Air pollution monitoring and modelling in RTH East Derbyshire.

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AIR POLLUTION MONITORING AND MODELLING IN NORTH EAST DERBYSHIRE

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ABSTRACT

Previous work on biological monitors for atmospheric lead has been reviewed. Experiments with hair-net and flat nylon-mesh envelope monitors failed to confirm a claim of reproducibility by previous workers, a percentage relative standard deviation of 24.5 for hair-net monitors and 13.4 to 56.7 for flat nylon-mesh envelopes was achieved. An homogenised acid-washed moss monitor in a diffusion tube produced a significant increase in lead deposition. Replicate diffusion tube monitors initially showed poor reproducibility. Homogenisation of the moss to < 1mm and maintained saturation produced a range of % RSD's of 8.6 to 12.8. Samples unwashed with acid showed more depostion than washed samples. Replicate monitors in which moss was replaced with various physical media displayed poor reproducibility. It seems unlikely that such passive monitors can replace established air filtration methods.

At the commencement of this study in 1981, two types of dust gauge were in use in the North East Derbyshire area, they were the B.S. Standard Deposit Gauge and the B.S. Direction Dust Gauge. Sampling errors of the British Standard Deposit Gauge had been established by previous workers as being considerable. Proposed models to apply a wind direction correction to amounts of dust collected by Directional Gauges have inherent weaknesses. A new model was developed and its performance improved with successive refinements of input data. Wind data from a localised weather station was applied to the model and showed to improve the performance compared to using remote weather station data.

Daily smoke and sulphur dioxide levels at 6 sites covering a 3 year period were used to develop a model which employs data collected at one monitoring station to predict levels in other parts of the area.

Precipitation acidity has been measured within the area since 1950. Previous work on precipitation acidity data has been reviewed and an increase in precipitation acidity for the area was indicated.

A rationalised air pollution monitoring network is proposed to fulfil the air quality management function for the N.E.D.D.C.

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(a) INTRODUCTION TO AIR POLLUTION

Air is essential to human life and must be breathed continually to survive. Dirty water or tainted food may be rejected unlike air which is involuntarily inhaled.

Pollution may take many forms. Air pollution, water pollution, land pollution and the pollution of estuaries and the seas are forms which are readily understandable. It is sometimes possible when preventing one form of pollution to cause other forms. For example, when flue gases are washed before being discharged to the atmosphere, the effluent may be discharged directly to a stream or river. This could pollute the river and so the prevention of one form of pollution may, if not properly controlled, cause another.

Modern methods of monitoring enable the detection and measurement of substances in very small quantities. In earlier days, such amounts would have been described as "traces" and often disregarded. When considering certain pollutants, the amount is important, for it could be small and of little significance. Some gases, although generally regarded as toxic are only so, if they are of a sufficient concentration.

Some air pollutants occur naturally. Perhaps the best example is that produced by volcanoes. The amount of smoke, apart from lava, liquid mud, ashes and cinders that a volcano emits is immense. Another form of natural pollution which is common in this country, is sea salt which adds to the general corrosiveness of the atmosphere.

However when considering atmospheric pollution, its source is often anthropogenic. The serious air pollution events, such as those which occurred in London in 1952, Donora in 1948 and the Meuse Valley in 1930 produced acute effects, especially on the inhabitants of those areas. They led to various legislative controls on emissions to atmosphere in this country[1].

Recently attention has also been directed towards the potential dangers of atmospheric heavy metals. Lead has attracted most concern because of its widespread use as an anti-knock agent in petrol, but other metals also cause fears from time to time, especially around industrial plants.

It has been estimated that some 10,000 chemicals are produced by man in significant amounts (500 - 1,000,000 kg per year). Some of these have always occurred naturally in the environment, others appeared in the biosphere for the first time when they were synthesised by man. The following criteria have been suggested[2] for recognising a potentially harmful chemical.

1. Toxic in small amounts (acceptable daily intake less than 100 $mg.kg^{-1}$ body mass).
2. Not essential for life processes.
3. Accumulates with age (incompletely excreted or detoxified).
4. Environmentally persistent (poorly biodegradable; thermostable in air below 200°C).

5. Biochemically active (e.g. modifying enzyme activity, protein synthesis, redox states).
6. Rate of sequestration (deposition in fat or bone etc.) similar to absorption rate (i.e. pool of active chemical in tissues and body fluids).
7. Wide variation in toxicity with age or genotype or nutritional state (i.e. susceptible groups within a population).
8. Environmentally mobile (i.e. relatively low boiling point or melting point; relatively high vapour pressure at S.T.P.).
9. Does not form relatively stable complexes with organic matter, clay colloids, sediments and acid soils.
10. Pronounced increase in human environment in last 2,000 to 3,000 years or in environment of target species during its last 100 years.

The chief consideration is whether potential nuisance, or harm may be caused to man either directly, or indirectly. The effects may be outlined as follows:-

1. Chemical effects on man himself from ingesting contaminated air, water, food, or directly from drugs or contact, causing human health problems.

2. Chemical effects on livestock, crops or other cultivated species and resource organisms (e.g. trees, fibre plants). Absorption from contaminated air, water, soil, food, or from direct chemical treatment, may cause reduced productivity from resource species.
3. Chemical effects on wildlife which maintain the physical, chemical or biological stability of the environment or which influence the productivity of human food organisms. Absorption from contaminated air, water, soil or direct chemical treatment may cause reduced productivity, reduced genetic variability or species loss (e.g. in marine organisms forming the food base of a commercial fishery; in natural predators of crop-pests; in decomposer organisms involved in recycling minerals; in a key wild species responsible for maintaining the stability of an ecosystem useful to man).
4. Chemical contamination of the atmosphere and lower stratosphere by trace gases (e.g. CO_2, H_2O) and aerosols, which might effect global radiation balance and hence climate, causing sea-level changes, vegetation changes, etc.

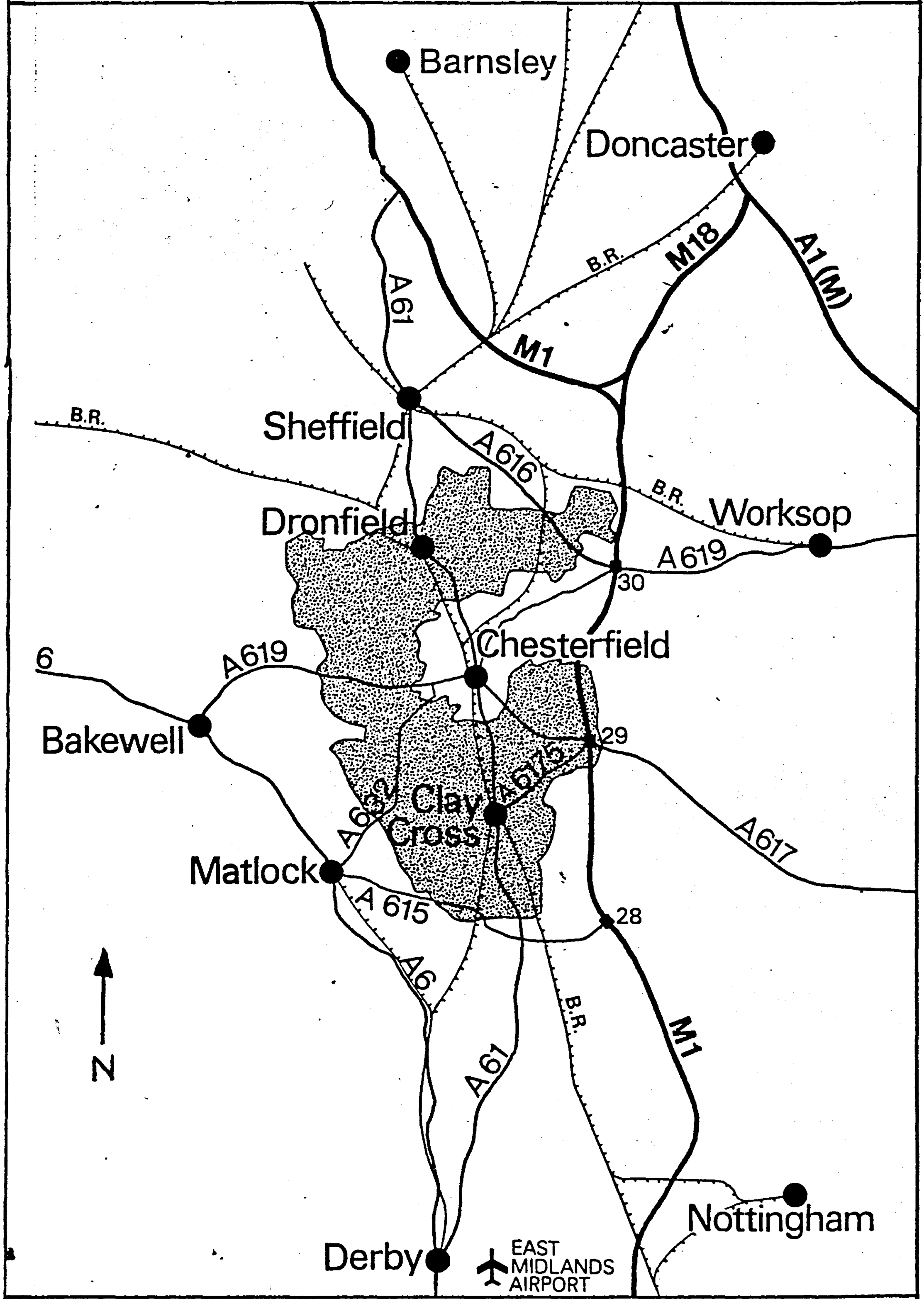
It is important to recognise that these four are not isolated from one another, but are mutually interactive components linked by the atmospheric, hydrological, geochemical and ecological processes which control the movements, distribution and effects of chemical substances injected into the biosphere. In this way, a chemical substance disposed of by release into air (chimney emissions) or water (sewage wastes) or soil, (dumping) can become redistributed among all three media. The contaminant is then available for absorption by a resource species either directly or via a wildlife species. Climatic changes could affect the productivity of a wild or resource species. In all cases, the ultimate recipient may be man.

The above considerations suggest that, of all the potentially harmful chemicals, those substances which are aerially dispersed in significant amounts and which have a high acute toxicity and environmental persistence, are the ones most likely to cause widespread problems and, in consequence, need some form of surveillance or monitoring. Especially important here are the so-called "heavy metals," many of which have been reported to be chronic health hazards to man and other living organisms, even in trace amounts[3,4].

(b) INTRODUCTION TO THE NORTH EAST DERBYSHIRE DISTRICT COUNCIL AREA

The North East Derbyshire District Council area comprises about 107 square miles, and almost entirely encircles Chesterfield, (see Figure 1). The estimated population of the Area is 96,000. The main areas of population are at Clay Cross, Dronfield, Eckington and Killamarsh. The area extends from the south of Sheffield to just north of Alfreton and from west of Bolsover to the beginnings of the Peak District National Park in the east.

FIG. 1. AREA LOCATION MAP.



NORTH EAST DERBYSHIRE DISTRICT COUNCIL AREA ▨

The eastern and northern parts of the District are part of a major coalfield area although mining has declined in recent years. However, there are still enough collieries in use to make this industry a significant factor in the local economy. The iron and steel and heavy engineering industry too is prominent at Clay Cross, Dronfield, Eckington, Killamarsh, Renishaw and other villages along the eastern and northern edges of the District. However, Dronfield, Eckington and Killamarsh are also important as residential areas for people working in Sheffield (in particular), which is only a few miles to the north.

(i) Clay Cross

Clay Cross has about 9,000 inhabitants and is located in the southern part of the District. Coal mining which was once the main industry of Clay Cross has now ceased and new industries have been brought in to augment the traditional iron and steel making role. Almost all of the older and cramped houses built cheaply and quickly in the early days of the town's development have gone and Clay Cross now has well over 1,400 modern houses and flats on several well planned estates. Industries located at Clay Cross include a large iron foundry, various steel and alloy producing plants, cardboard production and a wood waste processing plant.

(ii) Dronfield

Dronfield has a population of approximately 24,000 and is situated midway between Chesterfield and Sheffield, serving partly as a residential town for people who work in both. Although predominantly residential, there is a large industrial estate situated on the floor of the Dronfield valley. Industries include iron foundries, waste oil re-processing, ready mixed concrete production and machine tool manufacturing.

(iii) Eckington

This parish has an area of about 10 square miles and is located to the south east of Sheffield and stretches from Dronfield to the Rother Valley. Although mining is still important in the area, the parish includes a great deal of agricultural land use.

(iv) Killamarsh

Killamarsh is the most easterly parish within the District, and is on the east side of the Rother Valley and south east of Sheffield. It is an expanding township where a great deal of new residential development has taken place, both private and public. Mining and engineering provide much of the employment in the area.

(c) AIR POLLUTANTS IN THE AREA

The main air pollutants which are regularly monitored are lead, grit and dust, sulphur dioxide and smoke.

(i) Lead

Lead poisoning has been known for thousands of years. Until this century, the main hazards came from mining, and such sources as lead drinking pipes and cisterns, pewter and lead-containing vessels for food, drink, and cooking, lead paint, lead nipple shields for nursing mothers, certain cosmetics, lead toys, lead cider pressers and lead additives in wine.[5]

Whilst the worse excesses of industrial lead poisoning were abated during the first half of the 20th century, a new and more wide ranging source of lead was introduced following the discovery of the organolead anti-knock additive for petrol, tetraethyl lead (TEL), by the American industrial chemist, Midgley, in 1921.

The environmental consequences of using leaded petrol were largely under-estimated until 1965 when Patterson[6] concluded that from geochemical evidence the present day lead burdens which were regarded as "normal" were in fact enormously elevated over the "natural" levels against which man evolved as a species and to which he might be presumed to have adapted in some measure. Patterson suggested that modern lead burdens were a danger to public health, and identified the emissions from leaded petrol as a major source of these burdens.

Russian scientists, using techniques of behavioural toxicology then unknown in the west, had actually identified the hazard some years earlier, and leaded petrol was in consequence banned from major Russian cities[7]. In 1958 a request by the U.S. Petroleum industry to increase the current levels of lead in petrol triggered an investigation of the effects of existing exposure levels by the U.S. Public Health Authorities. The poisoning of emission control catalysts for cars, by lead, reinforced a growing medical awareness of the comparable poisoning of biochemical catalysts (enzymes) in man.

Since then a growing conflict has developed between bodies such as the United States Environmental Protection Agency and the manufacturers and industrial users of TEL and tetramethyl lead (TML). In this country amid contrasting reactions at Government level a growing number of research workers have embarked on studies of environmental lead and the effects of its intake by man.

The question whether contemporary lead burdens are sufficiently high to produce adverse effects on behaviour and intelligence among the general population (especially young children) is central to the environmental lead debate. The extensive literature on the subject has been reviewed in detail by the United States Environmental Protection Agency[8], Repko and Corum[9] and Jaworski[10]. Some of the studies are, as always open to criticism, but the bulk of studies indicate that blood lead levels insufficient to cause obvious clinical lead poisoning do produce disturbances in the biochemistry of the brain.

Lead is a neurotoxin and like other neurotoxins lead disturbs behaviour before it produces clinical illness. Lawther[11] concluded that children could exhibit symptoms of clinical lead poisoning at blood lead levels of 80 $\mu g\ dl^{-1}$. It is fully to be expected that intelligence and behaviour are liable to be disturbed at blood levels below that[13].

