.4	22	75.6										
P1																
P2																
P3																
P4	3.[illegible]	2.8	12.0	92.4	22	64.4										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 61

Date 1 80178 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	8·2		110·5		110		36·5			32·8		0·6		7·8		
S1																
S2																
S3																
S4	4·0	1·5	21·0	81·0	40	63·6	14·3	60·8		20·6	37·2	10·0		7·9		
M1																
M2																
M3																
M4	2·5	2·2	6·2	94·4	30	72·7	9·0	75·3		17·6	46·3	14·4		7·9		
P1																
P2																
P3														·		
P4	2·1	[illegible]	2[illegible]·0	[illegible]·6	[illegible]	[illegible]·1	[illegible]	[illegible]2·[illegible]		[illegible]1·[illegible]	[illegible]4·8	11·8		7·9		

180

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 62

1 6
Date 010278

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7 10			20	30			40		50		60		70		80	
INF	7·8		73·5		44		10·8			16·6		6·8		7·8		
S1			49·5	32·7	36	18·2	9·6	11·1						8·1		
S2			33·6	54·3	20	54·6	8·0	25·9		18·8	0·0	0·0		7·9		
S3			0·1	99·9	10	77·3	4·8	55·6						7·8		
S4	4·8	2·6	6·0	91·8	10	77·3	4·4	59·3		10·0	39·8	12·4		7·8		
M1			41·4	43·7	68	0·0	11·6	0·00						8·1		
M2			7·5	89·8	14	68·2	6·24	42·2						8·1		
M3			9·6	86·9	8	81·8	7·2	33·3						8·0		
M4	4·6	2·8	6·3	91·4	14	68·2	5·2	51·9		8·8	47·0	14·6		7·8		
P1			24·3	66·9	24	45·5	7·6	29·6						8·0		
P2			0·9	98·8	10	77·3	4·8	55·6						8·0		
P3			3·6	95·1	14	68·2	9·6	11·1						8·0		
P4	[illegible]	[illegible]	[illegible]	95·9	8	81·8	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		7·7		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 63

1 6
Date 100278

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	8.1		118.5		102									7.9		
S1																
S2																
S3																
S4	3.7	2.9	9.2	92.2	32	68.6								8.2		
M1																
M2																
M3																
M4	3.2	3.0	7.2	93.9	32	68.6								8.3		
P1																
P2																
P3																
P4	3.[illegible]	2.[illegible]	4.5	96.2	2[illegible]	78.4								8.3		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 64

Date 150278

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	8.0		117.9		118		28.0			29.4		2.0				
S1																
S2																
S3																
S4	2.1	2.3	23.4	80.2	52	55.9	13.5	51.8		12.8	56.5	10.0				
M1																
M2																
M3																
M4	3.0	2.5	7.65	93.5	32	72.9	10.5	62.5		15.4	47.6	13.0				
P1																
P2																
P3																
P4	2.4	1.5	12.2	88.8	38	67.8	10.0	64.3		20.2	31.3	8.8				

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 65

Date 1 240278 6

Ref. 7 10	Temp.	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	9.5				60									7.8		
S1																
S2																
S3																
S4	8.0	2.0			18	70.0								8.0		
M1																
M2																
M3																
M4	7.8	2.5			20	66.7								7.9		
P1																
P2																
P3																
P4	7.7	[illegible].0			[illegible]0	6[illegible].7								7.8		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 66

Date 030378

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20	30			40		50		60		70		80	
INF	8.4		45.8		98									7.8		
S1																
S2																
S3																
S4	8.1	2.3	9.0	80.4	20	79.6								7.9		
M1																
M2																
M3																
M4	7.9	2.5	14.1	69.2	16	83.7								7.8		
P1																
P2																
P3																
P4	7.9	[illegible]	7.8	83.[illegible]	18	81.6								7.8		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 67

Date 100378

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20	30			40		50		60		70		80	
INF			128.3		112									8.1		
S1																
S2																
S3																
S4	9.4	2.8	14.7	88.5	26	76.8								7.8		
M1																
M2																
M3																
M4	9.1	2.8	8.6	93.3	20	82.1								7.8		
P1																
P2																
P3																
P4	[illegible].3	2.[illegible]	10.7	91.7	[illegible]	78.[illegible]								7.8		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 68

Date 1 220378 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF	8·8		98·0		98									8·4		
S1																
S2																
S3																
S4	6·5	2·3	9·8	90·0	26	73·5								7·8		
M1																
M2																
M3																
M4	6·3	2·6	4·1	95·8	22	77·6								7·9		
P1																
P2																
P3																
P4	6·4	2·[illegible]	5·[illegible]	9[illegible]·9	26	73·5								7·9		

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 69

Date 1 6
290378

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	10·1		84·0		130		17·8			24·0		10·0				
S1			49·7	40·8	62	52·3	17·3	2·8								
S2			21·3	74·6	32	75·4	10·4	41·6								
S3			10·2	87·9	20	84·6	11·0	38·2								
S4	7·4	2·8	4·7	94·4	20	84·6	8·0	55·1		12·0	50·0	10·0				
M1			39·3	53·2	64	50·8	23·6	0·0								
M2			23·0	72·6	38	70·8	10·8	39·3								
M3			4·1	95·1	18	86·2	8·6	57·7								
M4	7·2	2·8	3·9	95·4	20	84·6	8·0	55·1		13·4	44·2	9·2				
P1			34·7	58·7	68	47·7	27·6	0·0								
P2			15·8	81·2	52	60·0	20·4	0·0								
P3			12·9	84·6	32	75·4	13·4	24·7								
P4	[illegible]	[illegible]	[illegible]	91·2	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]				

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 70

Date 1 140478 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	9·7		229·0		270											
S1																
S2																
S3																
S4	3·9	3·0	29·7	87·0	42	84·4										
M1																
M2																
M3																
M4	3·8	2·7	24·3	89·4	38	85·9										
P1																
P2																
P3																
P4	4·9	2·8	11·1	95·2	34	87·4										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 71

Date
1 6
190478

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	10.5				168		50.2			33.2		0.0		7.7		1.
S1																
S2																
S3																
S4	7.3	2.2			30	82.1	12.9	74.3		17.0	48.8	5.0		7.8		0.
M1																
M2																
M3																
M4	6.9	1.5			30	82.1	10.7	78.7		10.8	67.5	11.8		7.7		0.
P1																
P2																
P3																
P4	7.[illegible]	[illegible]			28	82.2	12.[illegible]	74.7		[illegible]5.[illegible]	[illegible].7	[illegible]2.[illegible]		7.9.		0.

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 72

Date 1 100578 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	13·4		238·5		80		24·3			26·2		0·0	0·0	8·0		1·
S1			97·8	59·0	40	50·0	5·4	77·8						7·8		1·
S2			31·2	86·9	42	47·5	12·2	49·8						7·9		1·
S3			31·8	86·7	32	60·0	11·2	53·9						7·8		1·
S4	10·5	2·7	25·2	89·4	30	62·5	9·3	61·7		13·6	48·1	6·6	0·9	7·7		0·
M1			90·6	62·0	76	5·0	17·6	27·6						8·0		1·
M2			44·7	81·3	60	25·0	15·7	35·4						8·0		1·
M3			10·2	95·7	22	72·5	10·6	56·4						7·8		0·
M4	9·9	2·2	12·3	94·8	24	70·0	8·2	66·3		8·0	69·5	12·8	1·3	7·8		0·
P1			102·9	56·9	64	20·0	18·2	25·1						8·0		1·
P2			44·1	81·5	38	52·5	12·3	49·4						8·0		1·
P3			27·6	88·4	38	52·5	10·4	57·2						8·0		1·
P4	1·	3·	2·	1·	3	60·	9·8	59·7		1·	4·	4·	·	7·9		1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 73

1
Date 1905

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Co
7	10		20		30		40		50		60		70		80	
INF	12·2		278·5		130								9·00			
S1																
S2																
S3																
S4	10·0	2·6	57·9	79·2	46	64·6							8·5			
M1																
M2																
M3																
M4	9·8	2·8	72·3	74·0	60	53·5							5·7			
P1																
P2																
P3																
P4	8·[illegible]	3·[illegible]	82·8	70·3	40	63·1							2·[illegible]			

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 74

Date 1 240578 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	13·1		247·0		112		39·8			32·0		0·0	0·0			1·
S1																
S2																
S3																
S4	12·5	2·3	62·1	74·9	66	41·1	21·0	47·2		19·0	40·6	7·6	11·7			1·
M1																
M2																
M3																
M4	11·3	2·4	74·7	69·8	64	42·9	22·2	44·2		21·6	32·5	9·4	2·3			1·
P1																
P2																
P3																
P4	11·7	2·9	82·8	66·5	70	37·5	20·0	47·7		29·4	8·1	1·6	1·8			1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 75

Date 1 290578 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Condu
7	10		20		30		40		50		60		70		80	
INF					152											
S1																
S2																
S3																
S4		2.9			36	76.3										
M1																
M2																
M3																
M4		3.2			50	67.1										
P1																
P2																
P3																
P4		.8			6	[illegible]										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 76

Date 090678

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Con
7 10			20		30		40		50		60		70		80	
INF	14·9		253·0		150								0·0			
S1																
S2																
S3																
S4	10·7	3·0	55·5	78·1	34	77·3							1·1			
M1																
M2																
M3																
M4	8·8	2·5	64·2	74·6	46	69·3							0·9			
P1																
P2																
P3																
P4	[illegible]	[illegible]	[illegible]	[illegible]	20	[illegible]							1·0			

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 77

Date 160678

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	13·5		71·5		128								0·25			0·
S1																
S2																
S3																
S4	12·0	2·8	18·6	74·0	36	71·9							1·00			0·
M1																
M2																
M3																
M4	12·2	2·5	27·6	61·4	34	73·4							0·55			0·
P1																
P2																
P3																
P4	11·7	2·6	20·7	71·1	40	68·8							0·75			0·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 78

1 6
Date 210678

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	15·2		224·5		100		38·1			32·0		0·0				
S1			214·2	4·6	128	0·0	28·4	25·5								
S2			43·2	80·8	40	60·0	24·5	35·7								
S3			30·6	86·4	28	72·0	15·5	59·3								
S4	14·0	2·7	25·8	88·5	26	74·0	16·3	57·2		16·0	50·0	16·0				
M1			125·7	44·0	78	22·0	30·6	19·7								
M2			62·4	72·2	50	50·0	20·5	46·2								
M3			56·1	75·0	48	52·0	18·9	50·4								
M4	13·9	3·0	32·1	85·7	28	72·0	16·6	56·4		20·0	37·5	12·0				
P1			142·2	36·7	68	32·0	32·5	14·7								
P2			75·0	66·6	42	58·0	25·9	32·0								
P3			48·0	78·6	30	70·0	19·8	48·0								
P4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	18·8	[illegible]				

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 79

1 6
Date 280678

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	15·3		145·5		122		34·4			17·6		0·0				0·
S1			89·0	38·8	72	41·0	24·0	30·2		16·8	4·6	0·0				0·
S2			34·8	76·1	36	70·5	22·4	34·9		18·6	0·0	4·0				0·
S3			39·6	72·8	34	72·1	20·0	41·9		10·2	42·1	17·4				0·
S4	13·7	2·6	21·6	85·2	24	80·3	17·6	48·8		17·2	2·3	19·6				0·
M1			95·4	34·4	60	50·8	46·4	0·00		16·4	6·8	0·0				0·
M2			25·2	82·7	52	57·4	19·2	44·2		21·0	0·0	1·0				0·
M3			24·3	83·3	50	59·0	30·4	11·6		17·2	2·3	13·0				0·
M4	13·4	2·8	17·7	87·8	22	82·0	19·2	44·2		8·0	54·6	19·4				0·
P1			46·2	68·3	64	47·5	20·8	39·5		17·4	1·1	0·0				0·
P2			45·6	68·7	40	67·2	20·0	41·9		19·2	0·0	0·0				0·
P3			30·9	78·8	34	72·1	18·4	46·5		18·6	0·0	1·2				0·
P4	[illegible]	2·8	25·[illegible]	[illegible]·7	[illegible]	77·[illegible]	18·4	46·5		[illegible]	1·1	[illegible]				0·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 80

Date 1 120778 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	15.3		173.5		108		36.8			27.2		1.2	0.10	7.5		1·
S1																
S2																
S3																
S4	13.3	2.8	26.1	85.0	24	77.8	9.0	75.5		15.2	44.1	17.4	0.70	7.7		0·
M1																
M2																
M3																
M4	13.4	2.9	27.6	84.1	26	75.9	8.5	76.9		19.8	27.2	9.8	0.80	7.9		0·
P1																
P2																
P3																
P4	12.9	2.7	47.1	72.9	44	59.3	9.0	75.5		27.0	7.4	2.0	0.65	8.1		1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 81

Date 1 190778 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	15·7		225·6		104		42·4			29·4		2·2				1·
S1			93·3	58·6	60	42·3	26·2	38·2								1·
S2			35·4	84·3	30	71·2	17·9	57·7								1·
S3			27·0	88·0	22	78·9	15·0	64·6								1·
S4	13·6	2·8	10·2	95·5	12	88·5	15·2	64·2		13·2	55·1	22·0				1·
M1			96·6	57·2	60	42·3	26·1	38·4								1·
M2			36·0	84·0	35	66·4	19·2	54·7								1·
M3			29·4	87·0	25	76·0	17·6	58·5								1·
M4	12·4	2·7	13·8	93·8	20	80·8	16·0	62·3		17·6	40·1	16·8				1·
P1			123·0	45·5	70	32·7	24·8	41·5								1·
P2			61·8	72·6	44	57·7	19·2	54·7								1·
P3			18·9	91·6	26	75·0	16·0	62·3								1·
P4	12·[illegible]	[illegible]	18·[illegible]	91·6	[illegible]6	75·[illegible]	17·[illegible]	58·5		3[illegible]	[illegible]0·0	[illegible]6·[illegible]				1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 82

Date 1 280778 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	18·0		130·8		80								0·00			
S1																
S2																
S3																
S4	17·0	2·3	18·3	86·0	14	82·5							1·0			
M1																
M2																
M3																
M4	17·0	2·8	18·3	86·0	14	82·5							0·6			
P1																
P2																
P3																
P4	17·5	[illegible]	[illegible]	89·[illegible]	16	8[illegible]							[illegible]·3[illegible]			

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 83

Date 1 02087 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	16.1		174.0		82		32.4			29.0		2.4				1.
S1			46.8	73.1	34	58.5	15.1	53.4		29.4	0.0	2.2				1.
S2			19.2	89.0	22	73.2	12.9	60.2		21.6	25.5	7.8				1.
S3			20.7	88.1	36	56.1	13.2	59.3		11.4	60.7	18.2				1.
S4	14.9	2.3	18.0	90.0	20	75.6	8.4	74.1		9.0	69.0	26.0				1.
M1			90.3	48.1	40	51.2	21.5	33.6		29.6	0.0	1.8				1.
M2			21.6	87.6	22	73.2	12.1	62.7		28.8	0.7	4.0				1.
M3			15.3	91.2	10	87.8	11.6	64.2		13.4	53.8	20.2				1.
M4	15.3	3.0	12.0	93.1	20	75.6	12.4	61.7		16.6	42.8	21.4				1.
P1			94.5	45.7	50	39.0	17.8	45.1		22.6	22.1	1.0				1.
P2			28.5	83.6	18	78.1	11.8	63.6		27.8	4.1	1.8				1.
P3			11.4	93.5	12	85.4	12.4	61.7		18.2	37.2	10.6				1.
P4	1[illegible].8	2.7	19.[illegible]	89.[illegible]	16	80.[illegible]	1[illegible].4	61.7		2[illegible].[illegible]	23.[illegible]	11.8				1.

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 84

Date 1 160878 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	16·0		207·0		106		35·8		209	30·6		0·0	0·0			
S1																
S2																
S3																
S4	13·9	2·9	24·6	88·1	22	79·3	11·8	67·0	170	11·0	64·1	20·2	1·95			
M1																
M2																
M3																
M4	13·5	2·3	16·5	92·0	18	83·0	12·6	64·8	10	11·8	61·4	19·4	1·62			
P1																
P2																
P3																
P4	13·7	2·4	11·4	94·5	16	84·9	11·0	69·3	190	15·4	49·7	14·2	1·54			

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 85

Date 250878

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	16.3		260.4		116								0.0			
S1																
S2																
S3																
S4	13.9	2.6	22.2	91.5	28	75.9							2.4			
M1																
M2																
M3																
M4	13.7	2.3	27.0	89.6	34	70.7							2.7			
P1																
P2																
P3																
P4	14.2	2.8	25.5	90.2	32	72.4							3.3			

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 86

Date 1 6
130978

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	16·6		290·4		94		48		410	39·8		0·0	0·0			1·
S1			162·0	44·2	64	31·9	31·2	35·0		36·8	7·5	0·60				1·
S2			103·2	64·5	30	68·1	25·2	47·5		27·2	31·7	1·60				1·
S3			51·0	82·4	16	83·0	21·2	55·8		18·0	54·8	5·6				1·
S4	15·6	2·8	28·2	90·3	8	91·5	15·2	68·3	10	17·8	55·3	7·6	4·3			1·
M1			91·5	68·5	32	66·0	24·0	50·0		36·2	9·1	0·8				1·
M2			71·7	75·3	28	70·2	20·4	57·5		34·2	14·1	0·0				1·
M3			36·0	87·6	20	78·7	13·6	71·7		21·6	45·7	5·2				1·
M4	15·5	2·9	38·7	86·7	10	89·4	17·2	64·2	0	20·2	49·3	5·8	4·2			1·
P1			168·0	42·2	40	57·5	31·6	34·2		29·8	25·1	0·0				1·
P2			88·5	69·5	26	72·3	22·4	53·3		30·0	24·6	0·0				1·
P3			59·1	79·7	16	83·0	19·6	59·2		23·8	40·2	3·0				1·
P4	16·1	2·8	35·4	87·8	8	91·5	16·0	66·7	10	21·2	46·7	4·8	2·7			1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 87

Date 1 200978 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7 10			20		30		40		50		60		70		80	
INF	16·1		294·0		150		45·0		400	36·8		0·0	0·0			1·
S1			185·4	36·9	108	28·0	32·9	26·9								1·
S2			138·9	52·8	68	54·7	26·2	41·8								1·
S3			54·6	81·4	48	68·0	23·2	48·4								1·
S4	13·7	5·2	71·1	75·8	58	61·3	18·6	58·7	390	25·4	31·0	7·2	2·3			1·
M1			167·7	43·0	76	49·3	30·2	32·9								1·
M2			124·8	57·6	64	57·3	24·2	46·2		33·0	10·3	1·8				1·
M3			89·4	69·6	54	64·0	20·5	54·4								1·
M4	13·3	4·9	64·5	78·1	50	66·7	18·5	58·9	10	25·0	32·1	4·4	1·1			1·
P1			210·0	28·6	76	49·3	31·8	29·3								1·
P2			102·9	65·0	62	58·7	27·2	39·6								1·
P3			110·7	62·4	60	60·0	22·8	49·3								1·
P4	14·4	5·1	52·5	82·1	46	69·3	18·0	60·0	90	27·0	26·6	3·6	0·7			1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 88