It may be concluded that there is a link (if somewhat ill-defined because of subjective human reaction) between environmental lead burdens and health. In consequence, the E.E.C. has adopted an air quality standard of 2 $\mu g\ m^{-3}$ for urban areas, not especially exposed to vehicular traffic.

North East Derbyshire District Council has monitored atmospheric lead levels at various locations within the area since 1980 and a schedule of results is included in Appendix A.

(ii) Grit and Dust

British Standard 3405[15] defines dust as small solid particles in the size range 1 to 75 μm in diameter and grit as particles above 75 μm. Particles below about 1 μm, if airborne, would tend to remain in suspension rather than settle out under their own weight. Particles more than 10 μm in diameter do not penetrate the alveoli of the lungs and particles below 1 μm in diameter pass freely in and out of the lungs[16].

Grit and dust concentrations which are normally found in the atmosphere do not constitute a hazard to human health but may cause nuisance. These particles may occur naturally or be mobilized during some industrial activity. Sea salt , road dust, pollen and seeds are examples of naturally occurring particles whilst industrial sources may include mineral dust from quarries, sand and cement from batch mixing plants and coal dust from storage depots and opencast coal extraction. The grit and dust may be dispersed for considerable distances by wind both from industrial processes and from boiler house chimneys. Nuisance may manifest itself as depositions on paintwork, dirty laundry or damaged vegetation.

Grit and dust measurements have been made throughout the Area using a variety of methods over many years.

(iii) Sulphur Dioxide

Sulphur dioxide at normal temperatures is a colourless gas formed by the oxidation of the element sulphur. Three principal processes contribute to the presence of sulphur dioxide in the atmosphere: the combustion of sulphurous impurities in some fuels; certain other industrial processes e.g. the reduction by smelting of metallic ores which occur as sulphur compounds, or which contain sulphurous impurities; and as a natural by-product of biological decay and geophysical activity (e.g. volcanoes).

In addition to sulphur dioxide, some industrial sources may emit small quantities of sulphur trioxide, and more may be formed subsequent to emission as some of the sulphur dioxide is oxidised to the trioxide form. Sulphur trioxide is chemically very reactive and in particular has a high affinity for combining with water. As a result its lifetime in the free atmosphere is likely to be very short. The lifetime of sulphur dioxide may be several days.

One stage in this sequence of chemical reactions will be the formation of dilute acids, sulphurous acid, formed directly from sulphur dioxide and water, and sulphuric acid, formed by further oxidation of sulphurous acid or directly from sulphur trioxide and water.

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$2H_2SO_3 + O_2 \rightarrow 2H_2SO_4$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

These acids are corrosive and attack most common materials - iron, steel, stone, textiles, leather, etc. Damage caused by this acid attack is a significant factor in the overall hazard of air pollution. Sulphur dioxide, as a gas, is, in sufficient concentration, an irritant to human and animal respiratory systems, and can damage vegetation.

Health

Studies on experimental animals[17] have shown that the presence of particulates, particularly those in the submicron size range, enhance the effect of enhaled sulphur dioxide when they are present simultaneously. The precise mechanism by which the oxides of sulphur and particulate matter can affect the lungs is not known. The considerable variations in the results of these experiments on animals reflect differences in sensitivity of individual species, exposure levels, and methods used to assess the effects. The extrapolation of these results on the synergistic effect of sulphur dioxide and particulate matter to human beings is not easy.

However, some studies have indicated possible mechanisms of biological action on the respiratory system, e.g. interference with mechanisms for the clearance of bacteria[18] and inert particles[19] from the lung.

The most clearly defined effects on mortality arising from exposure to sulphur oxides and particulate matter have been the sudden increases in the number of deaths occurring, on a day-to-day basis, in episodes of high pollution. The most notable of these occurred in the Meuse Valley in 1930[20] in Donora in 1948[21] and in London in 1952[22]. The people primarily affected were those with pre-existing heart or lung disease or both, and the elderly. The London episode lasted for 5 days and it was estimated that the number of deaths during and immediately after this period was about 4,000 more than expected under normal circumstances. On one day, the number of deaths was about three times the number expected at that time of the year. Concentrations of sulphur dioxide as high as 3,700 $\mu g.m^{-3}$ were recorded and that of particulate matter were too high to be measured properly. The 48 hour average of about 4,500 $\mu g.m^{-3}$ at a central site must be regarded as a conservative estimate.

In countries having reliable systems for the collection and analysis of data on deaths, based on cause and area of residence, death rates for respiratory diseases have commonly been found to be higher in towns than in rural areas. Many factors, such as differences in smoking habits, occupation or social conditions may be involved in these contrasts, but, in a number of countries, a general association between death rates from respiratory diseases and air pollution has been apparent for many decades.

The studies of Daly[23,23a] Pemberton and Goldberg[24] and Stocks[25], were all based on mortality data from towns in England and Wales, and each showed a positive correlation between bronchitis or pneumonia death rates and some index of pollution by sulphur oxides or particulate matter, as assessed for periods close to those for which death rates were calculated.

Vegetation

Research in this country specifically to determine the effect of sulphur oxides on plants and crops has been extremely limited. Little useful guidance can be obtained from simple field observations or experiments without adequate controls since so many other factors may in practice affect the growth of vegetation or the yield of crops, including soil quality, weather, pests and diseases, methods of husbandry, use of artificial fertilizers, etc., etc. In recent years, more reliable information has been forthcoming from research overseas, particularly in Germany and North America, which, with some qualification, can provide a useful guide to the levels of sulphur dioxide pollution which can cause discernible adverse effects on vegetation. These have been summarised in an Agricultural Research Council publication to which reference can be made for detailed figures[26]. Plant species differ considerably in their susceptibility to sulphur dioxide[27]; the plant is also markedly affected by the stage of growth at which it is exposed to pollution. Plants also have a definite diurnal variation in their susceptibility to this gas, and other environmental factors such as temperature, humidity, light intensity and nutrition can also modify the effects. For each species there is an irritation threshold concentration or 'first tolerance limit' which can be tolerated indefinitely without discernible injury. Higher concentrations may be tolerated for limited periods; although a given amount of gas at higher concentration generally causes more damage than the same amount at lower concentration over a longer time.

In any discussion of the effect of atmospheric sulphur dioxide on vegetation (and through the various food chains, indirectly on animals and human beings too), it cannot be overlooked that sulphur is an essential constituent of most proteins and is thus, one of the nutrients of growing crops.

Some confirmation of this view is seen in agricultural studies, notably in England[28], which have shown that where insufficient sulphur is being applied to soil in the form of fertilizer, to replace that taken by the growing crops, the sulphur derived from pollution of the air may help to prevent sulphur-deficiency arising in the soil in certain areas. Furthermore, an adequate sulphur supply has also shown to be essential to minimize crop losses from certain blights and diseases. The implication of these findings is that there might well be a minimum desirable level of SO_2 in the general atmosphere below which the health and yield of crops can suffer.

Increased acidity of precipitation has attracted recent attention. Forests in central Europe have been shown to be experiencing problems with trees (mainly fir, spruce and beech) showing visible injury. Such damage is widespread in West Germany especially at high altitude[14]. Acidity from precipitation and from dry deposited sulphur dioxide and oxides of nitrogen has been proposed as a possible cause of this damage[44]. Forests were identified as an ecosystem in which deleterious effects of acid precipitation were likely[122], but experimental work revealed no reduction in forest productivity in response to applications of acidified water on young Scots pine trees[123]. A casual link between deposited acidity and forest effects has yet to be demonstrated, however, and other factors including water stress and elevated summer ozone concentrations, have also been identified as possible causes.

Corrosion

On the basis of exposure tests made in many countries from 1928 onwards, the Atmospheric Corrosion Sub-Committee of the then Department of Scientific and Industrial Research reported many times that there is a correlation between the rate of corrosion of bare steel and of pure zinc or zinc coatings on steel, with the sulphur pollution of the atmosphere.

Alkaline building stones such as the limestones and dolomites used in many famous buildings are also susceptible to increased 'spalling' and erosion when exposed to polluted atmospheres. There are, however, considerable difficulties in isolating the effect of sulphur oxides from other pollutants and from natural weathering effects. (Weak carbonic acid formed from atmospheric carbon dioxide dissolved in rainwater, does of course, attack limestones over the course of time to an extent sufficient to form huge underground grotto systems like the Cheddar Caves). Some authorities have considered that a layer of sooty deposit on stonework arising from prolonged smoke pollution may absorb and retain sulphuric acid and hence, increase the severity of its attack on the stone. However, in some cases where building exteriors have recently been cleared of soot, it has been observed that intricate carvings in limestone have retained almost their original form, so that a number of factors are clearly involved. Little research in this field has so far been made in this country and more might profitably be done since corrosion is principally an economic loss and the costs and benefits of controlling sulphur dioxide emissions in relation to corrosion should be susceptible to economic analysis.

(iv) Smoke

Smoke is the term normally applied to the visible products of imperfect combustion. Smoke from chimneys ultimately becomes so well mixed with air that it ceases to be visible. After such attenuation smoke remains, however, a potential cause of nuisance, a significant air pollutant both in its own right and in combination with sulphur dioxide (see previous section).

In this discussion a distinction between suspended matter (smoke) and grit and dust must be made. The latter group of particulates will be discussed in Chapter Three.

Nuisance

The social awareness of pollution caused by suspended matter has been studied in a few areas. The results from different studies have been presented in a document on particulate matter[29]; they include those from a study carried out in St. Louis[30] where values for suspended particulates of around 100 $\mu g.m^{-3}$ produced annoyance reactions from a considerable number of people.

A similar study was carried out in Birmingham, Alabama, U.S.A.[31] in which levels of air pollution were correlated with annoyance. They found that about one half of the persons interviewed thought that air pollution was a general nuisance, when mean annual or mean summer concentrations of particulate matter reach 230 $\mu g.m^{-3}$ and one third when they reached 150 $\mu g.m^{-3}$.

Lung Cancer

The possibility that air pollution is a casual factor in cancer of the lung has given rise to considerable concern. The evidence in favour of a casual relationship is briefly: (a) the excess occurrence of the disease in urban areas; (b) the presence in the suspended matter in urban air of substances such as benzo (a) pyrene that can cause cancer under experimental conditions; and (c) the general rise in lung cancer that appeared, at one time, to follow certain assumed trends in pollution.

Early studies in the U.K.[25,32] indicated that variations in lung cancer mortality in urban areas were associated with variations in amounts of pollution and, following a recommendation by a W.H.O. Study Group in 1959[33], a pilot international study was undertaken in several cities where there were contrasts in lung cancer death rates. The results did not show any clear-cut relationship with measurements of particulate matter or its benzo (a) pyrene content[34] and it was clear that apart from the difficulties of making proper allowances for differences in smoking habits, it seemed likely that present day measurements of polycyclic hydrocarbons gave an inadequate assessment of past exposures to these compounds.

The Royal College of Physicians of London[35] reviewed the issue and concluded that the evidence against community air pollution being a casual factor in lung cancer was stronger than evidence for it. The urban/rural differential is greatest in countries with relatively low urban air pollution (Sweden, Norway, Denmark). The upward trend in mortality as well as other experimental and epidemiological evidence are best explained by the casual role of cigarette smoking.

(d) EXISTING MONITORING METHODS IN THE N.E. DERBYSHIRE AREA

(i) Lead

The nearest to an ideal system for monitoring metal particulates in air, is one involving the filtration of a measured volume of air, followed by the analysis of the filtered particulate matter. Because of the availability of apparatus used in the National Survey of Air Pollution (Warren Spring Laboratory, Department of Scientific and Industrial Research)[36], it was decided to utilise this with a carefully selected filter medium, which could be used with brass filter clamps.

When measuring the concentration of suspended particulates in the atmosphere, the collection efficiency of the filter medium is of vital importance[38]. Surveys of airborne metals have used a variety of filter media[39,40,41]. Because of the desirability to use readily available brass filter clamps, glass fibre papers are used.

Weekly samples are taken from each of the monitoring sites and subjected to analysis by atomic absorption spectrometry[41,12].

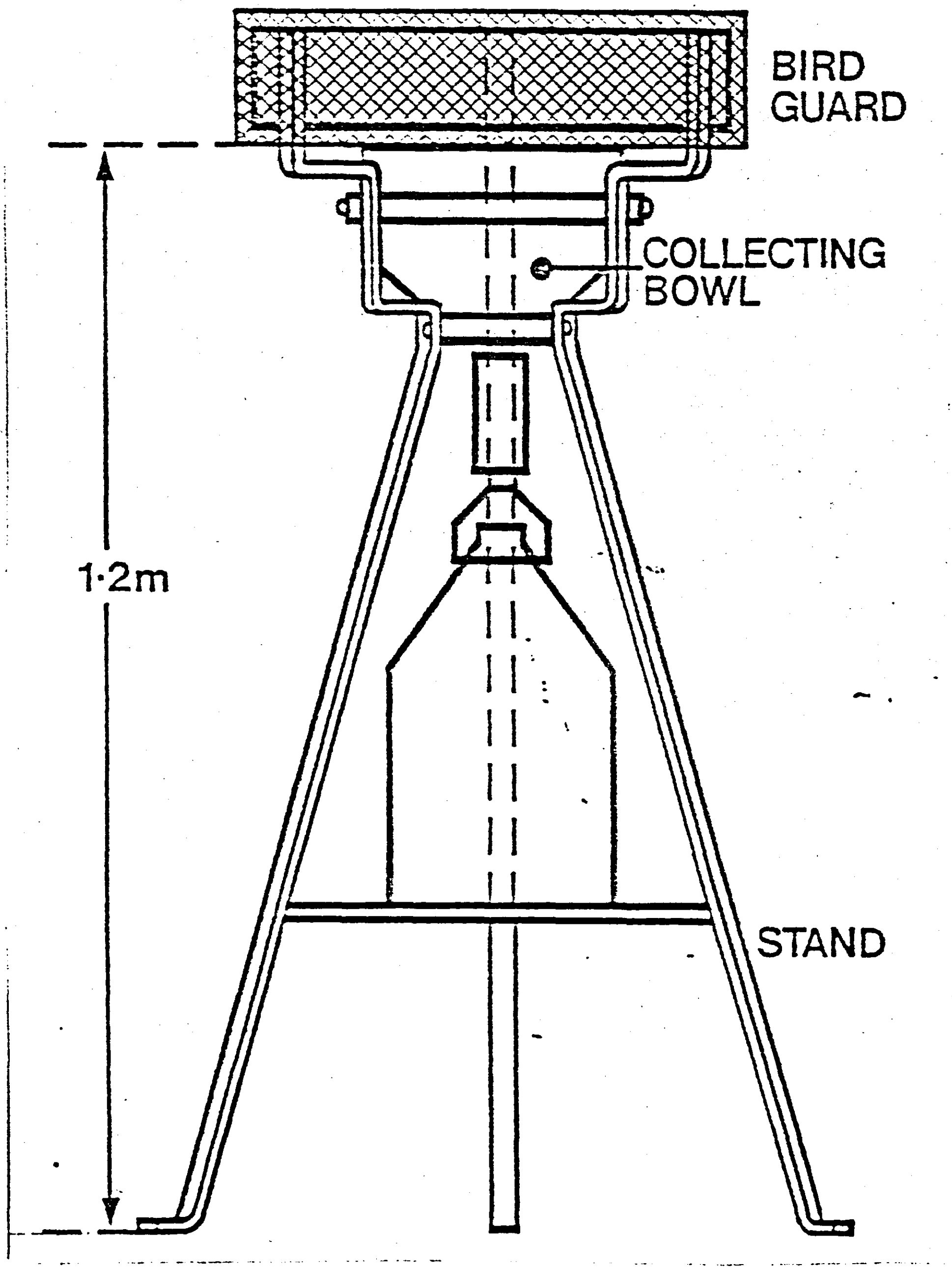
The method used is applicable to the measurement of concentrations of airborne particulate lead found either in ambient or industrial atmospheres.

(ii) Grit and Dust

Grit and dust deposition is monitored at a number of locations throughout the Area by the British Standard Deposit Gauge and the Directional Deposit Gauge.

The British Standard Deposit Gauge[42] is shown in figure 2.

FIG. 2 . <u>BRITISH STANDARD DEPOSIT GAUGE</u>.



Solid matter is collected in a hard glass bowl of known diameter (about 315 mm). It either falls or is washed by rain through the central outlet into a large capacity polythene bottle. On the first day of each calendar month the bottle is replaced and the contents are examined.

Total undissolved deposits are measured and expressed as milligrammes per square metre per day; pH, dissolved matter, ions, conductivity and ash from combustion of insoluble material may also be determined.

The Directional Deposit Gauge[43] (see figure 3), consists of 4 cylinders (0.6 m long) mounted vertically. The upper ends are sealed and a section is cut from the side of each cylinder to form a vertical slit. Solid matter entering the vertical slits is collected in jars fitted to the base of each cylinder. The amounts of undissolved matter are determined for each cylinder, usually monthly, allowing directional comparisons to be made.

(iii) Sulphur Dioxide and Smoke

Daily measurements are made at seven sites within the Area using the National Survey Volumetric Gauge[36,37] (see figure 4). This is the most common method of measuring smoke and sulphur dioxide used in in this country. Measurements are taken over 24 hour periods. Smoke is measured by drawing approximately 80 litres/hour of air through a filter paper. The area of paper exposed to the passing gas can be varied (25 mm, 50 mm and 100 mm diameter filter clamps are available), depending on the degree of pollution. Particles are filtered out and the intensity of the stain is determined using a reflectometer. The density is equated against a standard volume of air and results expressed as microgrammes per cubic metre.

FIG. 3 . DIRECTIONAL DEPOSIT GAUGE.

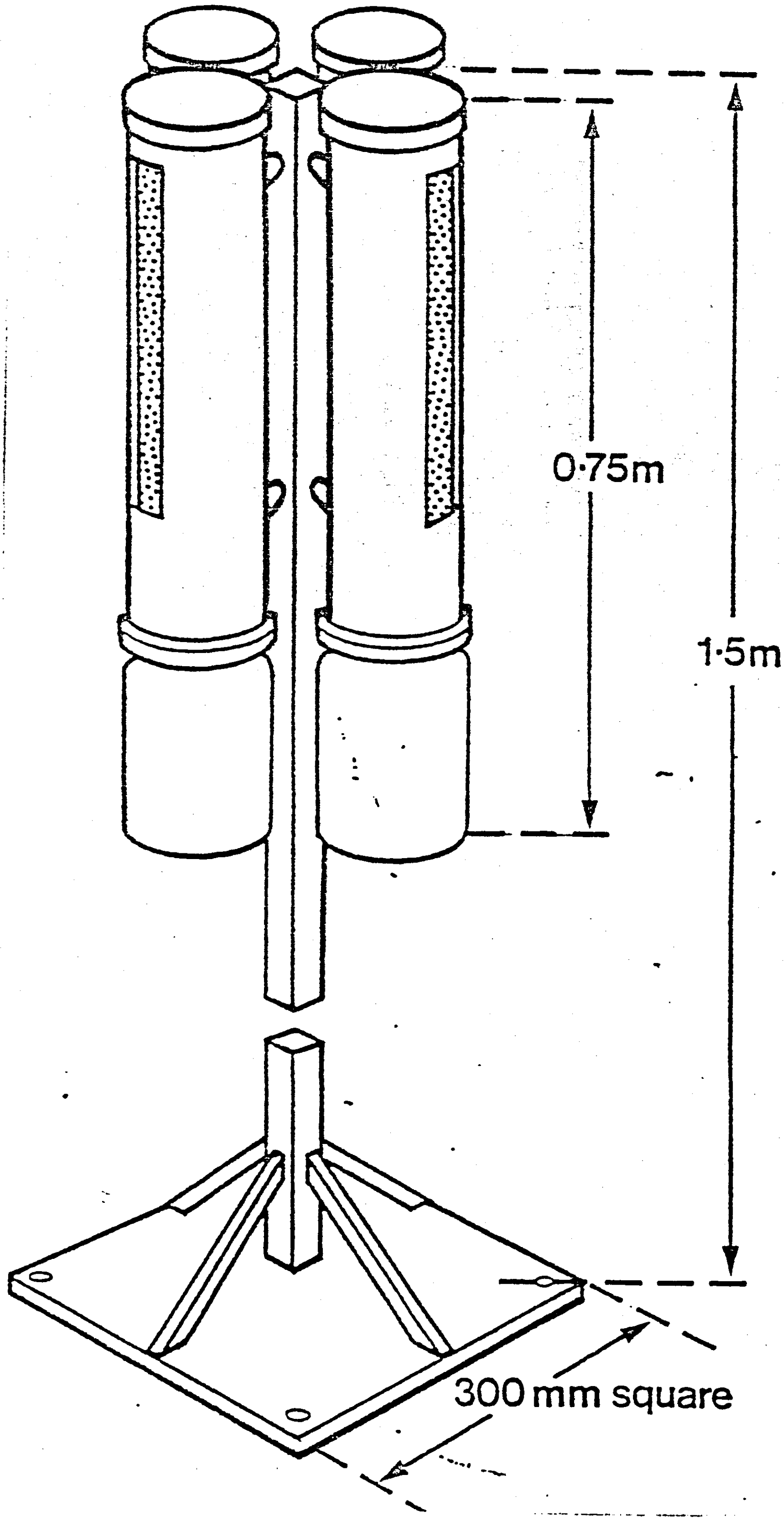
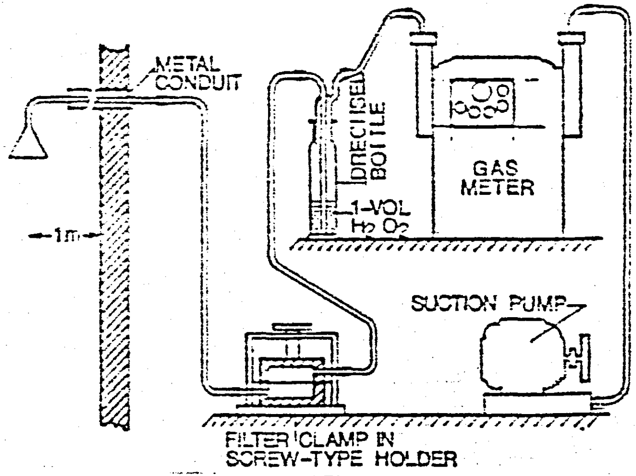


FIG. 4 . NATIONAL SURVEY VOLUMETRIC GAUGE.



Sulphur dioxide is determined by bubbling the already filtered air through a Drechsel bottle containing a solution of hydrogen peroxide, which reacts with sulphur dioxide to form sulphuric acid. The atmospheric concentration of sulphur dioxide ($\mu g.m^{-3}$) is determined by titrating with a standard solution of sodium borate.

(e) AIMS OF THE INVESTIGATION

Atmospheric pollution monitoring began in the last century but the first major survey took place in Leicester, England in 1937 - 39. Some fifteen monitoring stations were operated in that city. Beginning in the 1950's, urban air quality networks were established in many large cities of the world. Although the monitoring programmes were modest at first, there have been subsequent increases in station densities and in numbers of pollutants sampled. Some networks are now operated in real time at capital costs of hundreds of thousands of pounds and require trained technicians for maintenance and computer analysis, and professional staff for interpretation.

In common with many Local Authorities in the United Kingdom, the pollution monitoring network of the North East Derbyshire District Council has grown gradually since the early 1950's. Monitoring sites were established for a number of reasons:-

(a) To demonstrate reductions in the atmospheric concentrations of smoke and sulphur dioxide following the establishment of smoke control areas.

(b) To monitor specific pollution sources e.g. industrial processes, boilerhouse chimneys etc.

(c) To provide data for the National Survey of Smoke and Sulphur Dioxide, co-ordinated by the Warren Spring Laboratory.

(d) To establish prevailing atmospheric concentrations of lead in different parts of the N.E.D.D.C. area, especially in school playgrounds.

(e) To provide information on the environmental impact of large scale new open cast coal mining sites.

Many of the monitoring sites are still maintained, although the need for the data they now provide is questionable. Some monitoring sites are in established smoke control areas and industrial zones where the results indicate that air quality has improved or that nuisance is not being caused. In some cases the wrong type of gauge is being used; the British Standard Deposit Gauge for directional dust sources. Much of the data currently being obtained is not being interpreted and is merely filed and forgotten!

Some of the data can be used to establish relationships between pollution levels and meteorological parameters. Data from British Standard Deposit Gauges may be used to investigate the increasing acidity of precipitation.

Another factor is the financial implication, which in the case of Local Authority activities has now become increasingly important. The costs of operating (excluding the initial capital expenditure, and equipment replacements) a gauge at a smoke and sulphur monitoring site may be conservatively estimated at £600 per annum. N.E.D.D.C. currently maintains seven of these gauges.

The conditions at the time when many of the monitoring sites were established has changed. The gross effects of air pollution which prevailed in the 1950's have largely been controlled. There is a general consensus in this country that the emphasis in air pollution administration has shifted from one of pollution prevention to that of air quality management. All new potential air pollution sources require statutory approvals from either Local or Central Government Inspectorates. These approvals contain specific conditions which regulate emissions to atmosphere[1]. Large populated areas are, in general, within smoke control areas[1] and emissions of smoke to atmosphere are prohibited. Emissions from existing industrial processes have been subjected to increasingly more stringent statutory control.

One approach to air quality management has been that of pollution prediction by developing a model based on meteorological parameters, emission inventories and conditions within the atmospheric boundary layer. In the N.E.D.D.C. area this approach is inappropriate. An advanced model for the prediction of sulphur dioxide and smoke concentrations, would be unlikely to forewarn the local authority of levels which would constitute a hazard to health. The land use in the area is stable, and if any significant changes did occur in the emission inventory, they would be far more readily detected by the local authority through its area administration function (routine inspections and visits made by environmental health officers, building surveyors or applications for statutory approvals) than by a complex prediction model. The financial resources required to maintain and operate such an ongoing model would be hard to justify; the capital and running costs of operating an acoustic sounder, or the employment of staff required to update an emission inventory. Simplified models, however, have been developed for some areas of this country and abroad[46,47,48]. They tend to be specific to the modelled area and produce approximate predictions of ground level concentrations of sulphur dioxide and smoke. Such a model, if developed for the N.E.D.D.C. area could be used to indicate approaches to the European Community Limit Values.

To fulfil the air quality management function of the N.E.D.D.C. would involve the establishment of a monitoring and modelling technique for the determination and prediction of ground level concentrations of sulphur dioxide and smoke in the populated areas of the district, a technique for the evaluation of localised dust sources, determination of trends in precipitation acidity and the monitoring of levels of atmospheric lead.

The aims of this investigation were therefore to develop a rationalised network of pollution monitoring sites and to apply the results to various new and developed methods of data evaluation.

This involved

(a) The establishment of a representative monitoring network for the determination of ground level concentrations of sulphur dioxide and smoke.

(b) Development of a model, based on measured pollution levels to establish a correlation field to predict ranges of pollution levels at various sites using data from one reference station.

(c) An examination of current passive monitoring techniques used to determine deposition of atmospheric lead, and an investigation of other methods of quantitatively assessing atmospheric lead concentrations using passive monitors.

(d) Development of a model for the interpretation of the results from directional dust gauges monitoring localised sources of particulates, based on meteorological parameters and an investigation of gauge performance.

(e) Evaluation of precipitation acidity data which has been collected in the area since 1950 and establish a long term, representative monitoring programme.

(a) SPHAGNUM MOSS

(1) Introduction

Mosses have been increasingly studied in connection with air pollution over the past ten years. Tamm[49] showed that epiphytic mosses derived all of their nutrients from the atmosphere. Ruhling and Tyler[50] detailed the ability of woodland moss to absorb cations selectively from dilute solutions. Clymo[51] showed that the cation exchange capacity of bog moss was dependent on the chemical nature of the moss, which varied from species to species, with the pH of the rooting medium and with the nature and concentration of the cation.

Initial studies proved that freely growing indigenous mosses accumulate greater quantities of heavy metals from the atmosphere around emission sources than elsewhere and that they can be used to indicate zones of high and low heavy metal contamination[52,53,54,55,56]. Indigenous moss cannot, however, give precise information on heavy metal deposition as the length of exposure is not known.

Further studies, using samples of fresh, washed (in nitric acid) moss exposed in nylon mesh bags have provided indications of levels of atmospheric heavy metal concentrations[56,57,58,59,60].

The aim of this part of the project was to investigate further the performance of sphagnum moss as a passive heavy metal monitor and to attempt to correlate deposition rates on moss with atmospheric concentrations.

Previous work by Tranmer[41] indicated that there was an apparent correlation between airborne lead concentrations, as measured by air filtration, and lead deposition on sphagnum moss (Table 1 and figure 5).

Little and Martin[59], concluded in their paper that work was currently in progress to calibrate sphagnum bags quantitatively against standard deposit gauges and other sampling techniques, but any results from these experiments are not yet available.

G.T. Goodman et al.[58] investigated the relationship between atmospheric heavy metal concentrations and deposition rates of heavy metals on sphagnum moss bags. They concluded that air concentration sampling (air filtration at 5 $l.min^{-1}$ with no particle size separation) was, in comparison with moss bag sampling, unbiased, as moss bags tended to undersample in the intermediate particle size range, 2.0 - 0.1 μm. This, they concluded, was why they could find no linear relationship between deposition on moss bags and air concentrations measured by air filtration.