Date 290978

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7 10			20	30			40		50		60		70		80	
INF	15.4		154.2		88								0.0			
S1																
S2																
S3																
S4	13.0	5.5	20.4	86.8	14	84.1							1.2			
M1																
M2																
M3																
M4	12.4	5.3	15.3	90.1	18	79.6							1.4			
P1																
P2																
P3																
P4	12.9	4.8	14.7	90.5	22	75.0							0.35			

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 89

1 6
Date 041078

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7 10			20		30		40		50		60		70		80	
INF	15.2		230.4		168		45.6		548	33.2		1.2	0.0			
S1			156.6	32.0	100	40.5	34.2	25.0								
S2			57.0	75.3	48	71.4	18.8	58.8								
S3			34.8	84.9	30	82.1	8.4	81.6								
S4	12.2	4.5	40.2	82.6	34	79.8	17.4	61.8	294	22.8	31.3	8.0	3.2			
M1			105.6	54.2	66	60.7	29.8	34.7								
M2			74.1	67.8	52	69.1	21.8	52.2		30.2	9.0	2.0				
M3			52.2	77.4	38	77.4	16.2	64.5								
M4	11.3	5.0	31.8	86.2	30	82.1	16.2	64.5	340	23.4	29.5	7.8	3.1			
P1			148.2	35.7	72	57.1	31.0	32.0								
P2			40.2	82.6	34	79.8	18.6	59.2								
P3			54.3	76.4	30	82.1	17.4	61.8								
P4	2.6	6.	[illegible].9	89.2	1[illegible]	89.[illegible]	15.8	65.[illegible]	44[illegible]	2[illegible]	[illegible]1.9	5.[illegible]	1.[illegible]			

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 90

Date 1 201079 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF			267.6		160											
S1																
S2																
S3																
S4					42	73.8										
M1																
M2																
M3																
M4			25.8	90.4	32	80.0										
P1																
P2																
P3																
P4			25.7	26.7	32	80.0										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 91

Date 1 251078 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
1NF	14.9		251.4		136		45.9		550	30.6		0.0				1.
S1			164.7	34.5	86	36.8	29.8	35.1		28.0	8.5	1.0				
S2			112.5	55.3	64	52.9	29.6	35.5		27.0	11.8	1.6				
S3			38.7	84.6	34	75.0	18.2	60.4		23.4	23.5	1.8				
S4	13.9	5.3	39.6	84.3	38	72.1	17.0	63.0	110	21.0	31.4	3.2				1.
M1			121.2	51.8	72	47.1	28.5	37.9		30.8	0.0	1.2				
M2			88.8	64.7	60	55.9	23.4	49.0		33.8	0.0	1.6				
M3			50.7	79.8	42	69.1	18.6	59.5		32.0	0.0	2.2				
M4	13.6	6.0	34.8	86.2	38	72.1	16.8	63.4	110	23.4	23.5	3.8				1.
P1			162.3	35.4	76	44.1	30.4	33.8		28.0	8.5	0.2				
P2			75.3	70.1	56	58.8	21.4	53.4		33.0	0.0	1.0				
P3			34.5	86.3	32	76.5	17.2	62.5		21.4	30.1	2.2				
P4	14.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15.8	65.[illegible]	60	24.4	20.3	3.8				1.

CHEMICAL ANALYSIS
(Treeton. Experimental Filters)

Sheet No. 92

Date 1 081178 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	14·8		261·6		120		43·4		338	35·0		1·0	0·0	6·6		1·1
S1			156·9	40·0	84	30·0	27·3	37·1		33·0	5·7	1·4		7·1		1·1
S2			126·6	51·6	78	35·0	25·9	40·3		36·0	0·0	0·8		7·2		1·
S3			50·7	80·6	40	66·7	12·0	72·4		31·8	9·1	1·6		7·3		1·
S4	13·4	5·2	41·4	84·2	54	55·0	11·7	73·0	25	26·2	25·1	3·0	8·5	7·1		1·
M1			161·1	38·4	90	25·0	34·5	20·5		34·0	2·9	1·6		7·0		1·
M2			93·9	64·1	70	41·7	22·6	47·9	95	31·4	10·3	1·0		7·2		1·
M3			44·7	82·9	40	66·7	13·5	68·9		34·0	2·9	1·0		7·2		1·
M4	13·5	5·2	29·7	88·7	44	63·3	11·5	73·5	20	25·8	26·3	3·8	4·8	7·4		1·
P1			166·2	36·5	76	36·7	27·8	36·0		37·6	0·0	1·4		7·3		1·
P2			82·2	68·6	78	35·0	26·5	38·9		36·4	0·0	0·6		6·8		1·
P3			41·7	84·1	44	63·3	14·6	66·4		26·0	25·7	2·6		6·9		1·
P4	13·4	5·7	29·6	[illegible]·9	116	61·7	12·2	71·9	115	27·6	21·1	2·4	5·5	6·8		1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 93

1 6
Date 171178

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	14·8		256·8		104										200	
S1																
S2																
S3																
S4	12·2	5·6	53·4	79·2	38	63·5									34	
M1																
M2																
M3																
M4	12·1	4·6	21·6	91·6	20	80·8									20	
P1																
P2																
P3																
P4	12·1	5·6	35·1	86·3	38	63·5									31	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 94

Date 1 29 11 78 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	11·5		208·2		84		45·2		425	34·8		0·0	0·2		240	0·
S1			198·0	4·9	46	45·2	32·5	28·1							160	0·
S2			120·3	42·2	48	42·9	30·8	31·9							116	0·
S3			54·0	74·1	28	66·7	20·1	55·5							66	0·
S4	7·7	5·2	42·9	79·4	28	66·7	17·1	62·2	292	32·4	6·9	1·4	3·3		43	0·
M1			149·1	28·4	50	40·5	33·9	25·0							150	0·
M2			88·2	57·6	32	61·9	26·0	42·5		36·2	0·0	0·2			95	0·
M3			46·8	77·5	18	78·6	19·6	56·6							48	0·
M4	7·4	4·8	25·2	87·9	18	78·6	16·9	62·6	154	31·0	10·9	3·4	2·9		36	0·
P1					54	35·7	38·3	15·3							160	0·
P2			108·3	48·0	54	35·7	36·9	18·4							114	0·
P3			66·6	68·0	28	66·7	22·8	49·6							66	0·
P4	7·5	5·3	33·2	84·0	16	81·0	18·5	59·1	88	30·6	12·1	01·8	3·2		40	0·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 95

1 6
Date 081278

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	9.5		112.2		134											
S1																
S2																
S3																
S4	8.0	5.7	8.4	92.5	32	76.1										
M1																
M2																
M3																
M4	8.2	6.0	9.3	91.7	24	82.1										
P1																
P2																
P3																
P4	7.9	5.[illegible]	[illegible].1	9[illegible].[illegible]	30	7[illegible].[illegible]										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 96

Date 1 131278 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Condu
INF			107·4		126											
S1																
S2																
S3																
S4			17·6	83·6	28	77·8										
M1																
M2																
M3																
M4			10·0	90·7	20	84·1										
P1																
P2																
P3																
P4			11·[illegible]	8[illegible]·[illegible]	[illegible]	[illegible]										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 97

1 6
Date 28 12 78

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7	10		20		30		40		50		60		70		80	
INF	8·2		42·6		66		11·0			7·0		6·0	1·5			0·
S1			41·7	2·1	16	75·8	7·5	31·5								0·
S2			37·2	12·7	14	78·8	6·9	37·1								0·
S3			14·1	66·9	2	97·0	5·7	48·2								0·
S4	8·3	5·9	13·8	67·6	2	97·0	6·4	41·6		0·8	88·6	9·4	7·8			0·
M1			17·1	59·9												0·
M2			12·0	71·8	6	90·9	6·1	44·2								0·
M3			8·7	79·6	4	93·9	7·6	31·3		3·2	54·3	6·2				0·
M4	8·2	5·2	7·8	81·7	1	98·5	5·8	47·6		0·2	97·1	8·4	2·8			0·
P1			26·1	38·7	16	75·8	7·3	33·5								0·
P2			24·9	41·6	8	87·9	6·9	37·5								0·
P3			10·5	75·4	6	90·9	6·5	40·6								0·
P4	8·3	5·0	10·5	75·4	2	97·0	5·9	46·0		1·0	85·7	8·0	8·1			0·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 98

Date 050179

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20		30		40		50		60		70		80	
INF	7·5		189·0		84					19·0		2·8		7·2	80	1·
S1																
S2																
S3																
S4	3·9	4·2	28·8	84·8	18	78·6				13·4	29·5	7·4		7·0	12	1·
M1																
M2																
M3																
M4	4·1	5·9	18·9	90·0	16	81·0				12·8	32·6	5·6		7·2	7	1·
P1																
P2																
P3																
P4														7·1	6	1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 99

Date 170179

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7	10		20		30		40		50		60		70		80	
1NF	7.9		159.0		86		31.2		350	25.2		2.8	0.1	7.1		0.
S1			142.5	10.4	82	4.7	11.4	63.5		21.2	15.9	2.4		7.4		1.
S2			75.6	52.5	40	53.5	8.9	71.5		26.0	0.0	1.2		7.2		1.
S3			14.7	90.8	20	76.7	4.9	84.3		24.2	4.0	3.2		7.2		1.
S4	6.2	5.7	24.6	84.5	20	76.7	7.3	76.6	250	24.0	4.8	4.2	2.8	7.1		1.
M1			120.6	24.2	64	25.6	13.0	58.3		25.4	0.0	1.6		7.0		1.
M2			89.1	44.0	52	39.5	9.3	70.2		26.6	0.0	2.4		7.1		1.
M3			15.0	90.6	20	76.7	5.2	83.3		24.2	4.0	4.0		7.2		1.
M4	5.0	5.8	17.1	89.3	18	79.1	5.2	83.3	195	22.2	11.9	5.0	2.8	7.2		1.
P1			112.5	29.3	58	32.6	13.4	57.1		28.0	0.0	0.4		7.2		1.
P2			62.4	60.8	36	58.1	8.4	73.1		27.6	0.0	0.8		7.1		1.
P3			18.9	88.1	18	79.1	5.4	82.7		27.4	0.0	1.0		7.3		1.
P4	5.0	5.[illegible]	15.9	90.[illegible]	[illegible]	72.1	[illegible].6	85.3	180	25.8	[illegible]	[illegible].8	2.[illegible]	7.2		1.

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 100

Date 1 31 01 79 6

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	7·3		120·0		112		22·3		338	16·6		4·0	1·0	6·9	100	1·
S1																
S2																
S3																
S4	5·2	5·0	26·1	78·3	34	69·6	8·6	61·4	145	17·2	0·0	5·0	2·2	6·9	10	1·
M1																
M2																
M3																
M4	5·3	5·2	20·1	83·3	36	67·9	8·3	62·8	90	16·0	3·6	5·0	2·4	6·9	13	1·
P1																
P2																
P3																
P4	5·	5·	1·3	·	3	6	·7	65·	12	16·	·4	6·	5·	6·8	[illegible]	1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 101

Date 1 070279 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7 10			20		30		40		50		60		70		80	
INF	7·3		125·4		88		21·7		538	17·8		6·6	0·0	7·0	105	1·
S1																
S2																
S3																
S4	5·2	5·2	18·3	85·4	18	79·6	7·3	66·2	185	10·8	39·3	6·0	2·4	6·9	13	1·
M1																
M2																
M3																
M4	5·1	5·0	0·9	99·3	16	81·8	6·7	69·0	90	11·2	37·1	7·8	1·9	7·0	7	1·
P1																
P2																
P3																
P4	[illegible]	[illegible]·7	5·7	95·5	16	81·0	6·9	68·1	9[illegible]	[illegible]	[illegible]3·8	8·[illegible]	2·0	7·1	9	1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 102

Date 1 6 160279

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	6·5				60					16·6		5·0	0·2	7·3		1·
S1																
S2																
S3																
S4	3·6	5·0			22	63·3				17·0	0·0	5·6	1·2	7·1		1·
M1																
M2																
M3																
M4	3·7	5·5			18	70·0				14·8	10·8	7·2	1·2	7·1		1·
P1																
P2																
P3																
P4	3·7	[illegible]			16	73·[illegible]				17·0	[illegible]	5·[illegible]	2·[illegible]	7·[illegible]		1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 103

Date 1 6 21 02 79

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20	30			40		50		60		70		80	
INF	7·1		173·4		184		33·9		275	23·8		3·4	3·2	6·8	97	1·
S1			94·8	45·3	64	65·2	13·6	59·9		21·8	8·4	0·4		7·0	69	1·
S2			25·8	85·1	26	85·9				27·6	0·0	1·0		7·1	19	1·
S3			8·4	95·2	12	93·5	5·6	83·5		16·0	32·8	4·0		7·7	4	1·
S4	6·2	5·1	26·1	85·0	20	89·1	6·6	80·5	95	16·0	32·8	4·8	2·7	6·9	10	1·
M1			67·5	61·1	48	73·9	20·2	40·4		28·2	0·0	0·8		7·0	56	1·
M2			43·2	75·1	40	78·3	8·7	74·3	106	20·0	16·0	0·8		7·2	30	1·
M3			13·5	92·2	10	94·6	7·2	78·8		19·8	16·8	2·2		7·2	7	1·
M4	5·1	5·3	21·9	87·4	14	92·4	6·0	82·3	95	15·6	34·5	6·2	2·2	7·0	8	1·
P1			84·3	51·4	66	64·1	15·2	55·2		24·4	0·0	0·6		6·9	80	1·
P2			40·5	76·6	12	93·5	10·5	69·0		14·0	41·2	0·8		7·0	29	1·
P3			19·5	88·8	10	94·6	7·0	79·4		15·4	35·3	2·6		7·0	4	1·
P4	5·0	5·[illegible]	11·7	93·[illegible]	1[illegible]	94·6	6·6	80·[illegible]	80	1[illegible]·6	38·7	4·[illegible]	3·0	7·0	[illegible]	1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 104

1 6
Date 140379

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7	10		20	30			40		50		60		70		80	
INF	7·9		93·0		58		17·5		325	17·2		3·0	0·3	6·9	82	0·
S1			75·0	19·4	34	41·4	13·9	20·6		15·2	11·6	0·0		6·9	50	0·
S2			41·1	55·8	24	58·6	9·3	46·9		17·8	0·0	1·2		6·8	33	0·
S3			13·5	85·5	14	75·9	6·9	60·6		14·0	18·6	2·8		6·8	7	0·
S4	6·5	5·7	14·1	84·8	14	75·9	6·5	62·9	160	14·0	18·6	6·4	3·5	6·6	9	0·
M1			48·3	48·0	26	55·2	22·3	0·00		15·8	8·1	1·0		6·8	38	0·
M2			25·5	72·6	18	69·0	9·3	46·9	370	18·0	0·6	1·4		7·0	20	0·
M3			19·5	79·0	12	79·3	7·9	54·9		15·0	12·8	1·8		6·9	10	0·
M4	6·0	5·7	11·4	87·7	14	75·9	7·1	59·4	60	12·0	30·2	6·6	2·4	6·7	5	0·
P1			70·5	24·2	38	34·5	12·1	30·9		22·0	0·0	0·4		6·8	56	0·
P2			39·6	57·4	18	69·0	9·7	44·6		20·0	0·0	0·8		6·8	28	0·
P3			12·6	86·5	8	86·2	6·5	62·9		16·0	7·0	3·8		6·9	4	0·
P4	5·7	5·9	12·6	86·5	12	79·3	6·5	62·9	570	14·0	18·6	5·8	3·2	6·8	7	0·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 105

Date 1 230379 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7	10		20	30			40		50		60		70		80	
INF	7·5		81·6		54		13·8						0·0	7·6	54	1·
S1																
S2																
S3																
S4	5·9	6·0	5·4	93·4	28	48·2	7·6	44·9					1·70	7·2	8	1·
M1																
M2																
M3																
M4	5·2	5·3	3·6	95·6	16	70·4	4·6	66·7					0·85	7·3	6	1·
P1																
P2																
P3																
P4	5·7	5·2	5·1	93·8	12	77·8	6·6	52·2					0·35	7·4	4	1·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 106

Date 1 280379 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7 10			20		30		40		50		60		70		80	
INF	6·9				58		7·2		38	6·4		9·8	0·0	6·6	58	0·
S1																
S2																
S3																
S4		4·4			24	58·6	3·6	50·0	55	4·2	34·4	13·8	1·70	6·7	8	0·
M1																
M2																
M3																
M4		4·7			18	69·0	3·4	52·8	75	4·0	37·5	14·0	2·4	6·8	4	0·
P1																
P2																
P3																
P4		4·7			20	65·5	3·2	55·6	35	3·8	40·6	[illegible]	1·4	6·9	3	0

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 107

Date 1 040479 6

Ref. 7 10	Temp.	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Cond
INF	8.2		87.0		66					11.2		4.0			64	0.
S1																
S2																
S3																
S4	6.7	5.8	15.9	81.7	22	66.7				9.4	16.1	9.6			10	0.
M1																
M2																
M3																
M4	6.7	4.6	11.7	86.6	16	75.8				8.6	23.2	9.6			7	0.
P1																
P2																
P3																
P4	6.9	[illegible].6	5.9	1.[illegible]	18	72.7				11.0	1.8	5.[illegible]			6	0.

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 108

Date 1 1 0 4 7 9
1 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7	10		20		30		40		50		60		70		80	
INF	8·4		109·2		152		28·4		300	10·4		7·8	2·6	7·2	118	0·
S1			43·2	60·4	46	69·7	13·4	52·8		14·0	0·0	7·0		7·3	63	0·
S2			21·6	80·2	30	80·3	10·8	62·0		14·4	0·0	5·8		7·2	28	0·
S3			9·6	91·2	22	85·5	6·0	78·9		10·4	0·0	7·0		6·8	8	0·
S4	9·2	6·0	9·3	91·5	26	82·9	6·4	77·5	78	4·0	61·5	12·4	4·4	6·7	12	0·
M1			28·5	73·9	36	76·3	23·2	18·3		11·2	0·0	2·0		7·3	37	0·
M2			15·3	86·0	18	88·2	6·4	77·5	116	11·6	0·0	6·0		7·3	10	0·
M3			8·4	92·3	20	86·8	5·8	79·6		8·0	23·1	8·0		7·0	7	0·
M4	9·2	6·4	5·1	95·3	22	85·5	5·4	81·0	76	2·6	75·0	9·0	4·0	6·8	8	0·
P1			27·0	75·3	42	72·4	9·4	66·9						7·3	49	0·
P2			29·4	73·1	36	76·3	7·1	75·0						7·4	24	0·
P3			15·0	86·3	20	86·8	6·3	77·8						7·1	9	0·
P4	9·[illegible]	5·9	11·[illegible]	89·[illegible]	2[illegible]	8[illegible]	6·3	77·8	[illegible]	[illegible]·0	61·[illegible]	7·0	8·5	6·9	8	0·

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 109

Date 250479

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Con
7	10		20		30		40		50		60		70		80	
INF	10·2		130·8		126				1405	15·4		15·5	3·2	6·8	92	0·
S1																
S2																
S3																
S4	7·9	5·2	20·1	84·6	20	84·1			180	16·4	0·00	7·0	2·5	7·0	10	0·
M1																
M2																
M3																
M4	7·2	5·7	14·4	89·0	20	84·1			52	15·2	1·3	8·6	2·9	7·0	11	0·
P1																
P2																
P3																
P4	8·7	4·9	4·5	96·6	20	84·1			128	17·4	0·00	5·0	4·6	7·1	8	0

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 110

Date 1 6 110579

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Con
7	10		20		30		40		50		60		70		80	
INF	11·8		186·0		170								3·5	7·6	150	
S1																
S2																
S3																
S4	12·0	5·0	36·3	80·5	32	81·2							6·1	7·3	21	
M1																
M2																
M3																
M4	12·2	6·0	30·0	83·9	26	84·7							4·5	7·3	16	
P1																
P2																
P3																
P4	12·[illegible]	[illegible]	[illegible]	86·[illegible]	[illegible]	[illegible]							6·0	7·[illegible]	10	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 111

Date 1 230579 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Cond
7 10			20		30		40		50		60		70		80	
INF	12·3		103·5		76					15·8		5·2	0·0	6·8	69	0·
S1			76·1	26·5	48	36·8				12·4	21·5	0·4		6·9	52	0·
S2			29·7	71·3	32	57·9				11·8	25·3	2·4		7·0	24	0·
S3			12·6	87·8	26	65·8				11·0	30·4	4·2		7·1	7	0·
S4	11·0	5·5	14·0	89·5	26	65·8				17·6	0·0	11·8	2·4	7·0	6	0·
M1			51·8	50·0	74	2·6				16·2	0·0	2·8		7·4	84	0·
M2			58·5	43·5	56	26·3				13·8	12·7			7·3	66	0·
M3			16·2	84·4	28	63·2				6·0	62·0	8·2		7·2	31	0·
M4	10·2	5·5	14·9	85·6	20	73·7				5·2	67·1	16·0	12·0	7·1	40	0·
P1			44·6	56·9	24	68·4				14·8	6·3			7·1	34	0
P2			32·9	68·2	20	73·7				12·6	20·3	2·0		7·1	18	0
P3			36·0	65·2	32	57·9				11·8	25·3	3·4		7·1	31	0
P4	10·8	5·0	36·7	64·5	30	60·5				15·6	11·3	6·0	3·8	7·1	33	0

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 112

Date 1 250579 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conc
7	10		20		30		40		50		60		70		80	
INF	13·8		165·8		100									7·0	101	
S1																
S2																
S3																
S4	11·7	5·7	34·0	79·5	18	82·0								7·2	12	
M1																
M2																
M3																
M4	11·6	4·8	37·2	77·6	24	76·0								7·1	27	
P1																
P2																
P3																
P4	15·0	6·[illegible]	50·[illegible]	69·6	[illegible]	5[illegible]·[illegible]								7·4	52	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 113

Date 1 06067

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Co
7	10		20		30		40		50		60		70		80	
INF			191.4		124				470	29.6		1.2	0.3	6.7	116	
S1																
S2																
S3																
S4	13.0	5.7	62.7	47.2	66	46.8			288	25.8	12.8	8.4	2.1	6.9	70	
M1																
M2																
M3																
M4	13.1	5.3	60.3	68.5	60	51.6			226	19.8	33.1	7.8	2.1	6.9	64	
P1																
P2																
P3																
P4	1[illegible].4	5.9	[illegible]6.[illegible]	60.[illegible]	6[illegible]	48.[illegible]			360	[illegible]8.[illegible]	1[illegible].[illegible]	1.6	1.4	7.1	76	

1

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 114

Date 130667

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Co
INF	14.1		185.7		92		32.8		2690	26.6		3.2	0.75	6.9	107	0
S1			148.5	20.0	36	60.9	27.1	17.4		24.4	8.3	0.4		7.4	46	1
S2			60.0	67.7	36	60.9	17.2	47.6		28.0	0.0	0.4		7.0	35	0
S3			40.5	78.2	46	50.0	14.3	56.4		27.0	0.0	1.6		7.0	26	0
S4	14.4	6.2	46.2	75.1	40	56.5	13.4	59.2	148	23.4	12.0	7.0	3.4	6.9	22	0
M1			102.0	4.5	96	0.0	31.5	4.0		33.8	0.0	0.4		7.2	84	1
M2			70.8	61.9	56	39.1	19.7	39.9		26.2	1.5	4.0		7.0	57	0
M3			52.5	71.7	46	50.0	17.6	46.3		25.4	4.5	2.6		7.0	34	0
M4	14.3	5.4	52.5	71.7	44	52.2	16.8	48.8	188	22.4	15.8	13.2	2.4	6.9	30	0
P1			108.6	41.5	68	26.1	22.6	31.1		24.4	8.3	3.0		7.1	68	0
P2			89.4	51.9	68	26.1	19.5	40.6		23.0	13.5	1.4		7.2	32	0
P3			53.4	71.2	50	45.7	17.2	47.6		27.6	0.0	3.6		7.1	27	c
P4	14.	.9	5.	0.	4	50.	16 4	0 0	180	.6	0.	.	2.	7.	23	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 115

1
Date 27067

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Co
7	10		20		30		40		50		60		70		80	
INF	15·8		260·4		160										210	
S1																
S2																
S3																
S4	13·9	6·3	32·4	87·6	22	86·3									48	
M1																
M2																
M3																
M4	14·0	4·8	39·3	84·9	34	78·8									66	
P1																
P2																
P3																
P4	15·5	5·7	48·0	81·6	44	72·5									78	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 116

Date 1 0407

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Co
7	10		20		30		40		50		60		70		80	
INF	16.6		228.0		132					25.6		0.0	0.15		170	
S1																
S2																
S3																
S4	15.2	6.5	45.9	79.9	56	57.6				17.2	32.8	3.0	2.1		48	
M1																
M2																
M3																
M4	15.5	6.3	50.7	77.8	56	57.6				20.0	21.9	5.4	1.6		68	
P1																
P2																
P3																
P4	16.2	5.5	51.2	77.5	62	54.2				24.4	41.7	0.6	0.8		69	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 117

Date 1 11077

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem..	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Co
7	10		20		30		40		50		60		70		80	
INF	16·2		452·4		220		56·6			29·4		0·0	0·60	6·1	210	1
S1			259·0	42·8	132	40·0	44·6	21·2		28·8	2·0	1·0		6·7	175	0
S2			140·4	69·0	64	70·9	31·5	44·4		24·0	18·4	1·6		7·0	88	0
S3			59·7	86·8	30	86·4	20·8	63·3		25·8	12·3	2·4		6·8	58	0
S4	16·0	6·9	53·7	88·1	26	88·2	19·3	65·9		21·0	28·6	2·2	5·3	6·7	38	0
M1			239·7	47·0	92	58·2	39·2	30·7		27·4	6·8	1·2		7·0	145	1
M2			125·4	72·3	66	70·0	28·3	50·0		24·2	17·7	2·0		6·8	111	0
M3			70·5	84·4	52	76·4	25·1	55·7		23·8	19·1	2·8		6·6	85	0
M4	16·0	5·2	63·6	85·9	50	77·3	21·9	61·3		16·2	44·9	4·8	2·6	6·7	60	0
P1			238·2	47·4	102	53·6	36·9	34·8		24·2	17·7	0·0		6·9	145	0
P2			48·6	89·3	46	79·1	20·2	64·3		24·8	15·7	0·0		7·0	64	0
P3			118·2	73·9	106	51·8	28·0	50·5		25·0	15·0	0·0		7·0	130	0
P4	[illegible]	[illegible]	[illegible]·2	87·1	[illegible]8	78·[illegible]	[illegible]·3	60·6		26·[illegible]	11·6	0·0	1·8	6·8	59	0

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 118

1
Date 27077

Ref. 7	Temp. 10	Flow	B.O.D. 20	%Rem.	S/S 30	%Rem.	P.V. 40	%Rem.	C.O.D. 50	Amm.	%Rem. 60	T.O.N.	Sludge 70	P.H.	Turbid. 80	Co
INF	17.0		259.8		140					20.4		0.0			230	
S1																
S2																
S3																
S4	16.8	5.9	51.3	80.3	32	77.1				19.0	6.7	0.6			61	
M1																
M2																
M3																
M4	17.1	5.4	36.3	86.0	24	82.9				16.6	18.6	1.4			42	
P1																
P2																
P3																
P4	17.1	5.7	40.2	84.5	36	74.3				24.2	0.0	0.6			44	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 119

1
Date 0108

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Co
7	10		20		30		40		50		60		70		80	
INF	17.5		246.0		114					19.2		0.0			270	
S1																
S2																
S3																
S4	15.2	5.2	41.1	83.3	30	73.7				17.4	9.4	1.6			68	
M1																
M2																
M3																
M4	15.2	5.5	33.9	86.2	18	84.2				14.2	26.0	2.0			44	
P1																
P2																
P3																
P4	15.5	5.2	30.[illegible]	87.2	30	73.7				17.4	9.4	1.2			37	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 120

Date 1 0808 7

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Con
7	10		20		30		40		50		60		70		80	
INF	17·2		184·8		114		66·6			18·8		0·0	0·0	7·2	170	0
S1			152·4	17·5	88	22·8	53·0	20·4		14·0	25·5	0·0		7·2	108	0·
S2			57·6	68·8	58	49·1	37·2	44·1		18·6	1·1	0·2		7·1	65	0·
S3			40·5	78·1	46	59·7	27·5	58·7		19·6	0·0	0·2		7·1	41	0
S4	14·2	5·4	32·7	82·3	40	64·9	28·4	57·4		19·0	0·0	0·6	5·6	7·0	40	0
M1			123·0	33·4	80	29·8	46·0	30·9		17·8	5·3	0·2		7·2	98	0·
M2			49·5	73·2	52	54·4	32·8	50·8		21·2	0·0	0·6		7·2	44	0
M3			20·7	88·8	36	68·4	25·5	61·7		18·6	1·1	1·4		7·2	18	0
M4	13·4	5·4	12·9	93·0	24	79·0	24·3	63·5		15·2	19·2	2·8	3·6	7·1	15	0
P1			122·7	33·6	70	38·6	35·0	47·5		17·2	8·5	0·0		7·1	86	0
P2			43·4	76·5	42	63·2	32·7	50·9		25·2	0·0	0·0		7·1	42	0
P3			12·6	93·2	26	77·2	22·2	66·7		23·2	0·0	0·0		7·0	9	0
P4	14·9	5·[illegible]	[illegible]5·[illegible]	86·4	2[illegible]	80·7	[illegible]5·8	61·2		20·4	0·[illegible]	0·[illegible]	4·5	6·9	22	0

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 121

Date 29087

1

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Con
7	10		20		30		40		50		60		70		80	
INF	16·6		201·0		150										205	
S1																
S2																
S3																
S4	14·2	5·5	52·0	74·1	42	72·0									69	
M1																
M2																
M3																
M4	14·3	5·5	22·4	88·9	20	86·7									32	
P1																
P2																
P3																
						0·0										

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 122

Date 01097

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Con
7	10		20		30		40		50		60		70		80	
1 NF			198.4		152										205	
S1																
S2																
S3																
S4		5.4	50.5	74.6	34	77.6									52	
M1																
M2																
M3																
M4		5.2	18.0	90.9	24	84.2									26	
P1																
P2																
P3																
P4		5.2	44.0	27.9	30	80.2									32	

CHEMICAL ANALYSIS
(Treeton Experimental Filters)

Sheet No. 123

Date 1 050979 6

Ref.	Temp.	Flow	B.O.D.	%Rem.	S/S	%Rem.	P.V.	%Rem.	C.O.D.	Amm.	%Rem.	T.O.N.	Sludge	P.H.	Turbid.	Conduct.
7	10		20		30		40		50		60		70		80	
INF	16·9		247·2		124		37·3		430	21·6		0·0	0·05	6·7	205	
S1			222·0	10·2	86	30·7	27·6	26·0	385	22·7	0·0	0·0		7·0	145	
S2			99·9	59·6	60	51·6	22·4	40·0	259	25·2	0·0	0·0		6·9	100	
S3			46·5	81·2	54	56·5	17·6	52·8	173	27·5	0·0	0·2		7·0	72	
S4	15·6	5·4	38·1	84·6	38	69·4	17·4	53·4	155	19·1	11·6	2·8	2·1	6·8	55	
M1			104·4	57·8	58	53·2	19·4	48·0	309	28·0	0·0	0·0		7·2	88	
M2			165·0	33·3	40	67·7	18·4	50·7	219	27·0	0·0	0·0		7·2	74	
M3			17·1	93·1	24	80·7	12·4	66·8	125	25·0	0·0	0·6		7·5	22	
M4	15·5	5·2	25·5	89·7	26	79·0	13·0	65·2	141	16·2	25·0	3·6	4·1	6·7	23	
P1			144·0	41·8	54	56·5	19·5	47·7	309	24·4	0·0	0·0		7·1	112	
P2			101·7	58·9	76	38·7	20·0	46·4	221	25·6	0·0	0·0		7·1	74	
P3			26·4	89·3	14	88·7	12·6	66·2	108	18·0	17·1	0·0		7·0	20	
P4	16·0	5·3	20·1	91·9	20	83·9	14·1	62·2	115	22·4	0·0	0·6	2·6	7·0	24	

SOLIDS OCTOBER 1977

Medium	Depth cm	Total film kgm-3	Total Solids kgm-3	Volatile Solids kgm-3	Percentage Settlement
Slag	0-30		4.12	3.08	8.8
	30-60		5.40	4.04	10.4
	60-90		5.04	3.64	10.4
	90-120		4.28	3.56	12.8
	120-150		3.56	2.84	10.4
	150-180		1.52	1.16	4.8
Mixed	0-30		7.12	6.00	13.6
	30-60		6.28	5.24	12.8
	60-70		9.44	7.60	20.0
	70-80		14.20	11.08	27.6
	80-90		10.76	4.36	21.6
	90-120		13.76	10.28	31.6
	120-150		10.36	7.60	22.8
	150-180		4.12	3.28	11.2
Plastic	0-30		11.64	9.64	21.6
	30-60		11.00	8.40	26.0
	60-90		4.96	3.88	12.0
	90-120		5.40	4.24	13.6
	120-150		4.36	3.56	12.4
	150-180		4.20	3.48	12.0

SOLIDS NOVEMBER 1977

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30		6.96	5.24	8.4
	30-60		5.12	3.68	8.4
	60-90		13.32	9.92	22.8
	90-120		12.36	9.16	20.0
	120-150		9.92	7.12	18.0
	150-180		4.32	3.08	8.4
Mixed	0-30		16.60	12.00	29.6
	30-60		18.88	13.92	42.4
	60-70		22.56	17.24	54.0
	70-80		10.64	8.04	20.8
	80-90		12.68	9.44	28.8
	90-120		12.60	9.24	29.6
	120-150		8.08	5.16	18.8
	150-180		4.68	3.08	11.6
Plastic	0-30		12.96	9.52	22.0
	30-60		17.16	13.36	21.6
	60-90		8.12	6.60	16.0
	90-120		11.56	9.08	22.8
	120-150		10.16	8.04	18.8
	150-180		4.28	3.24	12.0
Slag S1	0-30		6.96	5.24	8.4
SR	0-30		8.04	5.52	11.6
SC	0-30		7.08	4.96	11.2
SL	0-30		8.16	5.76	12.0
Mixed M1	0-30		16.60	12.00	29.6
MR	0-30		15.16	10.68	27.2
MC	0-30		13.00	9.60	22.4
ML	0-30		14.12	10.24	22.8
Plastic P1	0-30		12.96	9.52	22.0
PR	0-30		14.80	10.60	19.6
PC	0-30		13.84	10.24	20.8
PL	0-30		11.68	8.48	13.6

SOLIDS DECEMBER 1977

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	139.12	6.04	4.60	9.6
	30-60	178.44	6.60	4.84	10.8
	60-90	338.80	15.76	11.60	22.4
	90-120	521.60	29.20	21.44	52.0
	120-150	310.64	15.68	10.88	21.6
	150-180	157.04	5.68	3.84	12.0
Mixed	0-30	118.08	7.76	6.36	15.2
	30-60	84.36	5.16	4.44	8.4
	60-70	77.56	4.92	3.72	6.8
	70-80	106.08	5.32	4.12	7.2
	80-90	181.12	5.76	4.16	7.2
	90-120	198.64	9.88	7.20	13.6
	120-150	225.56	11.20	7.88	18.0
	150-180	172.96	6.40	4.08	10.4
Plastic	0-30	314.92	21.28	16.44	37.2
	30-60	161.68	9.32	7.36	15.6
	60-90	152.04	8.28	6.44	13.6
	90-120	168.00	10.56	7.76	18.4
	120-150	173.84	9.60	7.08	17.2
	150-180	186.04	11.36	8.24	18.8

SOLIDS JANUARY 1978

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	366.76	16.84	11.84	26.8
	30-60	293.12	11.28	7.68	14.8
	60-90	245.56	9.44	5.92	13.6
	90-120	433.72	23.52	16.56	30.4
	120-150	364.68	15.88	10.80	23.2
	150-180	307.52	12.48	8.28	21.6
Mixed	0-30	234.00	15.20	11.32	24.0
	30-60	102.36	6.80	5.16	10.4
	60-70	79.56	5.08	4.20	8.0
	70-80	104.92	2.84	2.16	4.0
	80-90	116.84	2.04	1.44	3.6
	90-120	140.28	2.32	1.44	3.2
	120-150	176.92	4.20	2.52	7.6
	150-180	99.00	2.52	1.56	3.2
Plastic	0-30	198.80	12.44	9.00	18.0
	30-60	70.04	3.40	2.56	4.8
	60-90	125.04	9.28	6.68	12.0
	90-120	152.44	10.24	7.48	13.6
	120-150	147.60	9.80	7.16	14.0
	150-180	179.32	11.48	8.20	17.2
Slag S1	0-30	366.76	16.84	11.84	26.8
SR	0-30	289.80	9.92	6.80	15.2
SC	0-30	277.44	12.80	9.00	20.0
SL	0-30	357.16	12.20	8.76	22.4
Mixed M1	0-30	234.00	15.20	11.32	24.0
MR	0-30	216.12	13.60	9.68	22.0
MC	0-30	163.44	9.92	7.28	16.0
ML	0-30	209.52	14.08	9.16	24.8
Plastic P1	0-30	198.80	12.44	9.00	18.0
PR	0-30	276.80	14.64	10.40	24.8
PC	0-30	288.08	14.72	10.36	26.8
PL	0-30	296.16	15.40	10.68	24.4