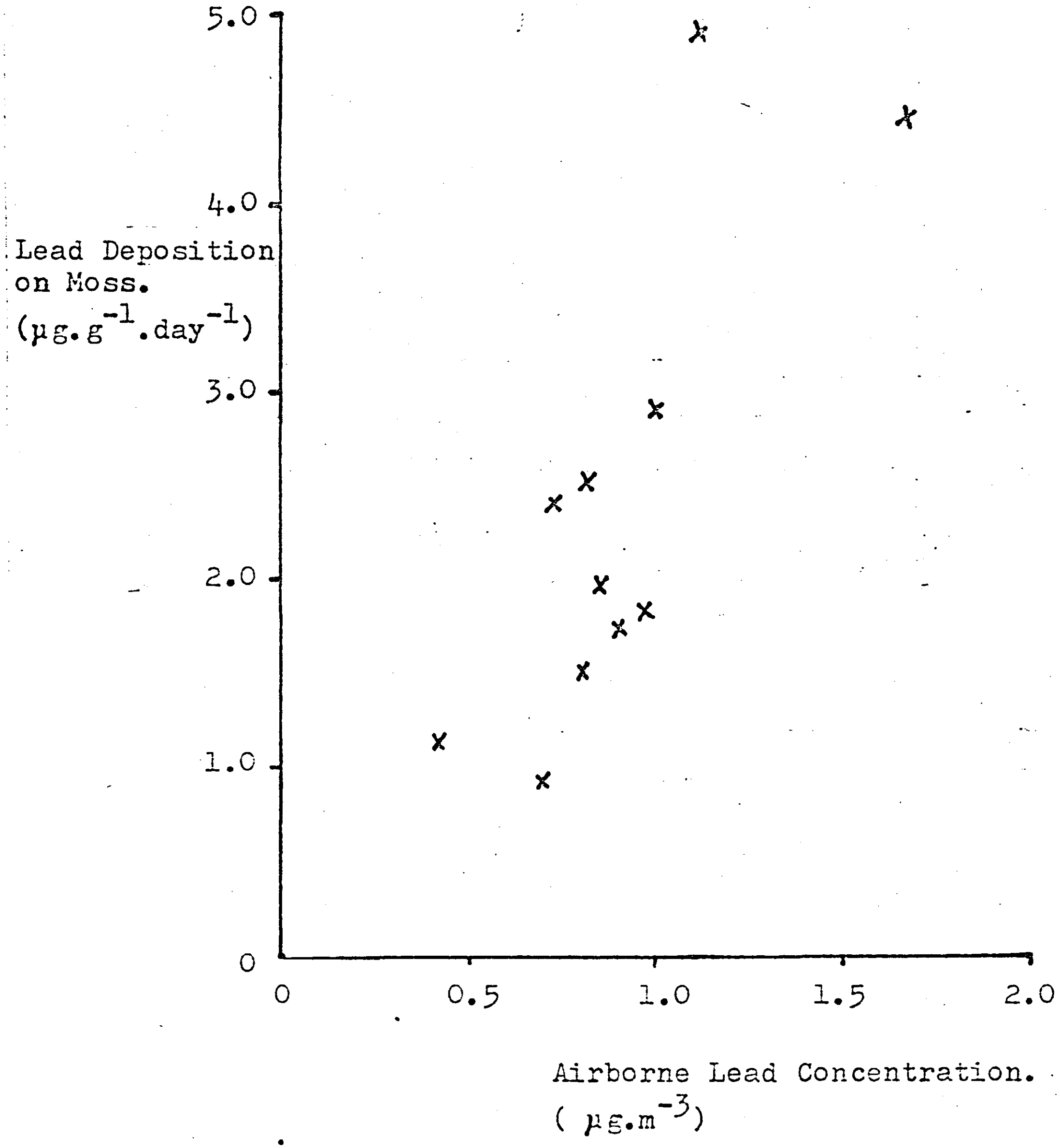
TABLE 1. MOSS BAG AND FILTER GAUGE RESULTS AT TRAMMER'S STATIONS[41].

SITE	JUNE 1978		JULY 1978		AUGUST 1978	
	MOSS*	FILTER'	MOSS*	FILTER'	MOSS*	FILTER'
3	2.8	1.0	1.6	0.9	1.9	0.9
25	1.4	0.8	0.8	0.7	1.8	1.0
27	4.9	1.2	2.4	0.7	4.4	1.8
29	2.4	0.8	1.1	0.4	NR	1.1

* $\mu g.g^{-1}.day^{-1}$

' $\mu g.m^{-3}$

FIG. 5. CORRELATION BETWEEN AIRBORNE LEAD CONCENTRATIONS AND DEPOSITED LEAD AT TRANMER'S STATIONS[41].



(2) Experimental - Analysis

(i) Reagents

All chemicals were obtained from BDH Chemicals, Poole, Dorset. Nitric acid, concentrated AnalaR grade. Distilled and distilled, de-ionised water were obtained from laboratories at Sheffield City Polytechnic and North East Derbyshire District Council.

(ii) Procedures

Digestion

Samples of exposed and unexposed mosses were placed in previously dilute acid washed pyrex beakers. A 1:1 solution of nitric acid and distilled de-ionised water was prepared and 100 ml. was added to each sample in the beakers. The samples were boiled and simmered to a reduced volume, allowed to cool and the digest made up to either 25 ml. or 10 ml. with distilled de-ionised water. All glassware was rinsed in dilute acid prior to use. No filtration was carried out. Small amounts of silica settled to the bottom of the flask.

Analysis of Digest

Total lead concentrations were determined by atomic absorption spectrometry. More than one type of instrument was used during the investigation. Hollow cathode lamps were used and the power supply set in accordance with the instrument manufacturers recommendations. Instrument wavelengths, slit widths and flows of fuel (acetylene) and air to the nebuliser were in each case detailed in the instrument manual. Signals were displayed on either digital or analogue displays which were damped or integrated prior to them being displayed.

Calibration standards were prepared to interpolate the instrument signals and at least five (depending upon digest volume) aspirations of each digest and standard were obtained and means determined.

(3) Experimental - Sample Pre-treatment and Exposure

(i) Hair Net Monitors

An initial investigation of the reproducibility of the moss bag technique was performed. Little and Martin[59] also investigated this reproducibility, see Table 2.

They concluded that the coefficients of variation were within acceptable limits, although they were all in excess of 10%.

Thorpe[62], using a similar moss monitor, exposed five moss samples, in hair nets, in close proximity to each other for monthly periods. He found an average coefficient of variation of 35% and concluded that the value was rather high and must also cast doubt on the precision and, therefore, the validity of the moss bag monitor.

Investigations of the reproducibility of the moss bag technique in the literature are scarce, whilst surveys and monitoring exercises using the technique are legion.

The simple and inexpensive technique described by Little and Martin[59] for monitoring heavy metals using sphagnum moss was initially investigated. This technique, with slight variations, has been used in many other published reports[55,56,62,63,64].

TABLE 2. QUANTITIES OF METAL COLLECTED BY SIX REPLICATE MOSS BAGS[59].

	Zn*	Pb*	Cd**
	127.0	47.5	1932.0
	179.0	67.6	3129.0
	162.0	55.7	2655.0
	166.0	70.7	2841.0
	152.0	64.9	2526.0
	143.0	49.1	2295.0
$\bar{x}$	155.0	59.3	2563.0
S.E.	7.53	4.03	171.0
Coefficient of variation.	11.9%	16.7%	16.3%

* $\mu g.g^{-1}.day^{-1}$.

** $ng.g^{-1}.day^{-1}$.

Initially six samples of washed moss (20 g) were each placed in a nylon hair met and suspended from a rack, 200 mm apart, over a known source of atmospheric lead (Council House Car Park, Saltergate, Chesterfield).

The moss samples were exposed for 33 days and then digested in 1:1 AnalaR nitric acid, distilled de-ionised water and analysed using atomic absorption spectrometry. The results are shown in Table 3.

These initial results showed little consistency in deposition of lead on adjacent samples of moss. The results did, however, suggest a spatial bias from sample 1 to sample 6.

(ii) Flat Nylon Mesh Envelopes

In an attempt to standardise the available area of exposed moss, Goodman *et al.*[65] used a flat nylon mesh envelope containing washed moss. No information was given of results from replicate monitors.

Temple *et al.*[66] used washed moss mounted in 2.0 mm polypropylene mesh envelopes 150 x 650 mm. They found a coefficient of variation for lead deposition in replicate envelopes, exposed for 30 days at the same location, near a lead source averaged 13.5% over a three month period.

To investigate the performance of replicate monitors and also the spatial bias suggested by the hair net monitors, 12 monitors were exposed, on the rack at Chesterfield.

The monitors and moss pre-treatment were the same as used by Goodman *et al.*[65]. Sphagnum moss was collected from a rural area of Derbyshire, away from industrial activity and roadways. Following three washes in 0.5N nitric acid for three days, the moss was washed

TABLE 3. QUANTITIES OF LEAD COLLECTED BY SIX REPLICATE MOSS BAGS.

Calib. Stds. (p.p.m.)	Moss Bag No.	Wt. of moss (g)	Instrument signal*	Conc. Pb in digest (p.p.m.)	Mass of Pb (µg)	µg Pb. g^{-1} moss
	1	0.70	0.34	2.7	27	39
	2	0.76	0.24	1.9	19	25
	3	0.70	0.22	1.8	18	26
	4	0.83	0.24	1.9	19	23
	5	0.70	0.24	1.9	19	27
	6	0.71	0.16	1.3	13	18
2			0.25			
5			0.59			
10			1.18			
$\bar{x}$						26
SD						6.4
% RSD						24.5

* Average of 5 aspirations

Digest volume = 10 ml

three times in distilled de-ionised water, surplus water removed and the moss mixed to obtain as homogenous a material as possible, approximately 20 g was then sewn into flat 100 x 100 mm nylon mesh bags of approximately 2 mm mesh size (Henry Simon, type 28 GGN[61]).

Moss monitors number one to six were periodically re-arranged to negate any spatial bias, whilst number seven to twelve remained in their original positions. After 49 days exposure the samples were removed for analysis (hot digestion in nitric acid: distilled de-ionised water followed by atomic absorption spectometry). The results are shown in Table 4.

The six monitors which were periodically "shuffled" and the six which remained in situ on the frame showed no spatial bias.

Further sets of six envelopes containing moss were exposed for approximately one month monitoring periods. The results are shown in Tables 5, 6, 7, and 8.

Results from these sets of replicate monitors showed poor percentage relative standard deviations (%RSD). Simultaneous sampling of air at both ends of the rack through separate filters indicated that there was no significant lateral stratification in atmospheric lead concentrations in the vicinity of the moss monitors. (Table 9).

(iii) Homogenised Moss

Ruhling et al.[52] concluded that the ability of moss to accumulate metal ions increased with its age.

To investigate this claim, samples of moss were obtained from within a 100 metre square area which was remote from industrial land

TABLE 4. QUANTITIES OF LEAD COLLECTED BY TWELVE REPLICATE MOSS ENVELOPES.

Calib. Stds. (p.p.m.)	Moss Env. No.	Wt. of Moss	Inst. Signal*	Conc. Pb in digest (p.p.m.)	Mass Pb (µg)	µg Pb. g^{-1} moss	µg Pb. cm^{-2} exposed moss
	1	0.78	0.82	5.0	130	170	1.3
	2	0.48	0.53	3.2	80	170	0.8
	3	0.69	0.66	3.9	100	170	1.
	4	0.61	0.83	5.0	130	210	1.3
	5	0.57	0.69	4.2	110	220	1.1
	6	0.59	0.61	3.7	91	150	.91
	7	0.61	0.89	5.5	140	230	1.4
	8	0.67	0.81	5.0	130	190	1.3
	9	0.71	0.80	4.8	120	170	1.2
	10	0.58	0.85	5.2	130	220	1.3
	11	0.57	0.76	4.6	120	210	1.2
	12	0.76	0.83	5.1	130	170	1.3
2			0.34				
5			0.83				
10			1.53				
$\bar{x}$						190	1.2
SD						25.5	
% RSD						13.4	25.3

* Average of 5 aspirations

Digest volume = 25 ml

TABLE 5. REPLICATE MOSS ENVELOPE RESULTS (32 DAYS).

Calib. Stds. (p.p.m.)	Moss Env. No.	Wt. of Moss (g)	Inst. Signal*	Conc. Pb in digest (p.p.m.)	Mass Pb (μg)	μg Pb. g^{-1} moss	μg Pb. cm^{-2} exposed moss
	1	0.63	0.22	1.0	25	40	0.25
	2	1.03	0.22	1.0	25	24	0.25
	3	0.98	0.44	2.0	50	51	0.50
	4	0.75	0.22	1.0	25	33	0.25
	5	0.78	0.22	1.0	25	32	0.25
	6	0.68	0.22	1.0	25	39	0.50
2			0.44				
5			1.1				
10			2.1				
$\bar{x}$						36.5	0.4
SD						8.3	0.14
% RSD						22.8	35

* Average of 5 aspirations

Digest volume = 25 ml

TABLE 6. REPLICATE MOSS ENVELOPE RESULTS (28 DAYS).

Calib. Stds. (p.p.m.)	Moss Env. No.	Wt. of Moss (g)	Inst. Signal*	Conc. Pb in digest (p.p.m.)	Mass Pb (μg)	μg Pb. g^{-1} moss	μg Pb. cm^{-2} exposed moss
	1	0.77	0.12	0.8	8.5	11	0.85
	2	0.80	0.37	2.4	24	30	0.24
	3	0.77	0.28	2.0	20	26	0.20
	4	0.93	0.28	1.9	19	20	0.19
	5	0.80	0.84	6.9	69	86	0.69
	6	0.88	0.79	5.8	58	66	0.58
2			0.29				
5			0.76				
10			1.42				
$\bar{x}$						39.8	0.46
SD						18.9	0.26
% RSD						47.3	56.7

* Average of 5 aspirations

Digest volume = 10 ml

TABLE 7. REPLICATE MOSS ENVELOPE RESULTS (29 DAYS).

Calib. Stds. (p.p.m.)	Moss Env. No.	Wt. of Moss (g)	Inst. Signal*	Conc. Pb in digest (p.p.m.)	Mass Pb (µg)	** µg Pb. g^{-1} moss	** µg Pb. cm^{-2} exposed moss
	1	0.85	0.58	6.4	64	0.53	0.45
	2	0.81	0.42	5.0	50	0.39	0.32
	3	0.78	0.43	5.0	50	0.41	0.32
	4	0.77	0.48	5.4	54	0.47	0.36
	5	0.77	0.38	4.4	44	0.34	0.26
	6	0.63	0.47	5.3	53	0.61	0.38
	Control	0.88	0.24	1.8	20		
2			0.18				
5			0.44				
10			0.83				
$\bar{x}$						0.46	0.35
SD						0.09	0.069
% RSD						19.7	19.9

* Average of 5 aspirations

** Corrected for control

Digest volume = 10 ml

TABLE 8. REPLICATE MOSS ENVELOPE RESULTS (37 DAYS).

Calib. Stds. (p.p.m.)	Moss Env. No.	Wt. of Moss (g)	Inst. Signal*	Conc. Pb in digest (p.p.m.)	Mass Pb (μg)	** μg Pb. g^{-1} moss	** μg Pb. cm^{-2} exposed moss
	1	0.64	1.7	1.6	41	59	0.38
	2	0.64	1.9	1.8	45	65	0.42
	3	0.89	1.8	1.7	43	44	0.38
	4	0.66	1.7	1.6	40	56	0.37
	5	0.85	1.7	1.6	40	42	0.36
	6	0.55	1.4	1.3	33	55	0.30
	Control	3.83	1.1	0.8	20		
1			1.2				
2			2.4				
5			5.5				
10			11.7				
$\bar{x}$						54	0.37
SD						13	0.036
% RSD						25	9.7

* Average of 5 aspirations

** Corrected for control

Digest volume = 25 ml

TABLE 9. RESULTS OF SIMULTANEOUS AIR FILTRATION SAMPLES FROM EACH END OF THE MOSS FRAME.

Calib. Stds. (p.p.m.)	Filter No.	Inst. Signal*	Conc. Pb in digest (p.p.m.)	Mass Pb (µg)	Air vol. filtered (m^3)	Atmos. Conc. (µg Pb. m^{-3})
	1	0.22	1.25	12.5	37.88	0.33
	2	0.23	1.25	12.5	36.76	0.34
	1	0.19	1.08	10.8	34.68	0.31
	2	0.19	1.08	10.8	35.83	0.30
1		0.18				
2		0.34				
5		0.83				

* Average of 5 aspirations

Digest volume = 10 ml

use and roads. Moss samples at different stages of growth were selected and sorted into four age groups, sample one being the youngest and sample four the oldest. The samples were rinsed with dilute acid to remove adhering particles and their lead content determined. The results are shown in Table 10.

The results tended to confirm the findings of Ruhling et al.[52]. To investigate whether the lack of consistency in replicate moss monitors was due to the monitors containing a bias of younger or older aged moss the following experimental steps were taken.

(1) Several kilograms of sphagnum moss were collected from a bog in Derbyshire, remote from industry or roads.

(2) The collected moss was carefully sorted, grass and extraneous material was removed and the top 5 cm of each moss strand was selected. The sorted moss was manually mixed and a one kilogram sample was obtained by standard division.

(3) The moss was washed three times, over three days in 0.5 AnalaR nitric acid and finally rinsed in distilled and de-ionised water.

(4) The moss was finally placed in a food blender for 30 seconds.

(5) Samples of homogenised moss were spread over circles of Whatman number 41 filter paper which had been placed in the bottom half of a sterile plastic petri dish and cover. The dishes had four drainage holes drilled in them to prevent the samples becoming water logged. The surface area of the exposed moss samples was 63.6 cm^2.

TABLE 10. FOUR DISCRETE ACID WASHED MOSS SAMPLE RESULTS.

Calib. Stds. (p.p.m.)	Moss Sample No.	Wt. of Moss (g)	Inst. Signal*	Conc. Pb in digest (p.p.m.)	Mass Pb (µg)	µg Pb.g^{-1} moss
	1	1.22	0.35	0.32	8	7
	4	0.82	0.75	0.71	18	22
	2	1.56	0.60	0.59	15	10
	3	1.02	0.60	0.59	15	15
1			1.10			
2			2.35			
5			5.45			
$\bar{x}$						14
SD						5.7
% RSD						40.7

* Average of 5 aspirations

Digest volume = 25 ml

(6) Four petri dish monitors were separately placed in the previously used nylon mesh envelopes and mounted horizontally, 200 mm apart on the monitoring rack. A fifth monitor was kept in an air tight container as a control.

The monitors were exposed for 34 days, oven dried, weighed, digested and analysed using atomic absorption spectrometry. The results are shown in Table 11.

A further set of monitors were exposed for 39 days, the results are shown in Table 12.

The replicates showed poor consistency in lead deposition.

(iv) Sintered Glass Funnels and Diffusion Tubes

During the exposure periods of the petri dish mounted moss monitors, single monitors, of a different type were secured to the rack. They consisted of a sintered glass funnel and a long tube. A sample of moss (homogenised) was placed on the top of a 60 mm diameter glass sinter within a glass funnel. Attached to the top of the funnel was a 400 mm long tube. The top of the tube was covered with a 90 mm diameter inverted petri dish. The cover was raised to allow a 10 mm gap between the petri dish base and the tube top.

The lead depositions for these monitors which were exposed concurrently with the petri dish monitors were 1.27 μg.Pb. cm^{-2} (Table 11) and 0.58 μg.Pb. cm.$^{-2}$ (Table 12). Both depositions were significantly higher than those of the petri dish mounted samples.

TABLE 11. REPLICATE HOMOGENISED MOSS SAMPLES ON PETRI DISH MOUNTS (34 DAYS).

Calib. Stds. (p.p.m.)	Moss Sample No.	Wt. of Moss. (g)	Inst. Signal*	Conc. Pb in digest. (p.p.m.)	Mass Pb (µg)	** µg Pb. g^{-1} moss	** µg Pb. cm^{-2} exposed moss
	1	0.92	1.40	1.33	33	23	0.2
	2	1.08	0.95	0.90	23	8	0.1
	3	1.56	0.40	0.43	10	-	-
	4	1.22	1.25	1.19	30	12	0.1
	Control	1.02	0.50	0.49	13		
1			1.10				
2			2.30				
5			5.63				
$\bar{x}$						14	0.13
SD						5.7	0.07
% RSD						41	54

* Average of 5 aspirations

** Corrected for control

Digest volume = 25 ml

TABLE 12. REPLICATE HOMOGENISED MOSS SAMPLES ON PETRI DISH MOUNTS (39 DAYS).

Calib. Stds. (p.p.m.)	Moss Sample No.	Wt. of Moss. (g)	Inst. Signal*	Conc. Pb in digest. (p.p.m.)	Mass Pb (µg)	** µg Pb. g^{-1} moss	** µg Pb. cm^{-2} exposed moss
	1	1.28	0.18	1.4	35	14	0.18
	2	1.15	0.	1.5	38	20	0.24
	3	1.13	0.62	5.0	152	122	1.38
	4	1.57	0.2	1.6	40	13	0.20
	Control	(from	results in	Table	11.)	12	
1			0.11				
2			0.23				
5			0.62				
$\bar{x}$						42	0.5
SD						46	0.5
% RSD						110	102

* Average of 5 aspirations

** Corrected for control

Digest volume = 25 ml

No relevant published information on this development of moss mounting was revealed during the literature survey, although some papers suggested that collection by a diffusion process may be applicable[67].

To investigate the apparent increased deposition due to a diffusion process, the following experimental steps were taken:-

(1) Several kilograms of sphagnum moss were collected from a bog in Derbyshire, remote from industry or roads.

(2) The moss was carefully sorted and the top 5 cm of each strand selected. A one kilogram sample was obtained by standard division.

(3) After acid washing, rinsing and blending to homogenise the moss, it was oven dried to a constant weight.

(4) Because the ratios of weights and available surface area of the exposed moss may have been affecting the replicate results, equal pre-weighed samples of dried moss were prepared.

(5) Six samples of dried moss were obtained by a standard division. Each of the six samples were divided into two, one half was exposed and the other half retained in separate air tight containers as controls.

(6) The samples for exposure were wetted with 50 ml distilled, de-ionised water after being placed in the sintered glass funnels. The 400 mm

diffusion tubes and petri dish covers were attached and the monitors fixed to the rack. The rack was positioned at a height of two metres above ground level in transport depot yard.

(7) The samples were exposed for 22 days. The results are shown in Table 13.

Again, the deposition of lead on replicate samples showed little consistency. The controls also displayed differing lead concentrations.

A further sample of moss was obtained from the remote Derbyshire bog and a similar pre-treatment and analysis carried out as outlined above but with the following changes in procedure:-

(1) Ten grams of dried, unwashed moss was placed in the blender for one minute with 300 ml distilled de-ionised water. The individual moss particles, from microscopic examination were less than 1 mm in length.

(2) The moss was dried to a constant weight.

(3) Samples (0.5g) were digested, simmered for one hour and the digest made up to 10 ml.

(4) The results from the three samples analysed are shown in Table 14.

Following these encouraging results, a further set of samples were prepared and analysed using the same technique. The results are shown in Table 15.

TABLE 13. REPLICATE MOSS SAMPLES EXPOSED IN DIFFUSION TUBES FOR 22 DAYS.

Calib. Stds. (p.p.m.)	Moss Samp. No.	Wt. of Moss. (g)	Inst. Sig.*	Digest Vol. (ml)	Conc.Pb in dig. (p.p.m.)	Mass Pb (μg)	Aquired μg Pb. g^{-1} moss	Aquired μg Pb. cm^{-2} exposed moss
	1							
	Exposed	0.72	1.5	21.0	1.3	27	21	0.14
	Blank	0.77	0.7	20.0	0.6	13		
	2							
	Exposed	0.77	0.7	26.0	0.6	17		
	Blank	0.705	0.8	29.0	0.7	20		
	3							
	Exposed	0.75	1.5	12.0	1.3	16	3	0.03
	Blank	0.74	0.7	21.0	0.6	13		
	4							
	Exposed	0.73	1.3	18.5	1.2	22	7	0.08
	Blank	0.75	1.0	11.5	0.9	10		
	5							
	Exposed	0.74	0.7	12.5	0.6	8		
	Blank	0.75	0.6	18.0	0.6	11		
	6							
	Exposed	0.79	2.0	24.0	1.8	43	22	0.2
	Blank	0.73	1.0	25.0	0.9	23		
1			1.1					
2			2.3					
5			5.4					

* Average of 5 aspirations

Area of glass sinter = 28.27 cm^2

TABLE 14. REPLICATE UNWASHED MOSS SAMPLE RESULTS.

Calib. Stds. (p.p.m.)	Moss Sample No.	Wt. of Moss. (g)	Inst. Signal	Digest Volume (ml)	Conc.Pb in dig. (p.p.m.)	Mass Pb (µg)	µg Pb. g^{-1} moss
	1	0.50	0.10	26.0	3.1	79	158
	1	0.50	0.10	26.0	2.9	77	150
	1	0.50	0.10	26.0	3.0	78	156
	2	0.50	0.09	32.5	2.3	75	150
	2	0.50	0.09	32.5	2.7	88	176
	2	0.50	0.09	32.5	2.8	89	178
	3	0.50	0.10	25.0	3.1	76	152
	3	0.50	0.1	25.0	3.2	80	160
	3	0.50	0.1	25.0	3.1	78	156
5			0.16 *				
10			0.35 *				
20			0.56 *				
$\bar{x}$							160
SD							15
% RSD							9.5

* Average of 5 aspirations

TABLE 15. REPLICATE UNWASHED MOSS SAMPLE RESULTS.

Calib. Stds. (p.p.m.)	Moss Samp. No.	Wt. of Moss. (g)	Inst. Sig.*	Digest Vol. (ml.)	Conc.Pb in dig. (p.p.m.)	Mass Pb (µg)	µg Pb. g^{-1} moss.
	1	0.5	5.2	27.0	2.8	76	152
	2	0.5	3.2	47.0	1.8	82	164
	3	0.5	5.2	26.0	2.8	73	146
	4	0.5	8.9	14.0	4.8	67	134
	5	0.5	5.0	24.5	2.7	67	134
	6	0.5	9.0	14.0	4.8	67	134
	7	0.5	5.5	24.0	3.0	72	144
5			9.5				
10			18.5				
20			35.5				
$\bar{x}$							144
SD							10.5
% RSD							7.3

* Average of 5 aspirations

Again, samples of moss were exposed, in the sintered glass, diffusion tube monitors. The moss, prior to exposure was acid washed, rinsed, homogenised to less than 1 mm particle size and oven dried to a constant weight. The results, after 21 days exposure are shown in Table 16. As can be seen from the table, all results were towards the lower end of the analytical working range. A modification to the method of moss exposure was subsequently introduced in an attempt to increase deposition levels.

It was noted that during the monitoring periods, the moss samples on the glass sinters were drying. In order to maintain a damp moss on the sinter, which may be more receptive than dry moss, the bottoms of the funnels were fitted with bungs. Before exposure 10 ml of distilled de-ionised water was poured into each funnel. The results after 29 days exposure are shown in Table 17. Monitor number three showed a concentration of lead near that of the control sample.

A further set of monitors were prepared and the following experimental steps were taken:-

(1) Several kilograms of sphagnum moss were collected from a bog in Derbyshire, remote from industry or roads.

(2) The moss was carefully sorted and the top 5 cm of each strand selected. A one kilogram sample was obtained by standard division.

(3) After acid washing, rinsing and blending to homogenise (less than 1 mm particle length) the moss, it was oven dried to a constant weight.

TABLE .16. REPLICATE DIFFUSION MONITOR RESULTS.

Calib. Stds. (p.p.m.)	Monitor Number.	Wt. of Moss. (g)	Inst Signal*	Conc. Pb in Digest. (p.p.m.)	Mass Pb (µg)	µg Pb. g^{-1} moss**
	1	0.5	0.98	0.9	9	14
	2	0.5	0.92	0.9	9	14
	3	0.5	0.87	0.9	9	14
	4	0.5	0.87	0.9	9	14
	5	0.5	0.95	0.9	9	14
	Control	0.5	0.12	0.2	2	-
2			2.50			
4			5.00			
8			11.50			
$\bar{x}$						14

* Average of 5 aspirations

** Corrected for control

Digest volume = 10 ml

TABLE 17. REPLICATE DIFFUSION MONITOR RESULTS.

Calib. Stds. (p.p.m.)	Monitor Number.	Wt. of Moss. (g)	Inst Signal*	Conc. Pb in Digest. (p.p.m.)	Mass Pb (μg)	μg Pb.g^{-1} moss**
	1	0.5	0.034	2.1	11	13
	2	0.5	0.035	2.1	11	13
	3	0.5	0.015	0.9	5	2
	4	0.5	0.032	1.8	9	10
	control	0.5	0.013	0.8	4	-
1			0.017			
5			0.081			
10			0.163			
$\bar{x}$						9.5
SD						4.5
% RSD						47

* Average of 3 aspirations

** Corrected for control

Digest volume = 5 ml

(4) Three sintered glass funnels were carefully washed in dilute HNO_3 and rinsed in distilled de-ionised water.

(5) Moss (approximately 0.70 g) samples were placed on circles of Whatman No. 1 filter paper within the sintered glass funnels. The moss was wetted with 50 ml distilled, de-ionised water.

(6) The bottoms of the funnels were fitted with bungs and 50 ml of distilled de-ionised water poured onto the moss within the funnel.

(7) Three samples of unwashed moss were prepared in an identical way and exposed next to the washed moss monitors.

(8) Two samples each of washed and unwashed moss were sealed in airtight containers and their lead content determined. The results are shown in Table 18.

(9) The moss monitors were exposed for 38 days. The results are shown in Table 19.

The exposed moss samples remained saturated throughout the monitoring period. Any distilled de-ionised water which was left in the stem of the funnel was included with the moss during the digestion step.

The spectrometer signals obtained during the analyses were significantly higher than those previously obtained and were within the calibration signals (except for one of the unwashed moss monitor

TABLE 18. UNEXPOSED WASHED AND UNWASHED HOMOGENISED MOSS RESULTS.

Calib. Stds. (p.p.m.)	Moss Sample	Wt. of Moss. (g)	Inst. Signal*	Conc. Pb in Digest. (p.p.m.)	Mass Pb (μg)	μg Pb. g^{-1} moss
	W1	0.70	0.009	0.9	9	13
	W2	0.78	0.009	0.9	9	12
	U1	1.00	0.071	7.6	76	76
	U2	1.00	0.077	8.2	82	82
1			0.008			
2			0.019			
5			0.047			
10			0.089			

* Average of 5 aspirations

Digest volume = 10 ml

Moss sample W = washed moss

Moss sample U = unwashed moss

TABLE 19. REPLICATE DIFFUSION MONITOR RESULTS.

Calib. Stds. (p.p.m.)	Moss Sample.	Wt. of Moss. (g)	Inst. Signal*	Conc. Pb in Digest. (p.p.m.)	Mass Pb (ug)	μg Pb. g^{-1} moss	μg Pb. g^{-1} moss**
	W1	0.64	0.41	2.7	27	42	29
	W2	0.71	0.47	3	30	42	29
	W3	0.52	0.32	1.9	19	37	24
	U1	0.48	1.21	7.8	78	160	81
	U2	0.57	1.51	9.7	97	170	91
	U3	0.73	2.05	14	140	190	110
1			0.13				
2			0.31				
5			0.82				
10			1.58				

* Average of 5 aspirations, except for calib. stds. - 3

** Corrected for control (see Table 18)

Digest volume = 10 ml

Moss sample W = washed moss

Moss sample U = unwashed moss

μg Pb.g^{-1}moss	Washed Moss (W)	Unwashed Moss (U)
$\bar{x}$	27	94
SD	2.4	12
%RSD	8.6	13

results). The amounts of lead retained by the monitors were also significantly higher than previously obtained results. This may be due to the continuously saturated state of the moss throughout the monitoring period.