SOLIDS FEBRUARY, 1978

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	318.04	14.00	10.08	22.0
	30-60	164.00	5.12	3.60	8.8
	60-90	131.68	3.72	2.72	6.4
	90-120	174.44	6.32	4.36	9.6
	120-150	335.88	14.44	9.84	22.0
	150-180	316.36	15.40	10.64	22.8
Mixed	0-30	274.76	14.88	11.16	27.2
	30-60	133.88	9.52	7.60	12.8
	60-70	97.52	5.52	4.64	8.8
	70-80	71.92	3.08	2.64	6.4
	80-90	140.44	2.40	1.84	3.2
	90-120	86.72	2.44	1.80	5.6
	120-150	136.60	3.72	2.52	3.2
	150-180	151.24	2.80	1.84	4.0
Plastic	0-30	221.80	14.28	10.44	24.8
	30-60	129.24	7.44	5.52	12.8
	60-90	101.32	5.88	4.52	10.0
	90-120	80.68	4.60	2.72	6.8
	120-150	121.52	7.20	5.16	10.8
	150-180	207.40	12.44	8.84	17.6

SOLIDS

MARCH 1978

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	396.92	20.80	15.40	31.6
	30-60	245.36	9.80	7.00	14.4
	60-90	390.80	16.68	12.36	25.6
	90-120	406.64	22.60	16.64	35.2
	120-150	551.84	27.44	20.08	37.6
	150-180	354.48	20.64	14.88	27.2
Mixed	0-30	347.16	22.88	16.52	39.2
	30-60	155.24	11.20	8.88	13.6
	60-70	156.24	10.60	7.92	16.0
	70-80	163.60	6.60	4.88	10.4
	80-90	171.04	5.52	4.32	7.6
	90-120	222.36	7.68	5.64	11.2
	120-150	219.40	9.40	6.56	14.4
	150-180	335.08	14.20	9.56	20.8
Plastic	0-30	166.32	11.60	8.96	12.0
	30-60	71.32	5.24	4.52	6.8
	60-90	76.12	5.20	4.40	6.0
	90-120	136.32	8.72	6.72	12.8
	120-150	173.80	11.60	8.52	17.2
	150-180	158.20	9.92	7.12	16.4
Slag S1	0-30	396.92	20.80	15.40	31.6
SR	0-30	375.48	18.80	13.80	26.0
SC	0-30	284.56	14.04	10.72	22.4
SL	0-30	258.16	13.40	9.88	20.4
Mixed M1	0-30	347.16	22.88	16.52	39.2
MR	0-30	146.84	9.72	7.28	13.6
MC	0-30	184.36	10.00	7.52	14.8
ML	0-30	242.96	15.80	11.96	22.0
Plastic P1	0-30	166.32	11.60	8.96	12.0
PR	0-30	271.84	14.64	11.00	19.6
PC	0-30	267.48	15.08	10.84	23.2
PL	0-30	182.52	10.84	8.20	13.2

SOLIDS

APRIL 1978

Medium	Depth cm	Total Film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	616.00	31.44	23.08	52.4
	30-60	255.32	10.12	7.12	14.8
	60-90	333.40	15.32	11.28	23.6
	90-120	301.20	14.32	10.32	21.6
	120-150	472.64	22.68	16.40	34.8
	150-180	351.84	19.72	14.24	26.8
Mixed	0-30	311.60	20.52	15.88	35.6
	30-60	120.44	6.00	4.76	8.8
	60-70	114.00	5.36	4.28	9.2
	70-80	120.08	3.92	3.16	7.2
	80-90	157.40	3.32	2.52	5.2
	90-120	172.44	4.92	3.88	8.4
	120-150	223.48	9.72	6.88	13.6
	150-180	196.44	7.12	4.88	10.8
Plastic	0-30	197.88	10.64	7.36	16.4
	30-60	87.72	3.92	3.08	5.6
	60-90	75.64	3.50	2.34	5.2
	90-120	111.32	6.16	4.80	10.8
	120-150	153.00	9.48	6.52	14.0
	150-180	121.80	7.96	5.88	12.0

SOLIDS

MAY 1978

Medium	Depth cm	Total Film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	220.96	9.48	7.28	10.4
	30-60	131.84	2.96	2.08	4.4
	60-90	154.92	3.96	2.92	4.4
	90-120	153.68	5.12	3.56	6.4
	120-150	376.84	19.52	13.60	31.6
	150-180	493.00	29.60	20.48	60.0
Mixed	0-30	202.60	12.68	8.76	17.6
	30-60	45.76	2.88	2.04	4.4
	60-90	36.80	2.16	1.84	3.6
	70-80	63.44	1.80	1.36	2.4
	80-90	110.52	2.72	2.04	4.8
	90-120	135.56	2.60	1.80	3.6
	120-150	141.44	3.52	2.16	4.4
	150-180	150.92	4.36	2.80	4.0
Plastic	0-30	97.04	5.92	4.72	6.8
	30-60	41.36	2.56	2.08	4.8
	60-90	31.92	1.52	1.24	3.2
	90-120	32.76	1.52	1.24	2.8
	120-150	53.92	3.16	2.36	5.2
	150-180	52.96	3.24	2.36	4.4
Slag S1	0-30	220.96	9.48	7.28	10.4
SR	0-30	216.72	6.72	4.80	8.4
SC	0-30	162.48	4.80	3.36	5.6
SL	0-30	260.76	9.36	6.04	7.2
Mixed M1	0-30	202.60	12.68	8.76	17.6
MR	0-30	86.44	3.80	2.80	5.6
MC	0-30	172.16	8.68	6.36	9.2
ML	0-30	126.48	6.16	4.56	6.8
Plastic P1	0-30	97.04	5.92	4.72	6.8
PR	0-30	95.32	5.20	3.68	6.4
PC	0-30	86.72	4.72	3.36	6.4
PL	0-30	128.16	6.28	4.60	9.6

SOLIDS

JUNE 1978

Medium	Depth cm	Total film kgm^{-3}	Total solids kgm^{-3}	Volatile solids kgm^{-3}	Percentage Settlement
Slag	0-30	95.92	2.80	2.36	4.0
	30-60	160.08	4.12	3.36	10.8
	60-90	146.12	1.88	1.52	4.8
	90-120	124.24	1.60	1.12	2.8
	120-150	116.16	1.48	1.04	2.4
	150-180	126.92	1.72	1.28	3.2
Mixed	0-30	34.04	2.00	1.88	3.6
	30-60	62.24	4.44	3.84	7.2
	60-70	28.68	1.12	1.04	2.4
	70-80	53.08	1.36	1.16	3.2
	80-90	96.80	1.68	1.40	3.6
	90-120	97.44	1.72	1.36	2.4
	120-150	89.08	1.04	0.76	2.0
	150-180	92.76	1.48	0.92	2.4
Plastic	0-30	51.92	3.24	2.44	3.6
	30-60	46.08	4.04	3.44	5.6
	60-90	39.12	1.88	1.44	2.8
	90-120	50.24	2.16	1.68	4.4
	120-150	52.08	2.12	1.72	4.4
	150-180	45.40	1.68	1.40	4.0

SOLIDS

JULY 1978

Medium	Depth cm	Total Film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	180.08	5.16	3.84	8.8
	30-60	183.28	4.24	3.52	5.3
	60-90	172.12	4.02	3.30	5.3
	90-120	106.48	2.44	1.80	2.9
	120-150	119.12	2.24	1.60	3.8
	150-180	175.32	5.56	3.84	8.0
Mixed	0-30	63.72	3.64	3.04	7.0
	30-60	48.44	2.40	2.12	5.2
	60-70	38.96	1.48	1.24	2.1
	70-80	80.80	1.16	0.96	2.0
	80-90	80.44	1.16	1.00	1.5
	90-120	103.36	1.00	0.76	1.4
	120-150	94.96	0.88	0.72	1.2
	150-180	136.20	2.24	1.52	3.8
Plastic	0-30	58.84	3.04	2.48	4.7
	30-60	35.08	1.44	1.32	3.1
	60-90	33.92	0.96	0.92	1.3
	90-120	28.28	0.60	0.48	0.8
	120-150	28.96	0.44	0.36	0.6
	150-180	30.28	0.72	0.56	1.2
Slag S1	0-30	180.08	5.16	3.84	8.8
SR	0-30	220.80	6.28	4.80	14.0
SC	0-30	209.72	6.80	5.24	16.8
SL	0-30	265.64	7.56	5.88	15.2
Mixed M1	0-30	63.72	3.64	3.04	7.0
MR	0-30	74.08	3.92	3.24	10.1
MC	0-30	42.28	1.92	1.64	3.2
ML	0-30	64.80	3.80	3.28	7.2
Plastic P1	0-30	58.84	3.04	2.48	4.7
PR	0-30	60.28	2.72	2.16	6.0
PC	0-30	63.08	3.56	2.80	4.7
PL	0-30	108.16	5.08	3.92	14.0

SOLIDS

AUGUST 1978

Medium	Depth cm	Total film kgm^{-3}	Total solids kgm^{-3}	Volatile solids kgm^{-3}	Percentage Settlement
Slag	0-30	167.16	7.32	5.24	11.2
	30-60	95.84	3.44	2.56	4.4
	60-90	189.88	3.84	2.60	6.5
	90-120	176.92	3.24	1.96	5.4
	120-150	139.88	2.84	1.76	4.8
	150-180	118.04	1.76	1.04	3.2
Mixed	0-30	192.16	11.84	8.44	19.6
	30-60	78.28	4.28	3.36	6.8
	60-70	50.04	2.40	1.80	3.8
	70-80	51.00	0.96	0.68	1.5
	80-90	97.28	1.44	1.04	2.2
	90-120	86.72	1.68	1.08	2.6
	120-150	93.04	1.12	0.80	1.7
	150-180	68.08	1.08	0.64	1.8
Plastic	0-30	176.56	10.88	8.32	20.0
	30-60	46.72	1.84	1.72	4.2
	60-90	32.04	0.56	0.56	0.6
	90-120	33.36	0.80	0.80	1.7
	120-150	35.12	0.80	0.80	0.9
	150-180	45.36	1.60	1.44	2.9

SOLIDS

SEPTEMBER 1978

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	209.16	7.12	5.84	8.8
	30-60	196.16	6.04	4.60	10.8
	60-90	193.28	7.40	5.64	17.2
	90-120	186.04	6.72	4.88	12.9
	120-150	172.28	2.68	1.92	4.6
	150-180	105.84	1.88	1.32	2.2
Mixed	0-30	86.76	5.56	4.16	11.2
	30-60	82.16	4.64	3.28	4.6
	60-70	108.28	6.80	4.88	10.0
	70-80	131.52	5.76	4.12	7.6
	80-90	114.60	2.72	1.92	3.4
	90-120	145.52	3.08	2.12	3.9
	120-150	194.28	3.40	2.24	5.6
	150-180	106.28	1.44	0.88	1.6
Plastic	0-30	80.88	6.44	5.20	5.8
	30-60	81.36	5.52	4.12	6.8
	60-90	174.20	10.12	7.32	16.4
	90-120	138.24	8.24	5.80	15.3
	120-150	123.08	6.04	4.20	19.2
	150-180	54.20	2.40	1.60	3.1
Slag S1	0-30	209.16	7.12	5.84	8.8
SR	0-30	230.00	7.16	5.56	8.4
SC	0-30	201.52	7.60	5.92	13.0
SL	0-30	188.88	6.08	4.48	11.8
Mixed M1	0-30	86.76	5.56	4.16	11.2
MR	0-30	110.56	6.24	4.68	8.5
MC	0-30	82.72	4.28	3.24	8.8
ML	0-30	89.16	4.84	3.72	6.3
Plastic P1	0-30	80.88	6.44	5.20	5.8
PR	0-30	110.20	6.44	4.76	10.8
PC	0-30	85.04	4.28	3.16	7.3
PL	0-30	89.16	3.84	2.76	7.6

SOLIDS

OCTOBER 1978

Medium	Depth cm	Total film kgm^{-3}	Total solids kgm^{-3}	Volatile solids kgm^{-3}	Percentage Settlement
Slag	0-30	196.88	5.88	5.00	10.8
	30-60	204.68	4.12	3.52	7.4
	60-90	234.40	4.76	4.00	10.4
	90-120	173.32	4.56	3.76	9.4
	120-150	188.48	5.28	4.04	12.4
	150-180	223.20	6.60	4.88	14.0
Mixed	0-30	148.52	8.76	6.92	11.0
	30-60	257.56	12.76	9.80	22.8
	60-70	155.48	7.52	5.80	13.6
	70-80	187.16	7.48	5.76	13.6
	80-90	184.36	4.16	3.16	6.1
	90-120	195.56	4.64	3.48	7.8
	120-150	209.88	5.68	3.92	10.0
	150-180	127.56	3.0	2.28	4.8
Plastic	0-30	147.52	8.32	6.48	17.4
	30-60	126.20	6.44	5.28	11.4
	60-90	205.08	9.92	7.88	16.4
	90-120	160.00	8.16	6.44	13.0
	120-150	136.00	7.20	5.36	11.4
	150-180	127.80	7.04	5.24	12.8

SOLIDS

NOVEMBER 1978

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	328.40	11.52	9.00	21.2
	30-60	163.16	4.68	3.64	9.2
	60-90	266.32	7.40	5.88	13.8
	90-120	366.56	14.88	11.68	30.4
	120-150	323.60	11.84	9.40	28.8
	150-180	284.12	10.12	8.08	18.8
Mixed	0-30	193.72	12.96	10.44	19.0
	30-60	140.60	8.00	6.64	13.2
	60-70	122.32	8.20	6.92	15.6
	70-80	153.04	6.84	5.64	12.0
	80-90	159.20	6.24	5.12	8.4
	90-120	133.00	5.20	3.96	8.4
	120-150	199.68	6.92	4.72	12.0
	150-180	230.36	6.80	4.88	13.2
Plastic	0-30	162.48	9.24	7.16	12.8
	30-60	112.24	5.72	4.52	10.0
	60-90	101.88	5.48	4.36	10.8
	90-120	174.24	9.68	7.24	22.0
	120-150	310.88	16.36	12.24	32.4
	150-180	378.84	21.36	16.04	56.0
Slag S1	0-30	328.40	11.52	9.00	21.2
SR	0-30	253.20	8.68	6.84	17.2
SC	0-30	303.52	11.04	8.80	28.4
SL	0-30	319.12	10.80	8.60	21.6
Mixed M1	0-30	193.72	12.96	10.44	19.0
MR	0-30	213.24	11.96	8.56	24.8
MC	0-30	192.76	10.16	7.40	20.6
ML	0-30	235.40	14.00	10.28	30.0
Plastic P1	0-30	162.48	9.24	7.16	12.8
PR	0-30	224.28	12.32	9.16	31.6
PC	0-30	206.32	11.60	8.88	29.6
PL	0-30	206.64	12.12	9.48	27.6

SOLIDS DECEMBER 1978

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	199.48	5.68	3.84	12.4
	30-60	195.52	4.20	3.04	10.0
	60-90	191.40	5.32	4.04	10.0
	90-120	145.92	3.48	2.48	5.2
	120-150	124.48	3.52	2.64	5.2
	150-180	186.56	3.88	2.64	6.2
Mixed	0-30	281.96	13.00	9.68	24.8
	30-60	288.88	11.20	8.60	26.8
	60-70	200.00	8.04	6.20	22.4
	70-80	178.56	6.12	4.68	16.4
	80-90	191.20	6.00	4.56	14.8
	90-120	301.12	10.96	8.08	23.6
	120-150	146.40	4.96	3.72	9.6
	150-180	206.72	8.24	5.88	12.4
Plastic	0-30	187.68	9.56	7.12	20.4
	30-60	209.16	10.12	7.64	20.4
	60-90	271.32	14.64	11.36	32.4
	90-120	278.88	13.00	10.12	26.8
	120-150	320.84	15.96	12.40	32.4
	150-180	208.32	11.80	9.28	21.6

SOLIDS JANUARY 1979

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	366.28	17.84	13.04	25.6
	30-60	363.28	17.04	12.60	23.6
	60-90	240.96	7.08	5.28	7.8
	90-120	201.92	5.60	4.12	5.8
	120-150	183.88	5.44	4.04	6.5
	150-180	274.88	10.68	7.80	14.0
Mixed	0-30	202.16	12.88	9.92	21.6
	30-60	213.28	12.52	10.00	18.0
	60-70	151.08	9.52	7.80	12.8
	70-80	187.08	6.32	4.96	8.4
	80-90	182.04	5.64	4.36	7.4
	90-120	214.04	5.40	4.20	6.8
	120-150	270.12	8.12	6.28	10.8
	150-180	151.92	3.96	2.92	5.6
Plastic	0-30	189.04	12.72	9.72	14.0
	30-60	154.80	9.36	7.40	15.8
	60-90	164.52	10.44	8.32	15.6
	90-120	109.32	6.44	4.72	10.4
	120-150	90.52	4.88	3.56	6.6
	150-180	111.40	6.92	5.00	8.2
Slag S1	0-30	366.28	17.84	13.04	25.6
SR	0-30	235.00	10.12	7.28	15.6
SC	0-30	308.36	13.24	9.60	23.6
SL	0-30	292.52	14.00	9.96	24.8
Mixed M1	0-30	202.16	12.88	9.92	21.6
MR	0-30	208.48	11.40	8.56	17.2
MC	0-30	185.08	11.08	8.56	18.8
ML	0-30	210.36	13.24	10.08	22.4
Plastic P1	0-30	189.04	12.72	9.72	14.0
PR	0-30	214.68	14.00	9.64	22.4
PC	0-30	176.80	11.68	8.08	20.0
PL	0-30	226.36	14.00	10.20	19.6

SOLIDS FEBRUARY 1979

Medium	Depth cm	Total film kgm^{-3}	Total solids kgm^{-3}	Volatile solids kgm^{-3}	Percentage Settlement
Slag	0-30	407.68	19.84	14.44	30.8
	30-60	426.56	22.32	16.32	28.8
	60-90	245.48	12.64	9.64	17.6
	90-120	192.88	8.40	6.40	9.2
	120-150	145.08	4.12	3.32	4.0
	150-180	145.64	4.04	3.16	3.6
Mixed	0-30	271.20	19.12	14.20	26.8
	30-60	418.84	29.28	21.64	40.0
	60-70	381.40	26.56	19.96	38.4
	70-80	324.92	17.08	12.76	25.2
	80-90	236.36	10.56	7.92	17.2
	90-120	426.92	24.16	18.20	31.2
	120-150	267.84	11.56	8.92	14.6
	150-180	275.24	9.04	6.84	11.2
Plastic	0-30	329.52	25.80	19.16	32.0
	30-60	250.00	19.16	14.40	22.6
	60-90	207.72	16.00	12.20	17.0
	90-120	207.52	17.52	13.08	18.4
	120-150	127.36	9.92	6.20	12.0
	150-180	87.08	5.48	3.24	6.2