(4) Discussion of Moss Monitor Results

The unwashed moss monitors showed an increase in lead deposition compared with the acid washed moss samples. This difference may be explained by the acid wash disrupting the biological mechanisms responsible for the epiphytic action of the moss.

Although increased attention to moss pre-treatment decreased the percentage relative standard deviation of the replicate monitor results, other factors require accurate determination before sphagnum moss may be used as a quantitative passive monitor. Moss is a biological medium and its epiphytic capability will fluctuate with its age, the time of year and its moisture content.

The effects of acid washing on the moss have been investigated and although the lead content of the moss prior to exposure is reduced, its ability to retain lead on exposure is impaired.

Sphagnum moss has been used to monitor qualitatively atmospheric lead and it has been claimed that simultaneous exposure of monitors using moss from one source will provide comparative indications of atmospheric lead levels at different monitoring sites. However, the results obtained from experiments using replicate moss monitors must cast doubts on the validity of using moss in such monitoring exercises. Without accurate determination of the biological variables affecting the epiphytic performance of moss it is not possible to use moss as a quantitative passive monitor.

(b) PHYSICAL PASSIVE MONITORS

(1) Introduction

During the exposure of replicate moss samples, moss in the diffusion tube monitor assimilated more lead than the conventionally mounted samples. Using the diffusion tube monitors, chemical substitutes for moss were initially investigated. Two, low volatility solutions containing dithizone were exposed in beakers within the diffusion tubes; liquid paraffin and ethanediol. Following exposure, difficulties were encountered with analysis. The liquid paraffin was too viscous to be satisfactorily asprated and the dithizone in ethanediol interfered with the lead line signal.

The performance of a series of physical passive monitors were then investigated.

(2) Whatman No. 1 Filter Paper

With experience gained using the diffusion tube monitors the biological monitor was replaced with a moist Whatman number 1 filter paper.

(i) Experimental - Analysis

Reagents

All chemicals were obtained from B.D.H. Chemicals, Poole, Dorset.

Nitric acid, concentrated AnalaR grade. Distilled and distilled de-ionised water were obtained from laboratories at Sheffield City Polytehnic and North East Derbyshire District Council.

Procedures

Digestion

Exposed and unexposed filter papers were placed in previously dilute acid-washed pyrex beakers. A 1:1 solution of concentrated nitric acid and distilled de-ionised water was prepared and 50 ml was added to each filter paper in the beakers. The contents of the beakers were boiled and simmered to a reduced volume, allowed to cool and the digest made up to 10 ml with distilled de-ionised water. All glassware was rinsed in dilute acid prior to use. No filtration was carried out.

Analysis of Digest

Total lead concentrations were determined by inductively coupled plasma-optical emission spectometry (ICP-OES). ICP-OES is a direct reading spectrometer system using a microcomputer for data collection and analysis. A 2.5 kW crystal controlled R.F. generator operating at 27.12 MHz provides energy to the plasma torch.

The plasma source is a plasma torch surrounded by a water cooled induction coil. The R.F. generator provides energy to the torch and creates a magnetic field. Argon gas is passed through the field and is ionised to become plasma. Liquid samples are nebulised into a spray chamber where a stream of argon gas carries the sample to the plasma. The atoms and ions are excited to emit light at wavelengths characteristic of the elements present.

The emitted light energy is then directed through the slits, diffracted by a grating, refocussed on exit slits and projected onto photomultiplier tubes. Light energy is converted to electrical signals, digitized and processed by microcomputer. The limit of detection for lead is 0.025 p.p.m.

The instrument was calibrated using a single known standard and the slope of the calibration curve determined.

Repeated aspirations of each digest were made and the mean, standard deviation and percentage relative standard deviations of the signals determined by the micorcomputer linked to the plasma spectrometer. These were manually calculated to check for computational errors.

(ii) Experimental - Exposure and Results

Initially the lead content of an unexposed filter paper was determined. The filter paper was desiccated, weighed and digested. The results are shown in Table 20.

Six filter papers were exposed in the diffusion tube monitors. The papers were placed on the glass sinters and the funnels bunged. The funnels were filled with distilled de-ionised water up to the underside of the sinter. The filter papers remained moist throughout the monitoring period. After 32 days exposure the filter papers were removed from the monitors, sealed in sterile (previously acid rinsed) plastic petri dishes and covers and analysed using ICP-OES. The results are shown in Table 21.

A further set of four filters (two were lost during the exposure period) were exposed in the monitors for 34 days. The results are shown in Table 22.

These two sets of replicate cellulose filter paper monitors showed little consistency in amounts of accumulated lead.

TABLE 20. UNEXPOSED WHATMAN NO. 1 FILTER PAPER RESULTS.

Aspiration Number	Conc. Pb in Digest (p.p.m.)	Mass Pb (μg)
1	< 0.001	< 0.01
2	0.004	0.04
3	0.017	0.17
4	< 0.001	< 0.01
5	0.01	0.1
6	0.006	0.06
7	< 0.001	< 0.01
8	< 0.001	< 0.01
$\bar{X}^*$		0.05
SD		0.02
% RSD		41

Digest volume = 10 ml

*Assuming undetected levels to be zero.

TABLE 21 . REPLICATE FILTER PAPER MONITOR RESULTS.

Monitor Number	Conc. Pb in Digest.** (p.p.m.)	Mass Pb (μg)
1	0.2	2
2	<0.01	<0.1
3	0.3	3
4	0.3	3
5	0.2	2
6	0.1	1
$\bar{x}$*		2.2
SD		0.8
% RSD		36

Digest volume = 10 ml

*Assuming undetected levels to be zero.

**Mean of eight aspirations.

TABLE 22. REPLICATE FILTER PAPER MONITOR RESULTS.

Monitor Number	Conc. Pb in Digest.* (p.p.m.)	Mass Pb (μg)
1	0.15	1.5
2	0.02	0.2
3	0.05	0.5
4	0.04	0.4
$\bar{x}$		0.65

Digest volume = 10 ml

*Mean of 8 aspirations

(3) Adhesive Tape Monitors

Using the same procedures outlined above in (2) (i), adhesive tape ("3m", 25 mm wide) passive monitors were investigated. Initially unexposed samples were analysed using plasma spectrometry. The results are shown in Table 23.

Since the levels of lead in the adhesive tape were clearly low samples were exposed in the diffusion tubes. Strips of adhesive tape were mounted on cellulose filters to provide rigidity and prevent the tape curling up in the monitors.

After 30 days exposure the adhesive strip monitors were removed from the diffusion tubes, sealed in sterile (previously acid rinsed) plastic petri dishes and covers and analysed using ICP-OES.
The results are shown in Table 24.

The results indicate that very low levels of lead were accumulated and replicate samples had a high percentage relative standard deviation.

(4) Adhesive Disc Monitors

Using the same procedures outlined above in (2) (i) adhesive disc ("Fablon" 40 mm diameter) passive monitors were investigated. The exposed and blank discs were stripped of their adhesive layer and collected material by a hot acid wash; the complete digestion of the disc was not necessary. Previous attempts at complete digestion had produced a partly digested residue which affected aspiration.

Initially three adhesive disc blanks were analysed using ICP-OES. The results are shown in Table 25.

TABLE 23. UNEXPOSED ADHESIVE TAPE RESULTS.

Blank Number	Conc. Pb in Digest.* (p.p.m.)	Mass Pb (μg)
1	0.01	0.1
2	$<$ 0.01	$<$ 0.1
3	$<$ 0.01	$<$ 0.1

Digest volume = 10 ml

*Mean of three aspirations.

TABLE 24. REPLICATE ADHESIVE TAPE MONITOR RESULTS.

Monitor Number	Conc. Pb in Digest*. (p.p.m.)	Mass Pb (μg)
1	< 0.01	< 0.1
2	< 0.01	< 0.1
3	0.01	0.1
4	0.2	2.0
5	0.2	2.0
6	0.15	1.5
$\bar{x}$		1.0
SD		.92
% RSD		92

Digest volume = 10 ml

*Mean of 8 aspirations

**Assuming undetected levels to be zero.

TABLE 25 . UNEXPOSED ADHESIVE DISC RESULTS.

Blank Number	Conc. Pb in Digest*. (p.p.m.)	Mass Pb (μg)
1	< 0.01	< 0.1
2	0.0	0.0
3	< 0.01	< 0.1

Digest volume = 10 ml

*Mean of eight aspirations.

Six adhesive discs were each attached to glass slide covers (previously acid rinsed) to provide rigidity and were exposed in the diffusion tubes for 37 days. The results are shown in Table 26.

The results indicate that very low levels of lead were accumulated and replicate samples had a high percentage relative standard deviation.

(c) CONCLUSIONS

The investigation of sphagnum moss monitors and physical passive monitors did not produce acceptable replicate monitor results which was a pre-requisite to any attempt to calibrate lead deposition with atmospheric lead concentrations as a function of the flux past the monitor. The sampling errors associated with passive monitors, especially moss, require accurate definition.

The six diffusion tubes were identical in every respect, as were the available surface areas of the physical collection media. Lateral stratification of lead particles and differing particle sizes may account for the high relative standard deviations of replicate monitor results. Although passive monitors would present a more economical alternative to conventional air filtration techniques, sphagnum moss and physical passive monitors would not indicate whether the European Community air quality standard of 2 $\mu g.m^{-3}$ was being approached or breached.

Levels monitored in the N.E.D.D.C. area (Appendix A) indicate compliance with the air quality standard. It is therefore proposed that atmospheric lead monitoring be continued using conventional air filtration techniques at different locations within the area.

TABLE 26. REPLICATE ADHESIVE DISC MONITOR RESULTS.

Monitor Number	Conc. Pb in Digest*. (p.p.m.)	Mass Pb (μg)
1	0.011	0.11
2	0.021	0.21
3	0.064	0.64
4	0.030	0.30
5	0.13	1.3
6	0.019	0.19
$\bar{x}$		0.46
SD		0.41
% RSD		89

Digest volume = 10 ml

* Mean of eight aspirations.

(a) INTRODUCTION

The subject of dustfall, or deposited matter is of great importance in air pollution monitoring. It concerns particles large enough to settle out of the atmosphere at an appreciable rate (i.e. greater than 20 μm in diameter). Although such particles are not generally respired into the body, in certain cases e.g. lead, the deposits can present a hazard to health by other routes. Dust deposition can be a serious nuisance or disamenity. Calculations of dust deposit are often important in decisions on industrial plant siting.

In a number of countries measurements are made by networks of dustfall gauges of differing designs. In this country, two types of gauges predominate: the British Standard Deposit Gauge[42] and the Directional Dust Gauge[43]. (See figures 2 and 3).

(i) British Standard Deposit Gauge

In 1912, a number of Local Authorities in Great Britain agreed to unify their procedure in measuring deposited atmospheric pollution. The deposit gauge which they adopted has been reduced a little in size, and undergone other slight modifications, but remains in essentials the same. The gauge should be sited away from buildings and trees.

The solid matter and rainfall which falls within the 315 mm diameter collecting bowl passes down the connecting pipe into the collecting bottle. Material which falls on the outside of the collecting bowl and on the galvanised iron stand is prevented from entering the bottle by an inverted funnel. The collecting bottle is changed every month and its contents examined. Total undissolved and dissolved deposits are determined and usually expressed in $mg.m^{-2}.day^{-1}$.

The sampling errors of the gauge are considerable. Results of a single month's observations can only be relied on within a standard deviation of about 20%. When a deposit gauge is exposed for a number of consecutive months at the same site, it is found that successive monthly estimates of deposited matter vary by more than 20%. The standard deviation is at most places about 40% of the average: this means that about one reading in three is different from the average by more than 40%. This large variation has been found to be due partly to changes in emission rates from chimneys, but mostly to fluctuations in meteorological parameters such as monthly rainfall, and direction and speed of wind[68].

Ralph and Barrett[69] concluded that the British Standard Deposit Gauge suffered severely from particle blow-out at moderate wind speeds and that the fitting of a baffle inside the gauge bowl markedly reduced blow-out and improved the efficiency of catch.

The effect of the large variance in collection performance renders it necessary to have a long period of observations before significant conclusions can be drawn about rates of deposition. In practice, the most useful conclusions have been drawn from five year groups of sixty monthly observations[68].

In the post 1956 era in Great Britain, the role of the British Standard Deposit Gauge has diminished in importance.

(ii) Directional Dust Gauge

Experience with the British Standard Deposit Gauge has shown that they collect only very coarse dust under light wind conditions, but are inefficient collectors at higher wind speeds and may even lose some of the previously collected dust under strong wind conditions[69]. They do not adequately take account of the fact that pollution by dust, particularly of vertical surfaces, takes place even with fairly strong winds. A different type of gauge, which until about ten years ago had been known as the C.E.R.L. (Central Electricity Research Laboratory) Directional Dust Gauge, has been developed and is the subject of a British Standard[43].

The gauge measures the tendency of objects to become dirty in a dusty atmosphere. It collects the dust that is likely to impinge on objects on the Earth's surface. The period of exposure of the gauge for long term measurements is commonly a calendar month, but may also be used in certain circumstances for short term measurements.

(b) THE N.E.D.D.C. DIRECTIONAL DUST GAUGE

The area administered by North East Derbyshire District Council (N.E.D.D.C.) contains several processes and operations which generate dust. They include coal stocking, opencast coal extraction, cement batching and industrial boilerhouse grit and dust emissions. Complaints are regularly received from members of the public alleging dust nuisance from specific activities.

In view of the complaints that were being received and the limitations of the British Standard Deposit Gauge in assessing nuisance, the use of directional dust gauges was considered. The advantages that these gauges offered i.e. directionality and more efficient particle collection, suggested that they were suitable for specific dust source monitoring.

The N.E.D.D.C. Directional Dust Gauge complies with the British Standard[43] specifications for Directional Dust Gauges. The decision to construct the gauges within the Council's organisation was taken because of the availability of materials and craftsmen as well as the high purchase price of commercially available gauges. The N.E.D.D.C. Directional Dust Gauge is currently being used by many Local Authorities and other organisations throughout Great Britain.

(i) Apparatus

a. Assembly

The directional dust gauge comprises the following:-

one vertical supporting post;
four collecting heads;
eight collecting bottles;
one squeegee;
one wash bottle.

b. Support

The collecting heads are securely attached to the vertical post which is supported by a 450 mm square base. The tops of the collecting heads are 1.5 ± 0.1 m above ground level. In order that the gauge may withstand severe wind conditions (up to 40 $m.s.^{-1}$) long pins are driven through the base to a depth of about 300 mm.

c. Collecting Heads

The collecting heads are made of chemically resistant, rigid P.V.C. tube of a nominal internal diameter of 75 mm. The vertical slits are 340 $\pm$ 5 mm long and 45 $\pm$ 1 mm wide. The four heads are attached to the post at 90° to each other.

d. Collecting Bottles

The bottles are made of translucent plastic and are attached to the collecting heads so that water running from within the collecting head runs into the bottle. The bottles form a tight fit with the heads to prevent material washed off the external surfaces of the collecting heads entering the bottles. The bottles have a capacity of one litre and are indelibly marked with a code that identifies both the site on which it was used and the direction in which the aperture of its collecting head points.

e. Squeegee

The squeegee is made from a wooden dowel, 12 mm in diameter and 800 mm long to which is attached a wooden disc, 60 mm in diameter. Attached to the outer circumference of the disc is a rubber ring ('Hoover' vacuum cleaner belt).

(ii) Siting

The gauge is sited with the post vertical and, whenever possible, in an open space. The gauge stand is securely fixed to the surface on which it stands so that individual orifices face the cardinal compass points. Gauges to assess nuisance should be sited at the point of complaint or where complaints are likely to arise.

(iii) Operation

After one calendar month, any adherent dust in each collecting head shall be washed into the appropriate collecting bottle with the assistance of the squeegee, care being taken to avoid loss of material. The bottles are removed and a water tight cap applied to each one. Clean bottles are substituted. The bottles are delivered for analysis with the following information:-

particulars of site;
period of exposure;
a note of any unusual event or events that may have influenced the character or the amount of the deposit.

(iv) Examination of the Deposit

a. By Absorptiometer[43]

Foreign matter such as leaves or insects should be removed. The standard beaker is filled with water, placed in the absorptiometer and the meter reading of the instrument adjusted to zero. The beaker is then emptied and the collected liquid and solid matter added to it and the liquid level made up, with water, to the standard volume. If the reading is in excess of 70% obscuration or if the amount of collected liquid is too great for a single measurement, a number of sub-samples shall be measured and their readings added. The ten day percentage obscuration is then calculated as follows:-

$$10 \text{ day percentage obscuration } (\%) = \frac{10aT}{AN}$$

where a = area of base of beaker (mm^2),

A = area of gauge aperture (mm^2),

N = number of days exposed,

T = sum of absorptiometer readings in "obscuration percent"

b. By Filtration

The contents of each collecting bottle in turn are poured into a one litre pyrex beaker, any adhering particles are removed by a wash bottle. Any foreign matter is removed and the contents of the beaker are filtered through a dessicated, pre-weighed Whatman No. 41 filter paper. The filter paper and filtrate are then air dried, dessicated and weighed. The amounts of collected material are expressed as $mg.m^{-2} day^{-1}$.

(c) ASSESSMENT OF RESULTS

The British Standard[43] states that the precise measurement of the particulate material at any particular site is difficult and it should be noted that the amount collected and retained in the gauge is influenced by factors such as the height of the gauge above ground level, the nature of the site and the meteorological conditions.

(i) Performance Characteristics of the Directional Dust Gauge

Prior to 1973, little had been published on the behaviour and use of the directional dust gauge. Work undertaken by the British Steel Corporation[70] to assess the environmental impact of a large integrated steel works at Redcar, in the north of England, included an examination of the performance characteristics of the gauge. The studies which were carried out investigated the effects of height, adjacent collecting heads, wind speed and rainfall on the performance of the gauge. The main conclusions were as follows:-

a. An increase in height (3m) tended to increase the amount of solids collected, but this was offset to some extent by the capture of dust entrained from the ground in gauges situated at ground level, see figure 5.

b. Correlation coefficients between gauges situated 20 m apart on level land was high (0.93) showing that the gauge had good reproducibility, see figure 6.

c. Collection efficiency increased with wind velocity, but the effect was small compared to the increase in airborne dust with wind velocity, see figure 7.

d. Rainfall did not affect collection efficiency of the gauge but did reduce airborne dust.

e. The amount of material in a given collecting head was not significantly influenced by the distortion in air flow resulting from the presence of the other three heads, see figure 8.

FIG. 5. EFFECT OF GAUGE HT. ON COLLECTION CHARACTERISTICS[70].

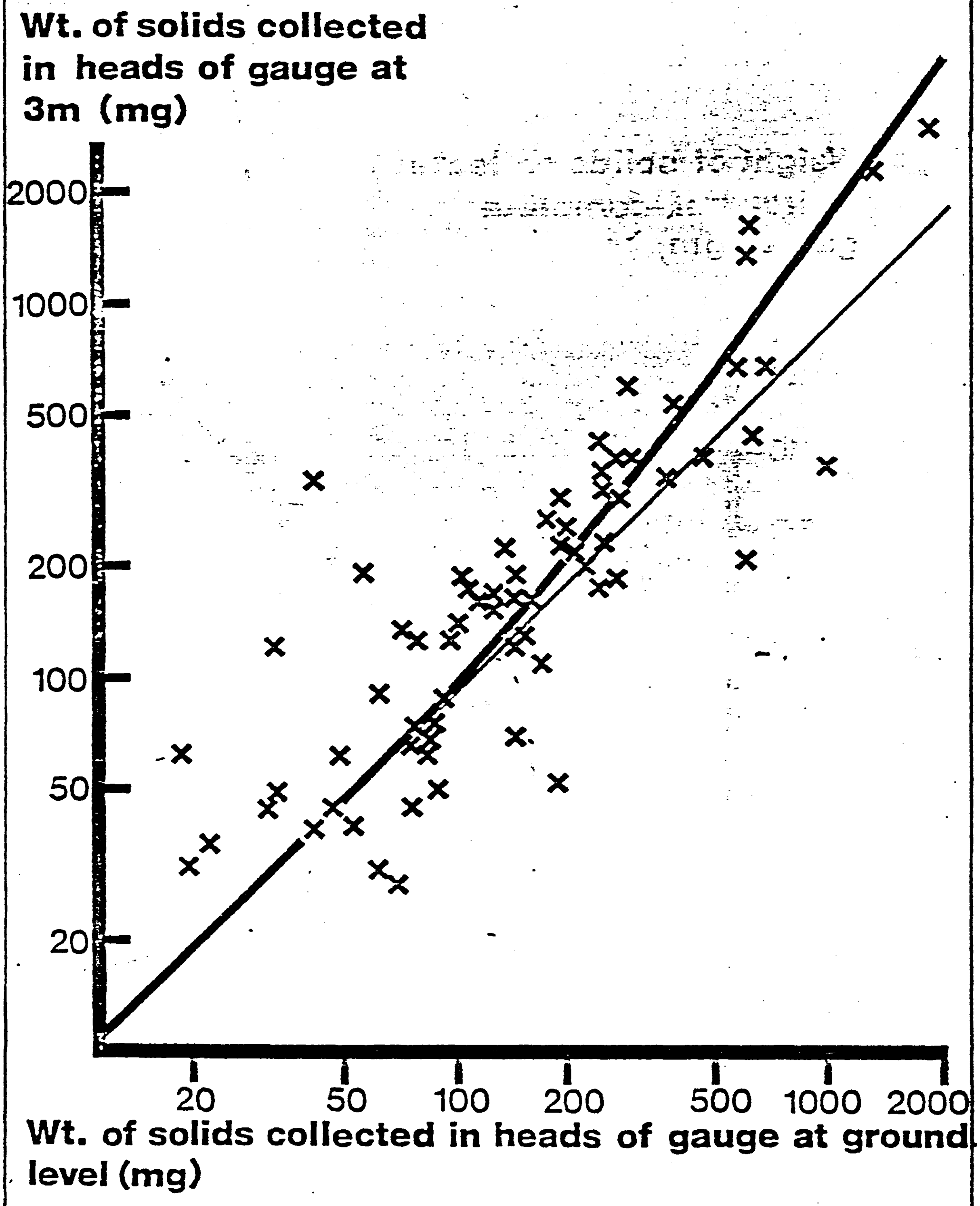


FIG. 5 . CORRELATION BETWEEN DEPOSITS COLLECTED IN TWO CLOSELY SITED DIRECTIONAL DUST GAUGES.[70]

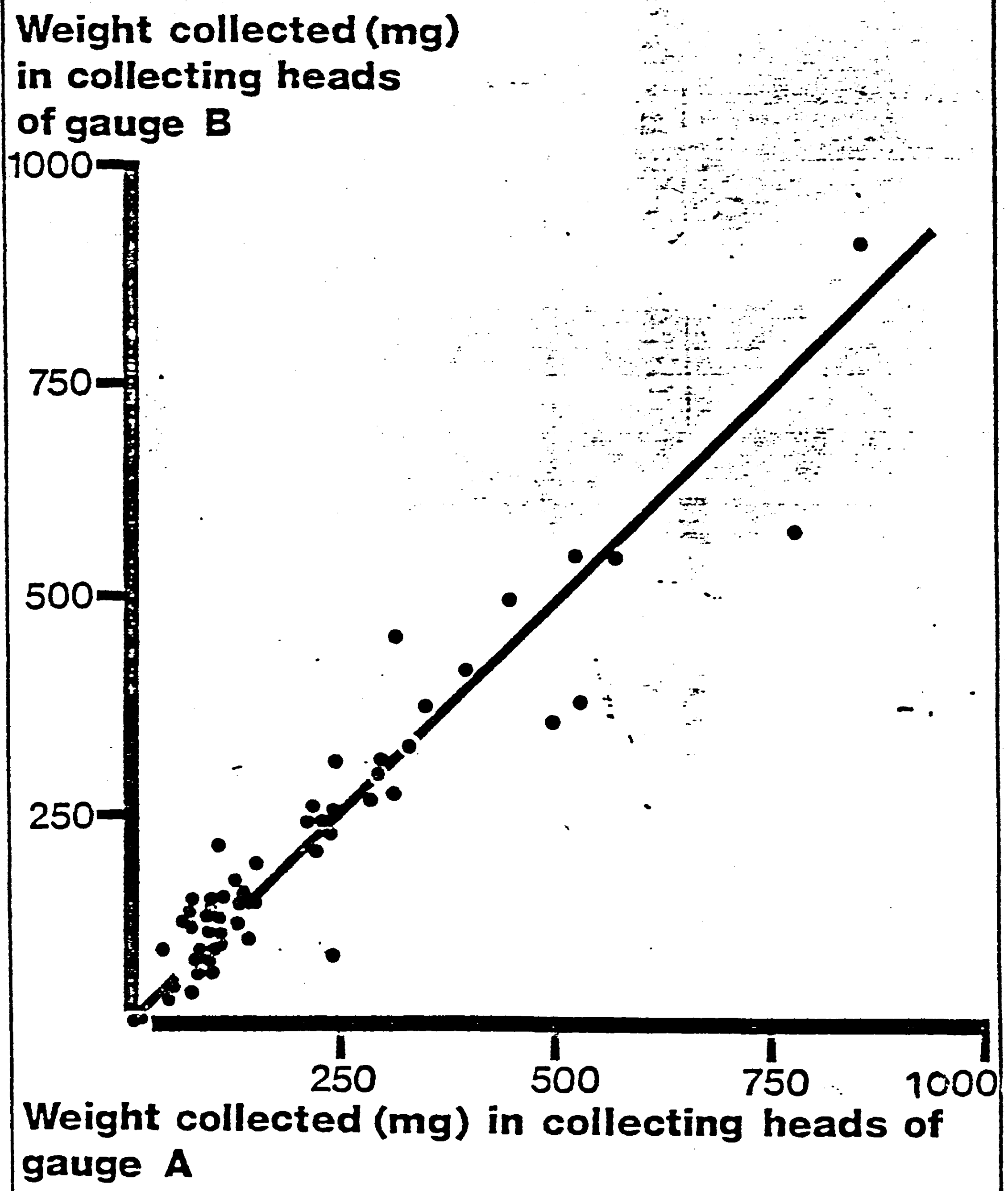


FIG. 7 . COLLECTION EFFICIENCY AS A FUNCTION OF WIND SPEED.[70]

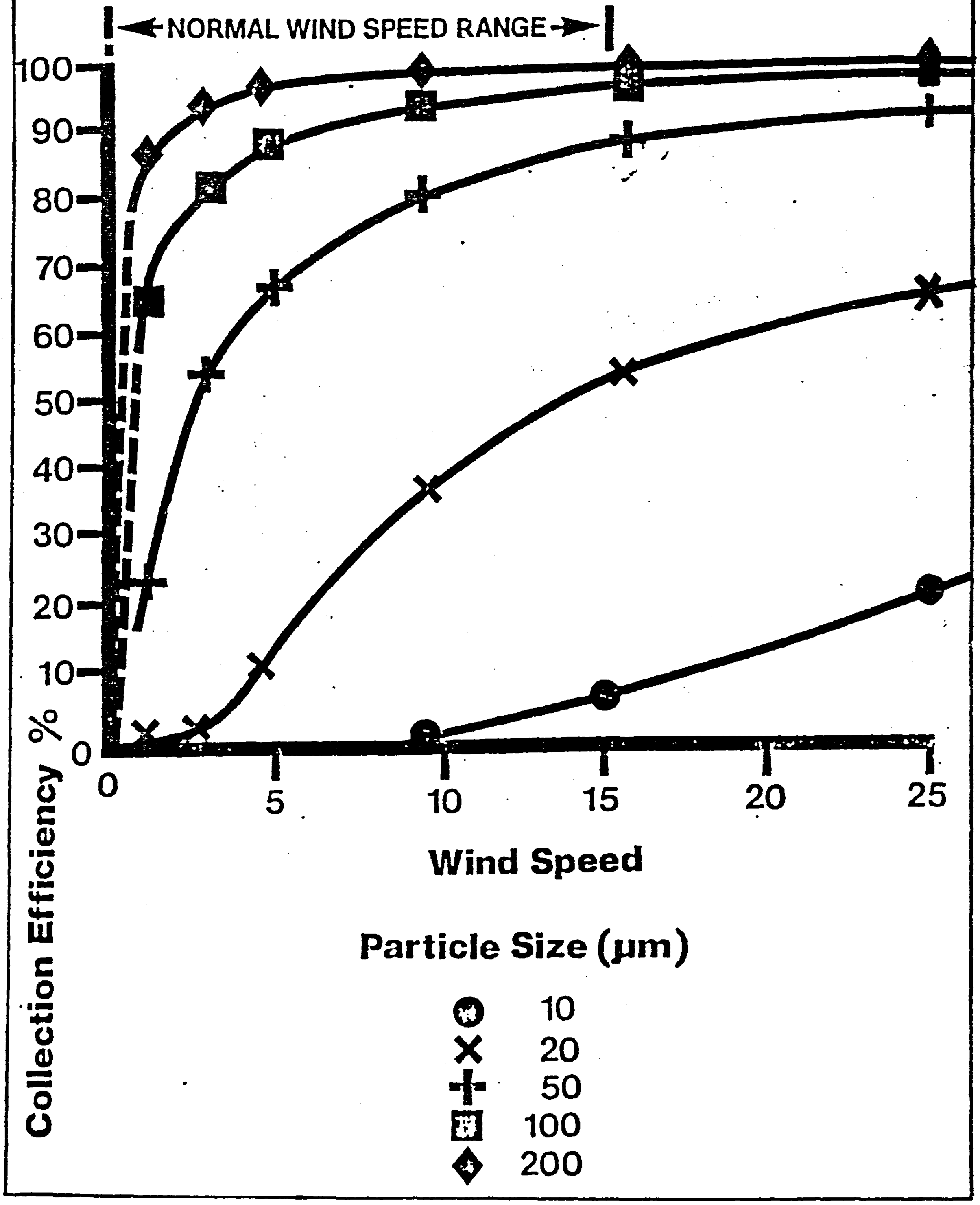
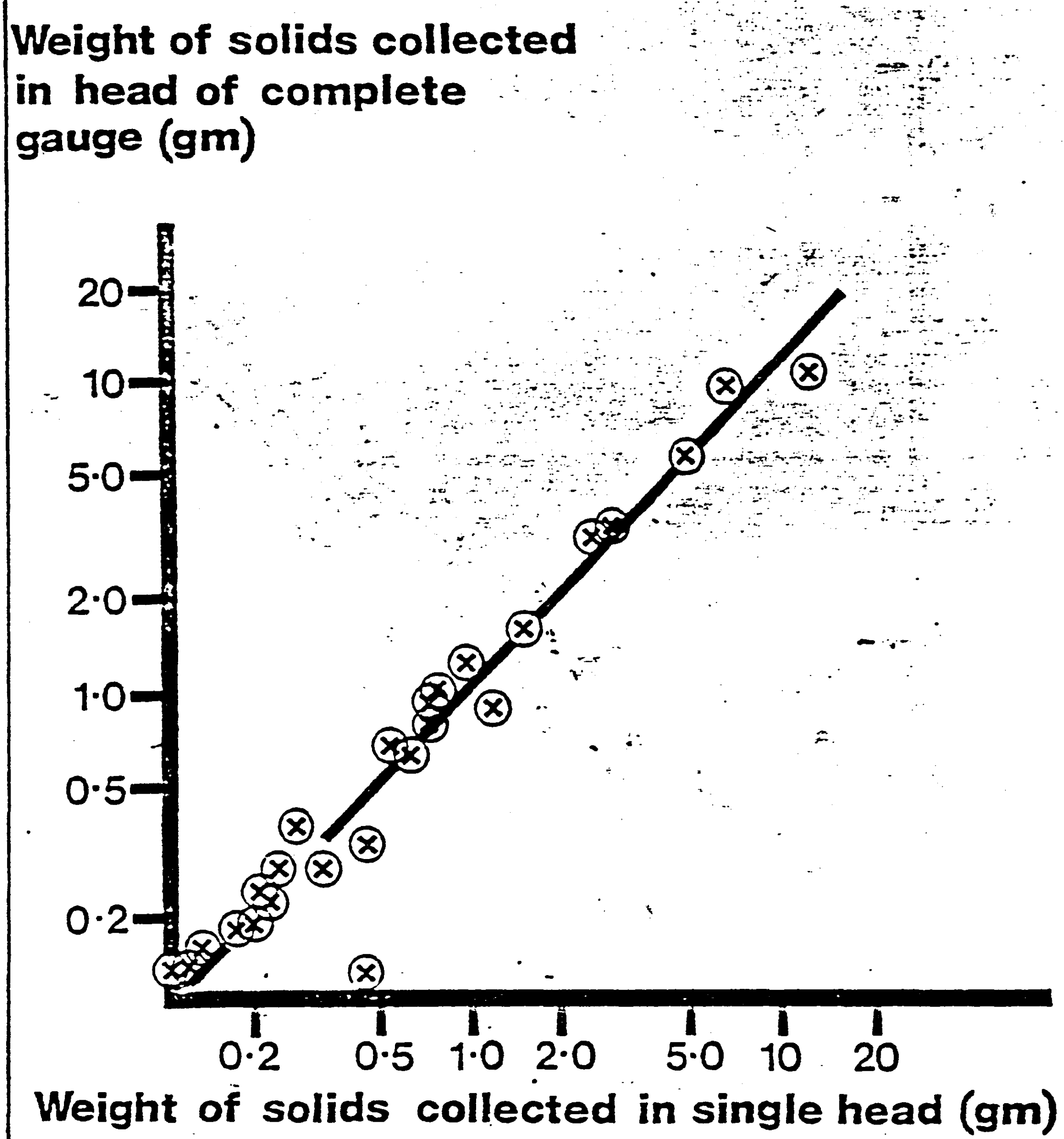