SOLIDS MARCH 1979

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	494.24	32.56	23.68	48.0
	30-60	435.36	31.52	23.16	40.0
	60-90	304.80	11.00	8.12	15.2
	90-120	174.64	7.36	5.68	10.6
	120-150	193.16	5.28	4.12	5.2
	150-180	161.92	4.28	3.24	5.4
Mixed	0-30	347.40	28.52	20.60	40.4
	30-60	197.68	13.60	10.44	16.0
	60-70	306.48	22.24	16.76	32.0
	70-80	193.36	10.20	7.92	13.8
	80-90	195.44	8.48	6.52	10.4
	90-120	273.32	12.56	9.68	18.0
	120-150	165.96	4.44	3.52	6.0
	150-180	146.64	4.16	3.24	5.1
Plastic	0-30	396.28	30.80	22.44	43.2
	30-60	473.96	33.92	25.08	48.0
	60-90	201.44	14.60	9.80	17.6
	90-120	183.20	13.24	9.96	17.6
	120-150	143.56	8.56	6.44	14.2
	150-180	143.12	8.52	6.28	13.0
Slag S1	0-30	494.24	32.56	23.68	48.0
SR	0-30	323.44	15.52	10.36	19.6
SC	0-30	246.48	8.64	6.48	9.2
SL	0-30	375.16	21.92	16.08	35.2
Mixed M1	0-30	347.40	28.52	20.60	40.4
MR	0-30	256.72	16.88	12.60	22.0
MC	0-30	258.24	17.04	12.68	20.8
ML	0-30	264.60	17.88	12.92	27.6
Plastic P1	0-30	396.28	30.80	22.44	43.2
PR	0-30	351.48	26.20	19.16	43.2
PC	0-30	246.52	18.16	13.60	28.8
PL	0-30	340.28	25.20	19.24	42.4

SOLIDS APRIL 1979

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0	218.80	9.04	7.04	6.6
	30	242.16	10.0	8.48	8.6
	60	200.36	4.36	3.80	3.4
	90	165.24	3.36	2.80	2.6
	120	148.88	3.40	2.64	2.7
	150	144.92	3.56	2.68	3.4
Mixed	0	228.24	19.0	13.12	17.2
	30	80.28	5.96	4.16	4.6
	60	46.84	2.92	2.36	2.4
	70	98.20	2.96	2.44	2.8
	80	111.00	3.16	2.76	2.4
	90	126.76	3.12	2.52	2.7
	120	102.88	3.48	2.88	2.5
	150	235.04	5.88	4.28	6.4
Plastic	0	363.76	30.52	21.56	42.0
	30	143.68	11.84	8.60	12.4
	60	86.68	6.40	4.96	6.2
	90	103.00	8.00	6.20	9.2
	120	105.56	7.28	5.60	8.0
	150	134.48	9.84	7.36	10.4

SOLIDS MAY 1979

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	267.56	14.00	10.64	11.2
	30-60	158.20	4.88	4.20	4.1
	60-90	106.72	3.24	2.80	2.5
	90-120	163.16	3.88	3.36	3.8
	120-150	83.32	2.56	2.12	2.4
	150-180	203.24	7.12	5.52	12.4
Mixed	0-30	172.52	12.16	9.96	12.0
	30-60	177.84	9.92	8.08	12.8
	60-70	199.20	10.68	8.60	16.4
	70-80	148.04	6.28	4.92	11.4
	80-90	223.84	6.12	4.88	8.5
	90-120	181.24	5.52	4.44	7.0
	120-150	147.80	3.88	2.96	3.4
	150-180	183.40	3.96	3.16	4.0
Plastic	0-30	286.44	18.60	13.80	30.4
	30-60	128.20	7.04	5.76	10.0
	60-90	258.20	13.56	10.80	28.0
	90-120	164.80	9.00	7.36	18.4
	120-150	95.88	5.28	4.40	6.4
	150-180	76.20	4.96	4.24	5.8
Slag S1	0-30	267.56	14.00	10.64	11.2
SR	0-30	264.04	14.04	10.92	13.4
SC	0-30	203.28	12.36	9.72	18.4
SL	0-30	297.52	14.96	11.52	19.6
Mixed M1	0-30	172.52	12.16	9.96	12.0
MR	0-30	137.12	10.20	7.92	12.8
MC	0-30	149.36	11.68	9.04	16.8
ML	0-30	164.52	11.40	9.04	14.4
Plastic P1	0-30	286.44	18.60	13.80	30.4
PR	0-30	124.48	9.56	7.56	10.4
PC	0-30	163.48	13.12	9.96	15.2
PL	0-30	154.08	10.56	8.24	11.6

SOLIDS JUNE 1979

Medium	Depth cm	Total film kgm^{-3}	Total Solids kgm^{-3}	Volatile Solids kgm^{-3}	Percentage Settlement
Slag	0-30	271.12	11.72	8.92	19.2
	30-60	284.48	10.64	8.48	15.6
	60-90	240.76	6.92	5.92	6.4
	90-120	191.08	6.28	5.20	6.8
	120-150	185.72	3.76	3.12	3.3
	150-180	124.28	2.40	2.00	2.8
Mixed	0-30	64.88	5.92	5.12	4.6
	30-60	72.16	5.48	4.60	7.6
	60-70	53.40	3.56	2.96	6.0
	70-80	92.56	3.00	2.40	4.8
	80-90	82.28	1.72	1.44	2.1
	90-120	134.36	2.28	1.80	2.6
	120-150	118.28	2.20	1.72	2.1
	150-180	93.24	1.48	1.08	1.5
Plastic	0-30	50.72	3.28	2.92	3.1
	30-60	54.88	3.76	3.40	4.0
	60-90	45.32	3.08	2.80	3.2
	90-120	37.24	2.00	1.76	2.2
	120-150	34.90	1.36	1.32	1.4
	150-180	34.00	1.36	1.20	1.7

SOLIDS

JULY 1979

Medium	Depth cm	Total film kgm^{-3}	Total solids kgm^{-3}	Volatile solids kgm^{-3}	Percentage Settlement
Slag	0-30	172.88	7.20	6.24	8.6
	30-60	188.48	8.04	6.80	14.0
	60-90	249.16	7.52	6.40	11.8
	90-120	151.56	5.80	4.88	7.2
	120-150	194.28	5.00	4.16	6.6
	150-180	149.20	2.48	1.92	3.2
Mixed	0-30	103.00	6.56	5.84	11.6
	30-60	278.48	16.00	13.32	59.2
	60-70	256.08	16.48	14.00	63.2
	70-80	152.88	8.48	7.44	24.8
	80-90	175.12	6.48	5.72	18.8
	90-120	153.12	3.68	3.24	6.8
	120-150	208.16	4.60	4.05	9.6
	150-180	116.56	2.88	2.52	4.4
Plastic	0-30	94.64	5.28	4.44	7.4
	30-60	149.68	11.48	9.76	27.2
	60-90	307.80	22.56	18.24	78.4
	90-120	291.00	20.00	16.32	60.8
	120-150	175.52	12.60	10.24	30.0
	150-180	116.28	7.72	6.40	22.4
Slag S1	0.30	172.88	7.20	6.24	8.6
SR	0-30	223.44	7.20	5.84	8.8
SC	0-30	195.12	8.00	6.44	10.0
SL	0-30	176.24	6.16	4.88	6.4
Mixed M1	0-30	103.00	6.56	5.84	11.6
MR	0-30	108.08	6.52	5.28	14.2
MC	0-30	113.76	8.28	6.84	16.0
ML	0-30	155.04	9.92	8.24	36.8
Plastic P1	0-30	94.64	5.28	4.44	7.4
PR	0-30	113.04	7.80	6.60	22.0
PC	0-30	103.96	6.40	5.40	23.2
PL	0-30	131.24	8.08	6.80	16.8

SOLIDS

AUGUST 1979

Medium	Depth cm	Total film kgm-3	Total solids kgm-3	Volatile solids kgm-3	Percentage Settlement
Slag	0-30	218.32	7.20	5.28	7.6
	30-60	222.76	5.76	4.40	7.4
	60-90	147.28	4.92	3.76	6.0
	90-120	137.56	3.64	2.76	4.0
	120-150	160.60	4.40	3.40	6.0
	150-180	141.00	3.52	2.64	5.6
Mixed	0-30	246.64	15.72	11.96	26.8
	30-60	153.16	8.40	6.76	7.2
	60-70	96.96	5.32	4.40	8.0
	70-80	153.28	7.80	6.16	12.2
	80-90	130.84	3.52	2.84	4.6
	90-120	156.08	4.92	3.80	6.8
	120-150	225.40	5.32	4.08	9.4
	150-180	97.68	2.52	2.00	4.1
Plastic	0-30	338.64	20.00	14.96	44.8
	30-60	399.48	26.36	20.32	54.0
	60-90	227.44	12.40	9.80	19.8
	90-120	150.20	8.60	6.88	15.6
	120-150	123.16	6.72	5.60	10.8
	150-180	51.64	1.84	1.52	3.2

APPENDIX V. FILM ACCUMULATION: NEUTRON SCATTERING TECHNIQUE

Results are expressed as the percentage saturation of the voids.

October, 1977 - August, 1978. Low loading rate (1.68 $m^3m^{-3}d^{-1}$)

September, 1978 - May, 1979. High loading rate (3.37 $m^3m^{-3}d^{-1}$)

Film Accumulation: Neutron Scattering Technique

October 1977

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	12.8	13.0	6.9	3.4	4.5	3.6
35	16.8	16.9	10.6	4.7	6.6	3.9
50	18.9	19.0	10.4	5.6	6.7	4.5
65	17.9	20.1	8.2	6.2	4.8	3.7
80	17.0	21.7	13.3	12.0	4.4	3.4
95	16.2	21.0	16.8	18.9	3.6	3.2
110	17.7	21.8	20.7	20.5	3.7	2.8
125	17.4	21.4	19.3	20.8	3.5	2.8
140	16.1	19.8	18.1	18.2	3.2	2.6
155	16.2	19.3	16.5	16.7	3.0	2.7
170	15.6	17.8	16.3	16.2	2.9	2.5
180	13.6	16.0	14.9	15.5	2.6	2.4

Film Accumulation: Neutron Scattering Technique

November 1977

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	23.9	24.2	5.9*	9.9	12.6	10.8
35	20.3	23.1	8.3	9.5	19.3	14.7
50	25.4	20.1	8.2	9.8	9.0	8.6
65	28.5	20.5	7.3	8.1	5.9	5.6
80	19.9	21.0	12.7	14.0	5.1	4.8
95	16.5	21.4	19.5	18.3	4.7	4.5
110	16.4	23.0	23.3	24.9	4.6	4.0
125	16.0	21.9	24.2	27.4	3.9	3.5
140	13.8	19.1	21.7	24.1	3.7	3.2
155	12.5	17.9	19.4	20.6	3.2	3.2
170	11.5	15.8	15.5	19.9	3.1	2.8
180	10.3	13.8	13.0	17.9	2.8	2.2

* Storm damage

Film Accumulation: Neutron Scattering Technique

December 1977

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	22.5	26.0	7.1	5.3	6.0	7.0
35	17.9	26.5	4.9	3.2	4.5	5.8
50	21.8	23.3	4.1	2.7	5.0	5.1
65	23.6	25.2	3.8	3.0	4.8	4.5
80	22.1	28.2	7.7	6.5	5.2	4.9
95	20.6	30.2	14.1	11.7	4.5	4.7
110	20.6	30.1	16.2	17.4	4.8	4.3
125	18.4	31.7	18.4	17.9	4.1	3.7
140	17.3	25.7	17.1	17.3	3.7	3.7
155	17.0	23.3	16.2	16.7	3.7	3.4
170	16.8	20.2	15.8	17.7	3.6	3.3
180	14.6	19.1	14.9	16.8	3.5	3.0

Film Accumulation: Neutron Scattering Technique

January 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	27.8	40.1	6.0	7.7	6.1	9.3
35	28.0	28.4	3.8	4.8	2.6	5.7
50	31.1	23.9	3.4	4.0	2.6	4.7
65	32.0	23.8	3.1	3.5	2.8	4.4
80	33.2	24.8	6.8	6.3	4.3	4.8
95	30.3	32.8	12.0	10.9	4.2	5.0
110	30.4	34.2	15.1	15.9	3.9	4.1
125	26.0	34.7	17.2	16.3	3.2	3.5
140	25.6	29.9	15.9	16.3	2.9	3.4
155	26.2	26.8	15.0	16.0	3.0	3.3
170	25.4	22.3	14.0	17.0	3.3	2.8
180	19.1	22.5	13.1	16.1	3.3	2.8

Film Accumulation: Neutron Scattering Technique

February 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	33.1	32.3	11.5	11.3	10.7	10.6
35	27.6	27.5	7.1	7.9	4.1	5.2
50	31.4	30.1	5.4	7.3	2.8	3.9
65	29.7	28.8	4.5	5.3	2.5	3.8
80	23.9	25.6	7.4	7.9	2.7	4.0
95	25.9	28.0	12.2	10.9	2.8	4.2
110	31.3	29.7	15.1	17.0	3.2	3.9
125	31.0	32.4	17.2	17.1	2.5	3.6
140	33.4	32.2	16.3	16.8	2.1	3.3
155	29.8	32.6	14.3	17.6	2.0	2.9
170	28.6	28.5	14.2	18.0	2.3	3.0
180	23.7	26.1	12.5	16.9	2.3	2.8

Film Accumulation: Neutron Scattering Technique

March 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	36.7	35.0	19.0	14.8	13.8	17.3
35	29.4	27.4	7.3	8.9	2.7	5.8
50	34.1	35.4	6.2	6.9	2.0	4.4
65	33.8	36.6	5.9	6.2	1.9	4.0
80	26.1	31.5	10.1	11.1	1.9	4.3
95	27.3	30.7	15.2	16.6	2.1	4.6
110	33.8	31.4	18.0	21.6	2.3	4.6
125	33.0	34.8	20.1	22.0	2.3	4.3
140	36.3	35.4	17.8	21.5	2.3	4.2
155	33.9	33.4	17.0	21.7	2.2	3.7
170	30.9	28.0	15.4	21.3	2.4	3.3
180	26.4	25.3	14.6	19.9	2.4	3.0

Film Accumulation: Neutron Scattering Technique

April 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	32.2	25.3	9.0	9.1	7.8	5.9
35	22.7	22.6	3.0	4.2	2.0	2.5
50	30.6	35.5	2.9	4.2	1.9	2.7
65	31.8	41.8	3.1	4.6	2.1	2.6
80	25.7	38.4	6.7	7.5	1.9	2.5
95	23.7	34.1	13.1	11.9	1.9	2.7
110	30.2	34.6	18.0	17.1	2.0	2.7
125	33.7	37.9	21.5	18.6	2.0	3.0
140	35.3	42.6	18.8	18.8	1.9	3.3
155	35.5	38.7	17.0	20.9	1.9	3.4
170	33.6	36.5	15.6	20.9	2.1	3.5
180	29.1	34.4	14.5	19.1	2.2	3.7

Film Accumulation: Neutron Scattering Technique

May 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	25.6	26.7	5.9	4.0	2.9	5.0
35	19.5	23.4	1.5	1.2	1.0	1.6
50	24.8	34.9	1.4	1.3	1.0	1.4
65	21.0	23.3	1.5	1.4	1.0	1.2
80	16.0	16.6	3.9	3.4	1.1	1.4
95	14.4	16.2	9.3	7.3	1.1	1.3
110	19.2	17.5	15.0	12.0	1.2	1.5
125	24.6	24.8	19.6	12.4	1.2	1.7
140	30.5	28.5	18.3	13.7	1.3	1.9
155	31.2	32.8	15.7	15.7	1.4	2.2
170	30.4	34.8	15.0	17.7	1.6	2.5
180	27.5	33.7	13.9	16.8	1.7	2.4

Film Accumulation: Neutron Scattering Technique

June 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	10.3	12.9	2.0	1.9	1.7	1.5
35	10.4	14.6	1.1	1.4	0.9	0.9
50	11.8	13.5	1.1	1.5	1.0	1.1
65	12.0	12.7	1.5	1.5	1.0	1.1
80	11.8	11.6	3.6	3.0	1.0	1.2
95	11.5	11.4	8.3	6.7	1.0	1.3
110	12.0	11.3	11.4	10.9	1.2	1.2
125	12.0	12.9	13.5	11.6	1.0	1.2
140	12.1	12.0	13.6	11.8	1.2	1.4
155	12.8	13.0	12.8	12.3	1.2	1.4
170	13.3	13.9	12.5	14.0	1.2	1.4
180	12.9	14.0	12.0	12.7	1.2	1.6

Film Accumulation: Neutron Scattering Technique

July 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	14.8	34.1	2.4	2.1	2.0	1.8
35	13.2	26.9	1.9	1.6	1.3	1.4
50	12.6	21.2	2.0	1.8	1.1	1.4
65	11.5	15.9	1.8	1.7	1.0	1.1
80	11.2	13.1	3.6	3.3	1.0	1.1
95	10.8	12.1	8.1	7.1	1.0	1.1
110	11.5	11.6	11.0	11.0	1.0	1.1
125	11.5	12.4	13.5	11.4	1.0	1.2
140	11.3	11.2	13.2	11.9	1.0	1.2
155	12.4	13.3	13.2	12.7	1.0	1.3
170	12.5	14.0	12.2	14.0	1.1	1.3
180	12.2	13.6	11.8	12.4	1.1	1.3

Film Accumulation: Neutron Scattering Technique

August 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	16.6	14.37	5.60	4.97	6.08	6.72
35	15.84	13.00	3.06	3.91	3.61	5.14
50	16.74	14.47	2.10	2.85	2.19	3.71
65	15.05	14.84	1.97	2.30	1.57	2.03
80	13.79	14.47	3.67	3.75	1.22	1.54
95	13.05	14.00	7.97	7.34	1.28	1.64
110	14.31	12.78	10.16	11.68	1.38	1.54
125	14.52	13.63	13.07	11.76	1.38	1.44
140	13.68	13.73	13.70	12.27	1.22	1.47
155	13.94	14.89	13.20	12.86	1.38	1.60
170	14.52	15.42	12.44	13.83	1.44	1.67
180	13,36	15.05	11.43	12.90	1.34	1.54

Film Accumulation: Neutron Scattering Technique

September 1978

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter *		Mixed Filter		Plastic Filter *	
	Left	Right	Left	Right	Left	Right
20			2.88	3.44		
35			2.40	2.63		
50			2.79	2.75		
65			2.53	2.95		
80			5.43	5.48		
95			10.43	9.59		
110			12.70	14.18		
125			14.65	14.70		
140			14.86	15.28		
155			14.18	15.44		
170			13.60	16.28		
180			12.70	15.13		

* No results due to failure of neutron probe.

Film Accumulation: Neutron Scattering Technique

January 1979

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	32.97	40.39	11.17	13.17	12.52	11.95
35	30.27	34.15	7.96	11.90	10.01	8.19
50	29.43	32.50	7.73	11.54	9.39	6.53
65	27.19	29.85	6.51	7.78	7.39	5.83
80	24.33	25.51	11.64	12.56	6.20	6.04
95	21.12	22.18	18.59	18.42	4.85	5.34
110	20.11	19.10	19.44	23.90	4.54	5.16
125	17.54	19.01	21.25	24.16	3.81	4.72
140	15.77	17.92	20.15	22.22	3.60	4.74
155	16.95	18.72	18.59	20.78	3.47	4.85
170	16.36	20.15	19.01	22.89	3.03	4.51
180	15.64	20.07	17.29	21.92	2.88	4.56

Film Accumulation: Neutron Scattering Technique

May 1979

MOISTURE CONTENT (Percentage saturation of Voids)

Depth cm	Slag Filter		Mixed Filter		Plastic Filter	
	Left	Right	Left	Right	Left	Right
20	30.44	33.01	10.34	5.44	4.74	4.46
35	34.61	41.36	10.76	3.81	2.83	2.62
50	34.57	45.91	7.88	3.81	3.79	3.29
65	29.22	47.39	4.33	2.85	3.22	2.57
80	22.56	38.66	5.65	4.60	2.10	2.02
95	18.80	26.81	10.50	8.90	1.32	1.50
110	17.62	20.36	12.99	12.65	1.19	1.43
125	17.37	20.95	15.47	13.28	1.09	1.32
140	17.03	21.42	15.30	12.90	1.14	1.37
155	21.92	25.17	15.64	13.07	1.27	1.45
170	28.29	30.73	17.12	15.73	1.37	1.48
180	27.66	32.67	15.64	14.46	1.45	1.61

APPENDIX VI: CORRELATION ANALYSIS OF BIOLOGICAL DATA

Parameters correlated

A. Major Groups

1. Film weight
2. Zoogloeal bacteria
3. *Subbaromyces splendens*
4. Sarcomastigophora
5. Ciliophora
6. *Sphaerotilus natans*
7. Enchytraeidae
8. Psychodid larvae
9. Nematoda
10. *Paracyclops* sp.
11. Acari-Astigmata
12. Air temperature
13. Organic Load
14. Effluent BOD

B. Protozoa

1. Film weight
2. Zoogloeal bacteria
3. *Subbaromyces splendens*
4. Sarcomastigophora
5. *Paramecium aurelia*
6. *Opercularia microdiscum*
7. *Colpidium colpoda*
8. *Uronema nigricans*
9. *Chilodonella uncinata*
10. *Paracyclops* sp.
11. Acari-Astigmata
12. Air temperature

C. Protozoa

1. *Paramecium aurelia*
2. *Opercularia microdiscum*
3. *Colpidium colpoda*
4. *Uronema nigricans*
5. *Chilodonella uncinata*
6. Ciliophora
7. *Sphaerotilus natans*
8. Enchytraeidae
9. Psychodid larvae
10. Nematoda
11. Organic Load
12. Effluent BOD

Values of Correlation Coefficient 'r'.

Degrees of freedom (n - 1)	r			
	$P < 0.05$	$P < 0.02$	$P < 0.01$	$P < 0.001$
10	0.576	0.658	0.708	0.823
11	0.553	0.634	0.684	0.801
68	0.250	0.295	0.324	0.408

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. Ciliophora	6. *Sphaerotilus* sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. *Paracyclops* sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight			* * (-)			* * (+)				* (-)		* * (-)		
2. Zoogloeal bacteria	-0.198													
3. *Subbaromyces* sp.	-0.750	0.133								* * (+)		* * (+)		
4. Sarcomastigophora	0.516	-0.420	-0.161								* (+)			
5. Ciliophora	0.338	-0.511	-0.295	-0.138										
6. *Sphaerotilus* sp.	0.794	0.055	-0.495	0.305	0.242									
7. Enchytraeidae	-0.072	-0.483	-0.262	0.144	0.003	-0.464								
8. Psychodid larvae	-0.491	-0.162	0.140	-0.402	0.098	-0.517	0.298							
9. Nematoda	0.335	-0.116	-0.440	0.009	-0.022	0.315	-0.055	-0.459				* * (-)	* (-)	
10. *Paracyclops* sp.	-0.604	-0.068	0.800	0.152	-0.252	-0.528	0.035	-0.170	-0.260		* (+)	* (+)		
11. Acari	-0.204	-0.405	0.245	0.590	-0.197	-0.490	0.535	-0.054	-0.247	0.650				
12. Air temperature	-0.689	0.106	0.783	-0.086	-0.170	-0.505	-0.102	0.472	-0.742	0.589	0.312		* * (+)	
13. Organic load	-0.351	0.062	0.356	0.361	-0.476	-0.260	0.251	0.228	-0.581	0.408	0.514	0.688		* * (+)
14. Effluent BOD	-0.035	-0.232	-0.002	0.532	-0.294	-0.086	0.289	0.459	-0.426	-0.012	0.415	0.431	0.766	

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. Ciliophora	6. *Sphaerotilus* sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. *Paracyclops* sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight				* (-)								* (-)		
2. Zoogloeal bacteria	-0.032								* (+)					
3. *Subbaromyces* sp.	-0.345	-0.075							* (-)	* (+)		* (+)		
4. Sarcomastigophora	-0.584	0.272	0.303											
5. Ciliophora	-0.525	-0.141	-0.147	0.233										
6. *Sphaerotilus* sp.	0.376	0.195	0.029	-0.525	-0.311									
7. Enchytraeidae	-0.121	0.069	-0.496	0.119	-0.105	-0.406								
8. Psychodid larvae	-0.059	-0.203	-0.155	0.162	-0.113	0.135	-0.030							
9. Nematoda	0.480	0.619	-0.580	-0.042	-0.226	0.041	0.368	-0.334						
10. *Paracyclops* sp.	-0.174	0.034	0.626	0.113	-0.262	-0.332	0.266	-0.436	-0.192					
11. Acari	0.358	0.022	-0.544	-0.019	-0.079	-0.185	0.345	0.210	0.361	-0.210				
12. Air temperature	-0.582	-0.012	0.555	0.268	0.335	0.026	-0.541	-0.021	-0.525	0.450	-0.213		* * (+)	* (+)
13. Organic load	-0.517	-0.076	0.349	0.147	0.069	-0.039	0.030	0.040	-0.350	0.325	0.140	0.688		* * (+)
14. Effluent BOD	-0.495	-0.266	-0.034	0.191	0.288	-0.183	0.098	0.444	-0.428	-0.028	0.364	0.589	0.779	

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. Ciliophora	6. Sphaerotilus sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. Paracyclops sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight										* * (+)		* * (-)	* (-)	
2. Zoogloeal bacteria	0.089		*** (+)											
3. Subbaromyces sp.	-0.038	0.883												
4. Sarcomastigophora	-0.131	-0.300	-0.300								* * (+)			
5. Ciliophora	-0.334	-0.365	-0.446	-0.074				*** (+)						
6. Sphaerotilus sp.	0.378	0.168	-0.205	-0.308	-0.178									
7. Enchytraeidae	0.365	-0.319	-0.389	-0.135	0.009				* * (+)			* * (-)		
8. Psychodid larvae	-0.531	-0.130	-0.136	0.155	0.804	-0.440	-0.124			* (-)				* (+)
9. Nematoda	0.521	-0.258	-0.478	0.409	-0.219	0.466	0.712	-0.404				* (-)		
10. Paracyclops sp.	0.756	0.440	0.365	-0.330	-0.521	0.444	0.150	-0.639	0.328					
11. Acari	0.008	-0.369	-0.463	0.684	0.330	-0.171	0.114	0.280	0.335	-0.392				
12. Air temperature	-0.779	0.247	0.261	-0.331	0.254	0.026	-0.768	0.300	-0.683	-0.419	-0.240		* * (+)	
13. Organic load	-0.589	0.239	0.042	0.189	0.159	0.251	-0.357	0.332	-0.236	-0.343	0.153	0.688		* * (+)
14. Effluent BOD	-0.483	-0.074	-0.224	0.070	0.507	0.074	-0.319	0.681	-0.401	-0.499	0.133	0.507	0.703	

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. Ciliophora	6. *Sphaerotilus* sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. *Paracyclops* sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight														
2. Zoogloeal bacteria	0.191			*** (+)										
3. *Subbaromyces* sp.	-0.369	0.519			*** (+)		* * (+)	* * (+)						
4. Sarcomastigophora	0.309	0.859	0.355											
5. Ciliophora	-0.481	0.434	0.934	0.267						* * (+)		* (+)		
6. *Sphaerotilus* sp.	0.384	0.225	0.362	0.003	0.346									
7. Enchytraeidae	-0.267	-0.543	-0.386	-0.182	-0.267	-0.489			* * (+)					
8. Psychodid larvae	-0.238	0.365	0.760	0.200	0.534	0.277	-0.384		* * (-)					* (+)
9. Nematoda	0.214	-0.429	-0.553	-0.121	-0.384	-0.135	0.719	-0.735						
10. *Paracyclops* sp.	-0.327	0.318	0.510	0.135	0.732	0.166	-0.304	0.019	-0.175					
11. Acari	-0.027	-0.090	-0.309	-0.197	-0.118	-0.278	-0.141	-0.528	-0.054	0.421				
12. Air temperature	-0.504	0.041	0.522	0.064	0.583	0.043	0.071	0.470	-0.158	0.453	-0.393		* * (+)	* * (+)
13. Organic load	-0.233	0.044	0.397	-0.082	0.441	0.277	-0.326	0.449	-0.487	0.482	-0.068	0.712		*** (+)
14. Effluent BOD	-0.279	0.058	0.481	0.148	0.503	0.428	-0.339	0.583	-0.498	0.429	-0.224	0.747	0.947	

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. Ciliophora	6. Sphaerotilus sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. Paracyclops sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight		*** (+)										* (-)		
2. Zoogloeal bacteria	0.890													
3. *Subbaromyces* sp.	0.056	0.098			* (+)									
4. Sarcomastigophora	0.516	0.375	0.475			* (+)	* (-)							
5. Ciliophora	-0.207	-0.333	0.631	-0.026										
6. *Sphaerotilus* sp.	0.265	0.073	-0.171	0.614	-0.320					*** (+)				
7. Enchytraeidae	-0.262	-0.064	-0.404	-0.654	-0.291	-0.415								
8. Psychodid larvae	-0.414	-0.382	0.290	-0.362	0.458	-0.453	0.135							*** (+)
9. Nematoda	0.367	0.315	-0.054	0.348	-0.178	0.103	0.140	-0.532						
10. *Paracyclops* sp.	-0.230	-0.282	-0.278	0.274	-0.367	0.840	-0.220	-0.214	-0.207					
11. Acari	-0.098	-0.262	-0.161	0.080	0.350	0.273	-0.318	-0.416	0.160	0.200				
12. Air temperature	-0.585	-0.366	0.309	-0.143	0.003	-0.093	0.161	0.547	-0.468	0.269	-0.528		** (+)	** (+)
13. Organic load	-0.333	-0.339	0.575	0.143	0.459	0.204	-0.129	0.518	-0.437	0.330	-0.196	0.712		*** (+)
14. Effluent BOD	-0.549	-0.496	0.352	-0.237	0.409	-0.150	0.200	0.856	-0.533	0.137	-0.353	0.765	0.832	

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. Ciliophora	6. Sphaerotilus sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. Paracyclops sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight														* (-)
2. Zoogloeal bacteria	0.485													
3. Subbaromyces sp.	0.341	0.239									* (-)		* (+)	
4. Sarcomastigophora	-0.310	-0.062	-0.366											
5. Ciliophora	-0.091	-0.080	-0.106	0.559										
6. Sphaerotilus sp.	0.261	0.406	0.270	-0.318	0.072			* (-)						
7. Enchytraeidae	-0.338	0.109	-0.441	0.014	-0.345	-0.009								
8. Psychodid larvae	-0.430	-0.478	0.271	0.430	0.148	-0.600	-0.226		** (-)				* (+)	** (+)
9. Nematoda	0.375	0.453	-0.515	0.108	0.186	0.168	0.362	-0.732			** (+)	* (-)	* (-)	* (-)
10. Paracyclops sp.	-0.430	-0.452	-0.123	-0.118	-0.019	0.458	0.379	-0.050	-0.215					
11. Acari	0.201	0.165	-0.624	0.077	-0.110	-0.062	0.496	-0.534	0.766	-0.151				
12. Air temperature	-0.251	-0.110	0.438	-0.221	-0.462	-0.086	0.234	0.532	-0.707	0.313	-0.501		** (+)	** (+)
13. Organic load	-0.280	-0.353	0.584	-0.214	-0.016	0.028	-0.015	0.582	-0.656	0.405	-0.561	0.712		** (+)
14. Effluent BOD	-0.601	-0.373	0.212	0.185	-0.142	-0.392	0.202	0.809	-0.664	0.214	-0.391	0.759	0.769	

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. Ciliophora	6. *Sphaerotilus* sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. *Paracyclops* sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight			* * (-)									* * (-)		
2. Zoogloeal bacteria	-0.151			* * (+)						* (-)	* (-)		* (+)	
3. *Subbaromyces* sp.	-0.636	0.145							* (-)	* * (+)		* * (+)		
4. Sarcomastigophora	0.162	0.606	0.042										* (+)	
5. Ciliophora	-0.136	0.283	0.308	0.377		* (+)		* * (+)					* (+)	
6. *Sphaerotilus* sp.	0.385	0.379	-0.051	0.331	0.430					* (-)	* (-)			
7. Enchytraeidae	-0.169	-0.141	-0.269	0.058	-0.125	-0.316			* (+)					
8. Psychodid larvae	-0.300	0.379	0.353	0.348	0.547	0.290	-0.167		* (-)				* * (+)	* * (+)
9. Nematoda	0.286	-0.173	-0.473	-0.051	-0.224	0.029	0.432	-0.528				* (-)		* (-)
10. *Paracyclops* sp.	-0.326	-0.451	0.579	-0.387	-0.218	-0.430	-0.188	-0.321	-0.162		*** (+)			
11. Acari	-0.086	-0.479	0.093	-0.199	-0.257	-0.449	-0.050	-0.421	-0.157	0.660				
12. Air temperature	-0.565	0.005	0.647	-0.036	0.305	-0.147	0.013	0.372	-0.442	0.384	0.027		* (+)	* * (+)
13. Organic load	-0.255	0.474	0.193	0.447	0.443	0.405	-0.023	0.562	-0.350	-0.302	-0.184	0.448		*** (+)
14. Effluent BOD	-0.161	0.177	0.158	0.279	0.370	0.377	-0.086	0.597	-0.426	-0.202	-0.047	0.541	0.840	

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. Ciliophora	6. *Sphaerotilus* sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. *Paracyclops* sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight		*** (+)										* * (-)		* (-)
2. Zoogloeal bacteria	0.670													
3. *Subbaromyces* sp.	0.164	0.397			* (+)								*** (+)	
4. Sarcomastigophora	-0.041	0.273	0.348											
5. Ciliophora	-0.228	0.039	0.482	0.159										
6. *Sphaerotilus* sp.	0.403	0.298	0.086	0.031	-0.169									
7. Enchytraeidae	-0.093	0.148	-0.204	-0.296	-0.113	-0.229								
8. Psychodid larvae	-0.159	-0.038	0.389	-0.140	0.365	-0.152	0.204						* * (+)	* * (+)
9. Nematoda	0.388	0.146	-0.113	0.073	-0.201	0.050	0.149	-0.298				* (-)		* (-)
10. *Paracyclops* sp.	-0.227	-0.232	-0.182	0.170	-0.330	0.291	-0.234	-0.230	-0.179					
11. Acari	-0.014	-0.415	-0.370	-0.069	-0.135	-0.235	-0.153	-0.262	0.283	0.002				
12. Air temperature	-0.572	-0.251	0.220	0.064	0.132	-0.064	-0.011	0.358	-0.473	0.344	-0.188		* (+)	*** (+)
13. Organic load	-0.027	0.293	0.680	0.184	0.417	0.332	0.108	0.547	-0.255	0.169	-0.359	0.448		* * (+)
14. Effluent BOD	-0.446	-0.184	0.268	0.023	0.365	-0.108	0.182	0.646	-0.450	0.053	0.066	0.665	0.643	

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. Ciliophora	6. Sphaerotilus sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. Paracyclops sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight		* * (+)	* (+)			* * (+)						* (-)		
2. Zoogloeal bacteria	0.611		* (+)			*** (+)				* (-)				
3. Subbaromyces sp.	0.427	0.532				* (+)					* (-)		* * (+)	
4. Sarcomastigophora	-0.279	-0.258	-0.323								* * (+)			
5. Ciliophora	0.027	0.123	-0.003	0.101										
6. Sphaerotilus sp.	0.540	0.686	0.461	-0.309	0.230								* (+)	
7. Enchytraeidae	-0.078	-0.204	-0.397	0.334	-0.275	-0.158			* * (+)					
8. Psychodid larvae	-0.158	-0.052	0.330	0.155	0.344	-0.191	-0.213		* (-)				* * (+)	*** (+)
9. Nematoda	0.349	0.070	-0.370	0.325	-0.029	0.116	0.595	-0.483				*** (-)		* (-)
10. Paracyclops sp.	-0.163	-0.478	-0.271	-0.034	-0.415	-0.399	0.274	-0.374	0.191				* (-)	
11. Acari	-0.193	-0.363	-0.458	0.608	0.008	-0.322	0.251	-0.184	0.377	0.062				
12. Air temperature	-0.439	-0.058	0.293	-0.246	-0.201	-0.094	-0.294	0.399	-0.665	-0.100	-0.215		* (+)	* * (+)
13. Organic load	0.166	0.364	0.641	-0.171	0.222	0.490	-0.246	0.591	-0.325	-0.521	-0.346	0.448		* * (+)
14. Effluent BOD	-0.381	-0.098	0.140	0.077	0.142	-0.112	-0.119	0.717	-0.497	-0.291	-0.055	0.632	0.603	

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. Ciliophora	6. Sphaerotilus sp.	7. Enchytraeidae	8. Psychodid larvae	9. Nematoda	10. Paracyclops sp.	11. Acari	12. Air temperature	13. Organic load	14. Effluent BOD
1. Film weight		* * (+)				*** (+)			* (+)			*** (-)		* (-)
2. Zoogloeal bacteria	0.381		* * (+)			*** (+)				* (-)	* (-)		* (+)	
3. Subbaromyces sp.	0.128	0.403			* (+)	* (+)		* * (+)			* (-)	* (-)	*** (+)	
4. Sarcomastigophora	-0.063	0.118	-0.078											
5. Ciliophora	-0.096	0.125	0.255	0.175										
6. Sphaerotilus sp.	0.412	0.453	0.268	-0.067	0.121									
7. Enchytraeidae	-0.131	-0.034	-0.239	-0.007	-0.163	-0.221								
8. Psychodid larvae	-0.168	0.021	0.369	0.081	0.390	-0.097	0.020							
9. Nematoda	0.310	-0.001	-0.241	0.074	-0.172	0.037	0.335	-0.351						
10. Paracyclops sp.	-0.244	-0.320	-0.085	-0.066	-0.291	0.015	-0.122	-0.251	-0.108					
11. Acari	-0.096	-0.308	-0.276	0.336	0.053	-0.193	-0.046	-0.137	0.116	0.026				
12. Air temperature	-0.517	-0.106	0.291	-0.101	0.041	0.090	-0.055	0.351	-0.476	0.245	-0.146			
13. Organic load	-0.044	0.370	0.533	0.104	0.329	0.392	-0.010	0.528	-0.297	-0.092	-0.266	0.448		
14. Effluent BOD	-0.304	-0.046	0.163	0.126	0.248	-0.018	0.010	0.618	-0.098	-0.025	0.610	0.685		

SLAG FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 11

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. P. aurelia	6. O. microdiscum	7. C. colpoda	8. U. nigricans	9. C. uncinata	10. Paracyclops sp.	11. Acari	12. Air temperature
12. Air temp.	** (-)		** (+)		* (-)			* (+)		* (+)		
11. Acari				* (+)						* (+)		0.312
10. Paracyclops sp.	* (-)		** (+)								0.650	0.589
9. C. uncinata					* (+)					0.054	0.284	-0.106
8. U. nigricans									-0.293	0.256	0.226	0.600
7. C. colpoda					* (+)			-0.290	0.373	-0.309	-0.268	-0.158
6. O. microdiscum	* (-)				* (-)		-0.270	0.464	-0.488	0.107	-0.212	0.382
5. P. aurelia	** (+)		* (-)			-0.554	0.654	-0.480	0.683	-0.446	-0.246	-0.590
4. Sarcomastigophora					0.020	-0.391	0.031	-0.033	-0.044	0.152	0.590	-0.086
3. Subbaromyces sp.	** (-)			-0.161	-0.580	0.469	-0.246	0.303	-0.199	0.800	0.245	0.783
2. Zoogloeal bacteria			0.133	-0.420	-0.199	-0.189	-0.045	-0.311	-0.222	-0.068	-0.405	0.106
1. Film weight		-0.198	-0.750	0.516	0.715	-0.581	0.538	-0.458	0.162	-0.604	-0.204	-0.689

MIXED FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 11

12. Air temp.	* (-)		* (+)									
11. Acari												-0.213
10. Paracyclops sp.			* (+)								-0.210	0.450
9. C. uncinata				* (+)						0.292	-0.022	0.454
8. U. nigricans	* (-)						*** (+)		0.217	-0.247	-0.165	0.448
7. C. colpoda								0.867	-0.225	-0.298	-0.113	0.285
6. O. microdiscum							-0.152	-0.102	0.011	-0.124	-0.140	-0.432
5. P. aurelia	* (+)					0.302	-0.124	-0.411	-0.192	0.075	0.369	-0.379
4. Sarcomastigophora	* (-)				-0.110	0.259	-0.097	0.204	0.676	0.113	-0.019	0.268
3. Subbaromyces sp.				0.303	-0.335	0.063	-0.355	-0.063	0.548	0.626	0.544	0.555
2. Zoogloeal bacteria			-0.075	0.272	0.235	0.021	-0.271	-0.155	0.463	0.034	0.022	-0.012
1. Film weight		-0.032	-0.345	-0.584	0.682	-0.018	-0.309	-0.595	-0.433	-0.174	0.358	-0.582
	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. P. aurelia	6. O. microdiscum	7. C. colpoda	8. U. nigricans	9. C. uncinata	10. Paracyclops sp.	11. Acari	12. Air temperature

PLASTIC FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 11

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. P. aurelia	6. O. microdiscum	7. C. colpoda	8. U. nigricans	9. C. uncinata	10. Paracyclops sp.	11. Acari	12. Air temp.
1. Film weight					* * (+)					* * (+)		* * (-)
2. Zoogloeal bacteria	0.089		*** (+)									
3. Subbaromyces sp.	-0.038	0.883										
4. Sarcomastigophora	-0.131	-0.300	-0.300								* * (+)	
5. P. aurelia	0.733	-0.041	-0.286	-0.365		* (-)				* (+)		
6. O. microdiscum	-0.541	-0.094	0.084	-0.040	-0.592							
7. C. colpoda	0.205	-0.177	-0.229	0.093	-0.066	0.105						
8. U. nigricans	-0.540	-0.246	-0.251	0.018	-0.378	0.338	-0.175			* * (-)		
9. C. uncinata	-0.060	-0.274	-0.297	0.258	-0.147	-0.128	0.464	0.007				
10. Paracyclops sp.	0.756	0.440	0.365	-0.330	0.568	-0.494	0.098	-0.695	0.121			
11. Acari	0.008	-0.369	-0.463	0.684	-0.187	-0.178	0.431	0.239	0.092	-0.392		
12. Air temperature	-0.779	0.247	0.261	-0.331	-0.326	0.305	0.215	0.387	-0.157	-0.419	-0.240	

SLAG FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 10

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. *P. aurelia*	6. *O. microdiscum*	7. *C. colpoda*	8. *U. nigricans*	9. *C. uncinata*	10. *Paracyclops* sp.	11. Acari	12. Air temperature
12. Air temp.						* (+)						
11. Acari												-0.393
10. *Paracyclops* sp.											0.421	0.453
9. *C. uncinata*										0.426	0.122	0.137
8. *U. nigricans*	* (-)								0.055	0.069	0.187	0.182
7. *C. colpoda*		* (-)		* (-)	* (+)			-0.307	-0.030	-0.119	0.117	-0.330
6. *O. microdiscum*			*** (+)				-0.382	0.362	0.038	0.527	-0.336	0.613
5. *P. aurelia*						-0.252	0.696	-0.209	0.281	0.353	0.227	0.016
4. *Sarcomastigophora*		*** (+)			-0.432	0.499	-0.640	-0.066	-0.012	0.135	-0.197	0.064
3. *Subbaromyces* sp.				0.355	-0.076	0.938	-0.234	0.513	-0.038	0.510	-0.309	0.522
2. Zoogloeal bacteria			0.519	0.859	-0.263	0.552	-0.594	0.114	0.166	0.318	-0.090	0.041
1. Film weight		0.191	-0.369	0.309	0.173	-0.401	0.180	-0.609	-0.372	-0.327	-0.027	-0.504

MIXED FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 10

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. P. aurelia	6. O. microdiscum	7. C. colpoda	8. U. nigricans	9. C. uncinata	10. Paracyclops sp.	11. Acari	12. Air temperature
12. Air temp.	* (-)											
11. Acari							** (+)		*** (+)			-0.528
10. Paracyclops sp.											0.200	0.269
9. C. uncinata							** (+)			0.016	0.914	0.500
8. U. nigricans									-0.209	-0.102	-0.275	0.379
7. C. colpoda								-0.173	0.709	-0.183	0.737	-0.513
6. O. microdiscum			*** (+)				-0.040	-0.135	0.176	-0.376	-0.041	0.183
5. P. aurelia						0.191	-0.186	-0.174	-0.110	-0.068	0.095	-0.136
4. Sarcomastigophora					0.204	0.312	-0.230	-0.566	0.047	0.274	0.080	-0.143
3. Subbaromyces sp.				0.475	0.371	0.867	-0.203	-0.086	-0.094	-0.278	-0.161	0.309
2. Zoogloeal bacteria	*** (+)		0.098	0.375	-0.066	0.069	-0.289	-0.397	-0.189	-0.282	-0.262	-0.366
1. Film weight		0.890	0.056	0.516	0.017	0.124	-0.163	-0.475	0.005	-0.230	-0.098	-0.585

PLASTIC FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 10

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. *P. aurelia*	6. *O. microdiscum*	7. *C. colpoda*	8. *U. nigricans*	9. *C. uncinata*	10. *Paracyclops* sp.	11. Acari	12. Air temperature
12. Air temp.												
11. Acari			* (-)									-0.501
10. *Paracyclops* sp.					** (+)						-0.151	0.313
9. *C. uncinata*						* (+)				0.030	-0.241	-0.246
8. *U. nigricans*									-0.007	-0.130	0.397	0.094
7. *C. colpoda*								-0.124	-0.131	-0.339	0.257	-0.520
6. *O. microdiscum*							-0.082	-0.144	0.693	-0.075	-0.076	-0.324
5. *P. aurelia*						-0.228	-0.259	0.082	0.162	0.753	-0.122	0.092
4. *Sarcomastigophora*					-0.424	0.473	-0.072	0.128	0.167	-0.118	0.077	-0.221
3. *Subbaromyces* sp.				-0.366	-0.099	0.259	-0.252	-0.199	0.116	-0.123	-0.624	0.438
2. Zoogloeal bacteria			0.239	-0.062	-0.373	0.218	0.010	0.422	0.328	-0.452	0.165	-0.110
1. Film weight		0.485	0.341	-0.310	-0.198	0.365	-0.201	-0.085	0.303	-0.430	0.201	-0.251

SLAG FILTER: BOTH LOADINGS
Degrees of freedom (n-1) = 22

	1. Film weight	2. Zoogloeal bacteria	3. Subbaromyces sp.	4. Sarcomastigophora	5. P. aurelia	6. O. microdiscum	7. C. colpoda	8. U. nigricans	9. C. uncinata	10. Paracyclops sp.	11. Acari	12. Air temperature
12. Air temp.	** (-)		** (+)			* (+)						
11. Acari		* (-)								*** (+)		0.027
10. Paracyclops sp.		* (-)	** (+)								0.660	0.384
9. C. uncinata					* (+)					-0.002	0.156	0.006
8. U. nigricans	* (-)								-0.076	0.058	-0.027	0.313
7. C. colpoda								-0.243	0.095	-0.322	-0.152	-0.275
6. O. microdiscum		* (+)	* (+)	** (+)			-0.155	0.349	0.003	-0.193	-0.357	0.423
5. P. aurelia	** (+)					-0.315	0.334	-0.313	0.479	-0.051	0.032	-0.286
4. Sarcomastigophora		** (+)			-0.335	0.555	-0.125	0.006	0.057	-0.387	-0.199	-0.036
3. Subbaromyces sp.	** (-)			0.042	-0.400	0.489	-0.186	0.361	-0.147	0.579	0.093	0.647
2. Zoogloeal bacteria			0.145	0.606	-0.350	0.469	0.024	-0.007	0.017	-0.451	-0.479	0.005
1. Film weight		-0.151	-0.636	0.162	0.582	-0.315	0.145	-0.466	-0.025	-0.326	-0.086	-0.565

MIXED FILTER: BOTH LOADINGS
Degrees of freedom (n-1) = 22

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. *Sarcomastigophora*	5. *P. aurelia*	6. *O. microdiscum*	7. *C. colpoda*	8. *U. nigricans*	9. *C. uncinata*	10. *Paracyclops* sp.	11. Acari	12. Air temp.
1. Film weight		*** (+)						** (-)				** (-)
2. Zoogloeal bacteria	0.670											
3. *Subbaromyces* sp.	0.164	0.397				*** (+)						
4. Sarcomastigophora	-0.041	0.273	0.348									
5. *P. aurelia*	0.226	0.045	0.325	0.092								
6. *O. microdiscum*	0.250	0.409	0.879	0.261	0.227							
7. *C. colpoda*	-0.063	0.031	-0.013	-0.105	-0.127	0.134			** (+)			
8. *U. nigricans*	-0.545	-0.267	-0.133	-0.037	-0.236	-0.164	0.163					
9. *C. uncinata*	-0.067	0.008	0.048	0.285	-0.104	0.215	0.554	-0.028				
10. *Paracyclops* sp.	-0.227	-0.232	-0.182	0.170	-0.044	-0.316	-0.227	-0.145	0.072			
11. Acari	-0.014	-0.415	-0.370	-0.069	0.080	-0.311	-0.017	-0.054	0.143	0.002		
12. Air temperature	-0.572	-0.251	0.220	0.064	-0.201	0.026	-0.286	0.399	-0.210	0.344	0.188	

PLASTIC FILTER: BOTH LOADINGS
Degrees of freedom (n-1) = 22

	1. Film weight	2. Zoogloeal bacteria	3. *Subbaromyces* sp.	4. Sarcomastigophora	5. *P. aurelia*	6. *O. microdiscum*	7. *C. colpoda*	8. *U. nigricans*	9. *C. uncinata*	10. *Paracyclops* sp.	11. Acari	12. Air temperature
12. Air temp.	* (-)											
11. Acari			* (-)	** (+)								-0.215
10. *Paracyclops* sp.		* (-)			* (+)						0.062	-0.100
9. *C. uncinata*										0.290	0.161	-0.144
8. *U. nigricans*									0.058	-0.258	0.307	0.258
7. *C. colpoda*								-0.159	-0.030	-0.244	0.049	-0.418
6. *O. microdiscum*		* (+)					0.072	-0.127	0.121	-0.361	-0.216	-0.231
5. *P. aurelia*						-0.241	-0.213	-0.172	-0.003	0.462	-0.081	-0.104
4. Sarcomastigophora					-0.327	0.095	-0.077	0.088	0.290	-0.034	0.608	-0.246
3. *Subbaromyces* sp.	* (+)	* (+)		-0.323	-0.186	0.398	-0.072	-0.236	-0.170	-0.271	-0.458	0.293
2. Zoogloeal bacteria	** (+)		0.532	-0.258	-0.270	0.440	0.214	-0.045	-0.201	-0.478	-0.363	-0.058
1. Film weight		0.611	0.427	-0.279	0.137	0.422	0.095	-0.374	-0.120	-0.163	-0.193	-0.439

SLAG FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 11

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraeidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD											* * (+)	
11. Organic Load	* (-)									* (-)		0.766
10. Nematoda											-0.581	-0.426
9. Psychoda sp.		* (+)		* * (+)						-0.459	0.228	0.459
8. Enchytraidae									0.298	-0.055	0.251	0.289
7. Sphaerotilus sp.								-0.464	-0.517	0.315	-0.260	-0.086
6. Ciliophora	* * (+)				* (+)		0.242	0.003	0.098	-0.022	-0.476	-0.294
5. C.uncinata	* (+)					0.580	0.004	0.319	-0.141	-0.134	-0.169	-0.295
4. U.nigricans					-0.293	0.123	0.496	0.184	0.701	-0.432	0.381	0.530
3. C.colpoda	* (+)			-0.290	0.373	0.516	0.386	-0.251	-0.229	0.139	-0.387	-0.296
2. O.microdiscum	* (-)		-0.270	0.464	-0.488	-0.028	-0.355	-0.224	0.568	0.022	-0.032	0.082
1. P.aurelia		-0.554	0.654	-0.480	0.683	0.739	0.526	0.005	-0.366	0.184	-0.614	-0.490

MIXED FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 11

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraeidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD											** (+)	
11. Organic Load												0.779
10. Nematoda	** (+)										-0.350	-0.428
9. Psychoda sp.										-0.334	0.040	0.444
8. Enchytraidae									-0.030	0.368	0.030	0.098
7. Sphaerotilus sp.								-0.406	0.135	0.041	-0.039	-0.183
6. Ciliophora			*** (+)	*** (+)			-0.311	-0.105	-0.113	-0.226	0.069	0.288
5. C.uncinata						0.179	-0.161	-0.246	-0.042	-0.194	0.192	0.070
4. U.nigricans			*** (+)		0.217	0.969	-0.227	-0.169	-0.022	-0.375	0.135	0.382
3. C.colpoda				0.867	-0.225	0.873	-0.147	-0.161	-0.082	-0.156	-0.022	0.285
2. O.microdiscum			-0.152	-0.102	0.011	0.084	-0.168	0.225	-0.247	0.260	-0.228	-0.497
1. P.aurelia		0.302	-0.124	-0.411	-0.192	-0.227	-0.015	-0.064	-0.385	0.763	-0.430	-0.513

PLASTIC FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 11

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraeidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD				** (+)					* (+)		* (+)	
11. Organic Load												0.703
10. Nematoda								** (+)			-0.236	-0.401
9. Psychoda sp.				*** (+)		*** (+)				-0.404	0.332	0.681
8. Enchytraidae									-0.124	0.712	-0.357	-0.319
7. Sphaerotilus sp.	** (+)							0.009	-0.440	0.466	0.251	0.074
6. Ciliophora				*** (+)			-0.178	-0.135	0.804	-0.219	0.159	0.507
5. C.uncinata						0.284	-0.084	0.318	0.159	0.213	0.012	0.142
4. U.nigricans					0.007	0.844	-0.338	-0.198	0.952	-0.449	0.355	0.707
3. C.colpoda				-0.175	0.464	0.322	-0.045	0.011	-0.087	0.306	-0.331	-0.351
2. O.microdiscum	* (-)		0.105	0.338	-0.128	0.323	-0.460	-0.100	0.340	-0.256	-0.149	-0.167
1. P.aurelia		-0.592	-0.066	-0.378	-0.147	-0.215	0.796	0.108	-0.518	0.393	-0.172	-0.067

SLAG FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 10

	1. *P.aurelia*	2. *O.microdiscum*	3. *C.colpoda*	4. *U.nigricans*	5. *C.uncinata*	6. Ciliophora	7. *Sphaerotilus* sp.	8. Enchytraeidae	9. *Psychoda* sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD									* (+)		*** (+)	
11. Organic Load												0.947
10. Nematoda								* * (+)	* * (-)		-0.487	-0.498
9. *Psychoda* sp.		* (+)								-0.735	0.449	0.583
8. Enchytraidae									-0.384	0.719	-0.326	-0.339
7. *Sphaerotilus* sp.	* (+)							-0.489	0.277	-0.135	0.277	0.428
6. Ciliophora		*** (+)					0.346	-0.267	0.534	-0.384	0.441	0.503
5. *C.uncinata*						0.206	0.019	0.119	-0.359	0.257	0.043	0.083
4. *U.nigricans*					0.055	0.432	-0.105	-0.238	0.378	-0.416	-0.082	0.000
3. *C.colpoda*	* (+)			-0.307	-0.030	-0.139	0.488	0.150	-0.274	0.298	-0.005	0.039
2. *O.microdiscum*			-0.382	0.362	0.038	0.904	0.171	-0.151	0.686	-0.382	0.353	0.414
1. *P.aurelia*		-0.252	0.696	-0.209	0.281	0.123	0.684	-0.231	-0.311	0.165	0.330	0.353

MIXED FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 10

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraeidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD				* (+)					*** (+)		*** (+)	
11. Organic Load		* (+)										0.832
10. Nematoda											-0.437	-0.533
9. Psychoda sp.				*** (+)						-0.532	0.518	0.856
8. Enchytraidae									0.135	0.140	-0.129	0.200
7. Sphaerotilus sp.								-0.415	-0.453	0.103	0.204	-0.150
6. Ciliophora		* * (+)					-0.320	-0.291	0.458	-0.178	0.459	0.409
5. C.uncinata			* * (+)			0.476	0.160	-0.228	-0.226	0.113	-0.112	-0.207
4. U.nigricans					-0.209	0.229	-0.431	0.192	0.863	-0.473	0.200	0.634
3. C.colpoda				-0.173	0.709	0.312	-0.195	-0.198	-0.265	-0.151	-0.413	-0.396
2. O.microdiscum			-0.040	-0.135	0.176	0.754	-0.191	-0.226	0.322	-0.104	0.606	0.408
1. P.aurelia		0.191	-0.186	-0.174	-0.110	0.325	0.064	-0.201	-0.176	0.437	0.162	-0.092

PLASTIC FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 10

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraeidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD				* (+)					** (+)	* (-)	** (+)	
11. Organic Load									* (+)	* (-)		0.769
10. Nematoda									** (-)		-0.656	-0.664
9. Psychoda sp.				* (+)						-0.732	0.582	0.809
8. Enchytraidae							* (-)		-0.226	0.362	-0.015	0.202
7. Sphaerotilus sp.								-0.009	-0.600	0.168	0.028	-0.392
6. Ciliophora		** (+)			* (+)		0.072	-0.345	0.148	0.186	-0.016	-0.142
5. C.uncinata		* (+)				0.705	0.495	-0.345	-0.196	0.247	0.002	-0.303
4. U.nigricans					0.015	0.158	-0.378	-0.128	0.647	-0.533	0.291	0.656
3. C.colpoda				-0.261	-0.131	0.280	-0.255	0.006	-0.212	0.311	-0.343	-0.325
2. O.microdiscum			-0.082	-0.219	0.693	0.781	0.298	-0.347	0.066	0.222	0.020	-0.239
1. P.aurelia		-0.228	-0.259	0.082	0.162	-0.088	0.446	0.201	-0.284	-0.010	0.371	0.054

SLAG FILTER: BOTH LOADINGS
Degrees of freedom (n-1) = 22

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
1. P.aurelia					* (+)							
2. O.microdiscum	-0.315					*** (+)			*** (+)		* (+)	* (+)
3. C.colpoda	0.334	-0.155					* * (+)					
4. U.nigricans	-0.313	0.349	-0.243						* (+)			
5. C.uncinata	0.479	0.003	0.095	-0.076								
6. Ciliophora	0.172	0.837	0.081	0.366	0.318		* (+)		* * (+)		* (+)	
7. Sphaerotilus sp.	0.331	0.276	0.551	-0.148	0.058	0.430						
8. Enchytraeidae	-0.176	-0.038	0.196	-0.144	0.167	-0.125	-0.316			* (+)		
9. Psychoda sp.	-0.360	0.723	-0.062	0.427	-0.184	0.547	0.290	-0.167		* (-)	* * (+)	* * (+)
10. Nematoda	0.166	-0.223	0.203	-0.402	0,035	-0.224	0.029	0.432	-0.528			* (-)
11. Organic Load	-0.236	0.492	0.223	0.062	0.053	0.443	0.405	-0.023	0.562	-0.350		*** (+)
12. Effluent BOD	-0.221	0.423	0.119	0.192	-0.057	0.370	0.377	-0.086	0.597	-0.426	0.840	

MIXED FILTER: BOTH LOADINGS
Degrees of freedom (n-1) = 22

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraeidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD									** (+)		** (+)	
11. Organic Load		*** (+)							** (+)			0.643
10. Nematoda	* (+)										-0.255	-0.450
9. Psychoda sp.										-0.298	0.547	0.646
8. Enchytraidae									0.204	0.149	0.108	0.182
7. Sphaerotilus sp.								-0.229	-0.152	0.050	0.332	-0.108
6. Ciliophora		** (+)	* (+)	** (+)			-0.169	-0.113	0.365	-0.201	0.417	0.365
5. C.uncinata			** (+)			0.377	0.108	-0.171	-0.136	-0.028	0.068	-0.087
4. U.nigricans					-0.028	0.602	-0.326	-0.013	0.301	-0.386	-0.027	0.412
3. C.colpoda				0.163	0.554	0.506	-0.031	-0.086	-0.114	-0.124	0.227	-0.124
2. O.microdiscum			0.134	-0.164	0.215	0.577	0.072	-0.014	0.418	-0.016	0.686	0.244
1. P.aurelia		0.227	-0.127	-0.236	-0.104	0.164	0.078	-0.143	-0.134	0.461	0.126	-0.188

PLASTIC FILTER: BOTH LOADINGS
Degrees of freedom (n-1) = 22

	1. P.aurelia	2. O.microdiscum	3. C.colpoda	4. U.nigricans	5. C.uncinata	6. Ciliophora	7. Sphaerotilus sp.	8. Enchytraeidae	9. Psychoda sp.	10. Nematoda	11. Organic Load	12. Effluent BOD
12. Effluent BOD				* * (+)					*** (+)	* (+)	* * (+)	
11. Organic Load									* * (+)			0.603
10. Nematoda				* (-)				* * (+)	* (-)		-0.325	0.497
9. Psychoda sp.				* (+)						-0.483	0.591	0.717
8. Enchytraidae									-0.213	0.595	-0.246	-0.119
7. Sphaerotilus sp.		* (+)						-0.158	-0.191	0.116	0.490	-0.112
6. Ciliophora		*** (+)					0.230	-0.275	0.344	-0.029	0.222	0.142
5. C.uncinata						0.277	-0.072	0.207	-0.122	0.218	-0.199	-0.050
4. U.nigricans					0.063	0.390	-0.324	-0.127	0.524	-0.462	0.075	0.063
3. C.colpoda				-0.229	-0.030	0.341	0.046	-0.064	-0.085	0.220	-0.033	-0.248
2. O.microdiscum			0.072	-0.164	0.121	0.692	0.483	-0.276	0.200	0.076	0.305	-0.115
1. P.aurelia		-0.241	-0.213	-0.172	-0.003	-0.179	0.209	0.170	-0.340	0.245	0.020	-0.025

APPENDIX VII : Correlation Analysis: Chemical Data

Parameters used:
1. Organic Load (kg BOD $m^{-3}d^{-1}$)
2. Effluent BOD (mgl^{-1})
3. Percentage removal BOD
4. Suspended solids load (kg $m^{-3}d^{-1}$)
5. Effluent suspended solids (S/S) (mgl^{-1})
6. Percentage removal S/S
7. Ammonia load (kg $m^{-3}d^{-1}$)
8. Effluent ammonia (mgl^{-1})
9. Percentage removal NH_3
10. Total Oxidised Nitrogen (mgl^{-1})
11. Effluent temperature (°C)
12. Film weight (kgm^{-3})

(Summary of the above parameters given in Table 6.3).

Values for Correlation Coefficient 'r'.

Degrees of freedom	$P < 0.05$	$P < 0.02$	$P < 0.01$	$P < 0.001$
(n-1) 12	0.532	0.612	0.661	0.780

SLAG FILTER : LOW LOADING RATE
Degrees of freedom (n-1) = 12

	1. Organic load	2. Final effluent BOD	3. % removal BOD	4. Suspended solids load	5. Final effluent S/S	6. % removal S/S	7. Ammonia load	8. Final effluent NH3	9. % removal NH_3	10. Total oxidised N	11. Final effluent temp.	12. Film weight
12. Film										* (-)	** (-)	
11. Effl. temp.	* (+)											-0.740
10. Total oxid.N											0.201	-0.631
9. % removal NH_3										0.411	0.282	-0.186
8. NH_3 effl.							** (+)		-0.301	-0.287	-0.232	0.058
7. NH_3 load			* (+)			** (+)		0.770	0.301	0.050	0.117	-0.288
6. % removal S/S			** (+)		*** (-)		0.671	0.380	0.316	0.104	0.245	-0.333
5. S/S effl.		** (+)	*** (-)			-0.884	-0.500	-0.119	-0.495	-0.273	-0.319	0.449
4. S/S load					0.376	0.067	0.268	0.492	-0.350	-0.364	-0.286	0.389
3. % removal BOD		** (-)		-0.215	-0.818	0.738	0.598	0.347	0.444	0.326	-0.081	-0.286
2. BOD effl.	** (+)		-0.712	0.263	0.536	-0.367	-0.076	0.111	-0.351	-0.392	0.377	-0.035
1. Org. load		0.749	-0.100	0.152	-0.101	0.263	0.469	0.433	-0.038	-0.255	0.543	0.349

MIXED FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 12

	1. Org. load	2. BOD effl.	3. % removal BOD	4. S/S load	5. S/S effl.	6. % removal S/S	7. NH_3 load	8. NH_3 effl.	9. % removal NH_3	10. Total oxid.N	11. Effl. temp.	12. Film
1. Organic load		*** (+)										
2. Final effluent BOD	0.781		* * (-)									
3. % removal BOD	-0.247	-0.767										
4. Suspended solids load	0.152	0.017	0.088									
5. Final effluent S/S	0.105	0.469	-0.509	0.334		*** (-)						
6. % removal S/S	0.100	-0.317	0.429	0.084	-0.876		* (+)					
7. Ammonia load	0.469	0.151	0.163	0.268	-0.388	0.590		* * (+)				
8. Final effluent NH_3	0.085	0.060	-0.020	0.007	-0.404	0.492	0.702		*** (-)			
9. % removal NH_3	0.257	0.067	0.123	0.223	0.329	-0.282	-0.250	-0.862				
10. Total oxidised N	-0.257	-0.263	0.091	-0.196	0.200	-0.366	-0.486	-0.516	0.358			
11. Final effluent temp.	0.528	0.431	-0.275	-0.286	-0.155	0.125	0.136	-0.218	0.367	0.196		
12. Film weight	-0.517	-0.495	0.306	0.406	-0.085	0.176	0.090	0.183	-0.207	-0.373	-0.522	

PLASTIC FILTER: LOW LOADING RATE
Degrees of freedom (n-1) = 12

12. Film	* (-)							** (-)	** (+)	* (+)	* (-)	
11. Effl. temp.	* (+)											-0.675
10. Total oxid.N	* (-)	* (-)						** (-)	*** (+)		-0.252	0.706
9. % removal NH_3								** (-)		0.786	-0.076	0.822
8. NH_3 effl.									-0.779	-0.661	0.051	-0.754
7. NH_3 load								0.423	0.206	0.056	0.135	0.106
6. % removal S/S			** (+)		*** (-)		0.523	0.187	0.160	0.039	0.097	0.037
5. S/S effl.		* (+)	** (-)			-0.896	-0.416	0.007	-0.323	-0.254	-0135	-0.109
4. S/S load					0.166	0.265	0.268	0.345	-0.220	-0.235	-0231	0.061
3. % removal BOD		** (-)		0.074	-0.721	0.726	0.093	-0.022	0.171	0.186	-0230	0.029
2. BOD effl.	** (+)		-0.731	-0.030	0.562	-0.481	0.076	0.333	-0.392	-0.593	0.447	-0.483
1. Org. load		0.694	-0.110	0.152	-0.051	0.213	0.469	0.526	-0.317	-0.626	0.546	-0.590

1. Organic load
2. Final effluent BOD
3. % removal BOD
4. Suspended solids load
5. Final effluent S/S
6. % removal S/S
7. Ammonia load
8. Final effluent NH_3
9. % removal NH_3
10. Total oxidised N
11. Final effluent temp.
12. Film weight

SLAG FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 12

	1. Organic load	2. Final effluent BOD	3. % removal BOD	4. Suspended solids load	5. Final effluent S/S	6. % removal S/S	7. Ammonia load	8. Final effluent NH$_3$	9. % removal NH$_3$	10. Total oxidised N	11. Final effluent temp.	12. Film weight
12. Film				* (-)							* (-)	
11. Effl. temp.	** (+)	*** (+)	* (-)	** (+)	*** (+)			* (+)				-0.630
10. Total oxid.N	** (-)	** (-)			* (-)						-0.484	0.032
9. % removal NH$_3$										0.260	-0.277	-0.174
8. NH$_3$ effl.	*** (+)	*** (+)	* (-)		*** (+)		*** (+)		-0.436	-0.501	0.547	-0.083
7. NH$_3$ load	*** (+)	*** (+)			** (+)			0.925	-0.094	-0.460	0.500	-0.143
6. % removal S/S							-0.309	-0.431	0.389	0.155	-0.112	-0.543
5. S/S effl.	*** (+)	*** (+)	* (-)			-0.451	0.778	0.823	-0.313	-0.595	0.847	-0.321
4. S/S load	* (+)	* (+)			0.517	0.277	0.286	0.296	-0.158	-0.505	0.720	-0.675
3. % removal BOD		** (-)		-0.481	-0.659	0.025	-0.451	-0.583	0.272	0.361	-0.640	0.546
2. BOD effl.	*** (+)		-0.693	0.613	0.931	-0.264	0.813	0.873	-0.393	-0.680	0.837	-0.329
1. Org. load		0.945	-0.477	0.614	0.863	-0.191	0.787	0.793	-0.296	-0.737	0.772	-0.256

MIXED FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 12

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
12. Film		* (-)	* (+)		* (-)						* (-)	
11. Effl. temp.	*** (+)	** (+)		** (+)	** (+)							-0.659
10. Total oxid.N	* (-)							* (-)	** (+)		-0.315	0.055
9. % removal NH3								** (-)		-0.685	-0.096	0.017
8. NH3 effl.	** (+)	* (+)			* (+)		*** (+)		-0.700	-0.619	0.403	-0.360
7. NH3 load	*** (+)	** (+)			** (+)			0.952	-0.478	-0.466	0.499	-0.442
6. % removal S/S		** (-)	** (+)		** (-)		-0.479	-0.483	0.399	-0.133	-0.201	0.354
5. S/S effl.	*** (+)	*** (+)	*** (-)			-0.735	0.700	0.632	-0.318	-0.157	0.688	-0.597
4. S/S load	** (+)				0.402	0.143	0.286	0.253	-0.154	-0.393	0.739	-0.356
3. % removal BOD		*** (-)		-0.128	-0.810	-0.673	-0.378	-0.246	-0.107	-0.289	-0.507	0.690
2. BOD effl.	*** (+)		-0.826	0.402	0.972	-0.668	0.697	0.594	-0.235	-0.155	0.749	-0.599
1. Org. load		0.805	-0.368	0.614	0.782	-0.354	0.787	0.763	-0.491	-0.572	0.781	-0.370

1. Organic load
2. Final effluent BOD
3. % removal BOD
4. Suspended solids load
5. Final effluent S/S
6. % removal S/S
7. Ammonia load
8. Final effluent NH3
9. % removal NH_3
10. Total oxidised N
11. Final effluent temp.
12. Film weight

PLASTIC FILTER: HIGH LOADING RATE
Degrees of freedom (n-1) = 12

12. Film		* (-)	* (+)		* (-)		* (-)	* (-)				
11. Effl. temp.	** (+)	** (+)		** (+)	** (+)			* (+)	* (-)	*** (-)		-0.395
10. Total oxid.N	*** (-)	* (-)		** (-)	* (-)		* (-)	** (-)	* (+)		-0.813	0.238
9. % removal NH3		* (-)			* (-)	* (+)		* (-)		0.653	-0.548	0.293
8. NH3 effl.	*** (+)	*** (+)			** (+)	* (-)	*** (+)		-0.563	-0.749	0.656	-0.618
7. NH3 load	*** (+)	* (+)			* (+)			0.913	-0.224	-0.548	0.484	-0.588
6. % removal S/S		*** (-)	*** (+)		** (-)		-0.363	-0.551	0.551	0.176	-0.268	0.539
5. S/S effl.	** (+)	*** (+)	** (-)			-0.777	0.582	0.768	-0.551	-0.588	0.726	-0.589
4. S/S load	* (+)				0.327	0.195	0.286	0.435	-0.425	-0.714	0.722	-0.322
3. % removal BOD		*** (-)		-0.017	-0.776	0.819	-0.192	-0.382	0.457	0.140	-0.461	-0.599
2. BOD effl.	** (+)		-0.799	0.318	0.980	-0.790	0.627	0.808	-0.606	-0.591	0.736	0.596
1. Org. load		0.742	-0.220	0.614	0.723	-0.314	0.787	0.883	-0.529	-0.864	0.762	0.320
	1. Organic load	2. Final effluent BOD	3. % removal BOD	4. Suspended solids load	5. Final effluent S/S	6. % removal S/S	7. Ammonia load	8. Final effluent NH3	9. % removal NH3	10. Total oxidised N	11. Final effluent temp.	12. Film weight

ABSTRACT

The highest rate of oxidation occurs in the top section of percolating filters, where the limiting factor is usually the amount of oxygen provided by natural ventilation. An investigation was carried out to ascertain whether the loading to a conventional single pass filter could be increased by replacing the surface layer of mineral medium with a 750mm layer of random plastic medium, which has greater surface area and voidage. This would allow greater film accumulation and subsequent removal of organic matter, at the same time avoiding ponding and anaerobic conditions normally associated with excessively loaded single pass mineral filters.

A pilot plant was designed and three identical filters constructed, one containing 2 m^3 of blast furnace slag and another 2 m^3 of random plastic medium and the third 0.8 m^3 of plastic medium upon 1.2 m^3 of slag. The comparative treatment efficiencies of the various packings were studied at three different loadings, for three months during maturation at 5.72 $m^3m^{-3}d^{-1}$ (0.85 kg BOD $m^{-3}d^{-1}$) and then for 12 months at 1.68 $m^3m^{-3}d^{-1}$ (0.28 kg BOD $m^{-3}d^{-1}$) and a further 12 months at 3.37 $m^3m^{-3}d^{-1}$(0.63 kg BOD $m^{-3}d^{-1}$). The ecology was studied both qualitatively and quantitatively throughout the depth of the filters, during the two longer loading periods. The film accumulation, temperature and retention time were all recorded and directly compared with the biological and chemical results.

Medium replacement was shown to be a viable system for uprating

filters, providing the operator with a more versatile filter, less susceptible to ponding, with less variable retention times and capable of treating greater organic loadings than conventional filters in excess of 0.2 kg BOD $m^{-3}d^{-1}$. The cost of the system is dependent upon specific requirements and availability of medium.

In the mixed filter the slag portion regulated the loss of animals from the plastic layer, retaining greater numbers of micro- and macro-grazers in the lower mineral portion, resulting in an increase in film control, and lower film accumulation at both the interface and slag portion of the mixed filter.