FIG. 8 . INFLUENCE OF OTHER COLLECTING HEADS ON COLLECTION CHARACTERISTICS.[70]



(ii) Wind Correction Factor

The wind does not blow uniformly from all directions during the collecting period of the dust gauge. Therefore the weights of the deposits collected are not truly representative of the source potential of each direction. Lucas and Moore[71] suggest that a correction factor may be applied to the data which will enable the source potentials of each direction to be compared, i.e.:-

$$\text{Correction factor} = \frac{100/\pi}{(0.74P + 0.97Q + 0.74R)}$$

where Q = percentage of the time that the wind blows in the primary octant of the gauge,

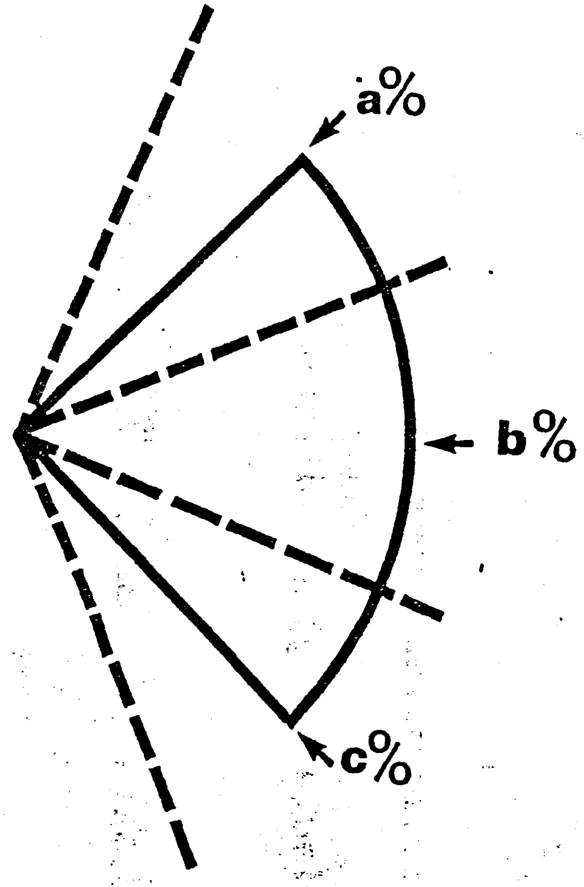
P & R = percentages of time that the wind blows in the adjacent octants,

0.97 & 0.74 = collection efficiences of the gauge for winds in primary and adjacent octants.

The correction factor (see figure 9) is necessarily simplified, and Lucas and Moore have never fully explained its derivation. Its major fault is that it can yield extremely high correction factors when the wind direction remains constant for most of the month under consideration.

Brown and Fisher[70] suggested that the correction factor could be improved by incorporating a factor to allow for the reverse capture efficiency. Bush *et al.*[72] carried out a mathematical analysis of particle flow and capture on a directional dust gauge and concluded that the formation of downstream wake may result in finer dust particles being carried by the turbulent air flow into the downstream collecting heads.

FIG. 9 . WIND CORRECTION OF DIRECTIONAL DUST GAUGE DATA.[71]



$$\text{CORRECTION FACTOR} = \frac{100/\pi}{0{\cdot}74a + 0{\cdot}97b + 0{\cdot}74c}$$

The modified correction factor is as follows:-

$$\text{Correction factor} = \frac{100}{(0.74\ (P\ \&\ R) + 0.97Q + kS)}$$

where S = percentage of time that the wind blows in the direction opposite to the primary octant,

k = reverse capture efficiency.

Brown and Fisher[70] never applied this improved correction factor to their data because of the difficulty in finding a representative value for k. They concluded that the reverse capture efficiency would probably be higher for small particles than for large particles, which was the reverse of the forward collection efficiency.

(iii) National Coal Board (U.K.) Western Area Scientific Department Method

A National Coal Board, U.K., scientific report[73] suggested that to detect the presence of an unsuspected dust source, directional dust gauge results may be corrected for wind direction.

The principle of the method is to re-express the "as measured" results, as if the wind had blown equally from all directions during the sampling period. The effect of this is to show accentuated results from one or more directions and to diminish those from other directions. The relative magnitude of the corrected figures for the four directions then indicates the order of importance of the dust sources surrounding the gauge.

The method is as follows:-

1. Define the four quadrants affecting the collecting heads, i.e. if collecting heads face north, south, east and west, the quadrant affecting the north collecting head is from north-west to north-east.

2. For each measuring period, total up the number of half days in which the wind generally lay in each quadrant. Count the number of half days which were calm as a separate total.

3. Add to the total for each quadrant a quarter of the total calm days to give a final total W_q for each quadrant.

4. Divide the total number of half days in the measurement period by four to give W.

5. Multiply the "as measured" % ten day obscuration for each quadrant by:-

$\frac{W}{W_q}$ for that quadrant

This gives the first stage of correction, $\%TDO_{C1}$ (%TDO 1st correction)

6. Add together all the "as measured" % TDO's to give total TDO_M

7. Add together the $\%TDO_{C1}$ to give total TDO_{C1}. It will usually be found that the sum of the TDO_{C1} is greater than the sum of TDO_M. To correct this a second correction is required.

8. Multiply each TDO_{C1} by $\frac{\text{total } TDO_M}{\text{total } TDO_{C1}}$

to give fully corrected results - $\%TDO_{C2}$

9. As a check TDO_{C2} should equal TDO_M to within 0.1.

10. Prepare a plan of the area showing fully corrected results and their direction. From this, the direction and possible location of a previously unsuspected dust source may become apparent.

This method involves a number of assessments and approximations and the author admits that it is rather crude. It may in some cases multiply a small, possibly inaccurate figure (i.e. an uncorrected dust level) by a large approximate factor.

(d) DIRECTIONAL DUST GAUGE MONITORING IN THE N.E.D.D.C. AREA

In December, 1983 there were 13 gauges located at various sites within the N.E.D.D.C. area involved in various monitoring activities:-

opencast coal extraction sites	-	7
coal stocking operations	-	1
road dust generation	-	2
research and development	-	3

It is envisaged that the location and number of gauges in operation will change as a result of changing monitoring priorities in general and following the development of an improved model to interpret the collected matter.

(e) METEOROLOGICAL DATA

The development of a model to assess the results from directional dust gauges requires an input of meteorological conditions prevailing during the monitoring period.

Lancaster [73] suggest that the N.C.B. method may be improved by considering wind directions every hour rather than every 12 hours.

Brown and Fisher [70] conclude that wind speed as well as wind direction affect the performance of the gauge.

Meteorological date is currently being obtained from three sources:

a. Meteorological Office, Watnall, Nottingham
   - wind direction and wind speed, four observations per day;

b. Weston Park Museum, Sheffield
   - wind direction and wind speed, one observation per day. Rainfall, minima, mean and maxima daily temperatures, hours sunlight and relative humidity;

c. Furnace Hillock Opencast Site, Chesterfield
   - continuously integrated hourly wind speed, wind direction, barometric pressure and temperature date;

d. British Coke Research Association Laboratories, Wingerworth Chesterfield (ceased December 1982)
   - several parameters, daily averages and 6 hourly readings.

Sample report forms from the monitoring souces are included in Appendix B.

(f) DEVELOPMENT OF A NEW MODEL

(i) Introduction

Previous workers had concluded that the prevailing wind direction conditions during the period of monitoring influenced the amounts of material collected in the directional dust gauge [69,71].

Lancaster's [73] model attempted to quantify the affect of wind direction on the amounts of dust deposited in specific collecting heads. A quadrant was ascribed to each collecting head and a correction applied for each half day the wind lay in the quadrant.

Bush et al.[72] suggest that the collection performance of the gauge is not as simple as that. With a gauge whose collecting heads face north, south, east and west, the available slit width of the north facing tube is greater than the available slit width of the west facing collecting head when the wind comes from the north, north-west.

Another important meteorological parameter is wind speed. Brown and Fisher[70] concluded that amounts of airborne dust increased with wind velocity as did the collection effiency of the gauge.

The developing model was applied to collected amounts of dust from gauges in the North East Derbyshire District Council area. Special emphasis was placed on the results from the seven gauges situated around a proposed opencast coal site. The gauges were commissioned in September, 1982 and the opencast coal site commenced earth stripping in January 1983.

The method of analysis is described above (B, iv, a) and meteorological data was applied to the model from the four measurement stations at different stages of its development.

Data processing was carried out using a Sinclair Spectrum microcomputer having 48 kilobytes of random access memory. All programming was in BASIC.

(ii) Initial Model

An initial model, based on prevailing wind conditions was used to interpret the amounts of collected material in the gauges.

In the absence of any dust source it was assumed that all directions were equally capable of generating dust. The model took the following into account:

a. daily average wind speed,
b. daily average wind direction, and
c. the time that the wind blew from a particular direction.

The model predicts the amounts of dust that may be expected in each collecting bottle, assuming that the area around the gauge is equally capable of generating dust. A "weighting" factor for each cardinal point of the compass is calculated as follows (e.g. for the collecting head facing north):

No. of days during monitoring period wind is from north = d
Ave. wind speed from north = s
No. of days during monitoring period wind from NE or NW = d'
Ave. wind speed from NE or NW = s'
Weighting factor, $W_N = ds + (0.5d's')$

The weighting factor is then calculated as a percentage of the four weighting factors calculated for the cardinal points;

$$\text{i.e. } \% \, W_N = \left(\frac{W^N}{W_N + W_S + W_E + W_W}\right) \times 100$$

The total amount of dust collected in all four gauge compartments is then multiplied by each weighting factor % to predict the amount of dust in each collecting bottle.

Finally, the difference between this predicted amount and the actual amount is an indication of the direction of a dust source.

The programme which was written to apply this initial model is shown in Prog. 1. below. The defined and programme variables are as follows;

AA = Number of days wind from north
BB = " south
CC = " east
DD = " west
EE = " ½ compass point containing north
FF = " " south
GG = " " east
HH = " " west
MM = Average wind speed fron north
NN = " south
OO = " east
PP = " west
QQ = " ½ compass point containing north
RR = " " south
SS = " " east
TT = " " west
rrr = Identification input of microcomputer operator
X$ = Identification of operator on result print out
oo = Identification input of gauge location
G$ = Identification of gauge location on result print out
kk = Number of month in year (1 to 12)
H$ = Identification of month in result print out

xxx = Number of days in monitoring period

II = Weighting factor north, (AA * MM)+((EE * 0.5) * QQ)

JJ = " south, (BB * NN)+((FF * 0.5) * RR)

KK = " east, (CC * OO)+((GG * 0.5) * SS)

LL = " west, (DD * PP)+((HH * 0.5) * TT)

UU = Sum of weighting factor

VV = % weighting factor north i.e. (II/UU) * 100

WW = " south

XX = " east

YY = " west

N = Weight of dust in collecting head bottle north

O = " south

P = " east

Q = " west

R = Actual dust result (mg.m^{-2}.day^{-1}) north

S = " south

T = " east

U = " west

EEE = R + S + T + U

NNN = Predicted dust result north i.e. $\frac{VV}{100} * EEE$

OOO = " south

PPP = " east

QQQ = " west

FFF = Difference between actual and predicted dust result north

GGG = " south

HHH = " east

III = " west

TTT = Actual % of total dust in collection bottle north

UUU = " south

VVV = Actual % of dust in collection bottle north

WWW = " south

AAA = % difference between predicted % and actual % distribution for bottle north

BBB = as above for bottle south

CCC = " east

DDD = " west

(iii) Gauge Configuration

An examination of the cross section configuration of the gauge was carried out when the collecting heads faced north, south, east and west, and a wind was incident from the direction of a half compass point.

The initial programme ascribed a value of 1 to the weighting factor when the wind blew from a cardinal compass point and 0.5 to adjacent cardinal compass point weighting factors when the wind blew from a half compass point.

By trigonometry, (see fig. 10) the available slit width of adjacent collecting heads is;

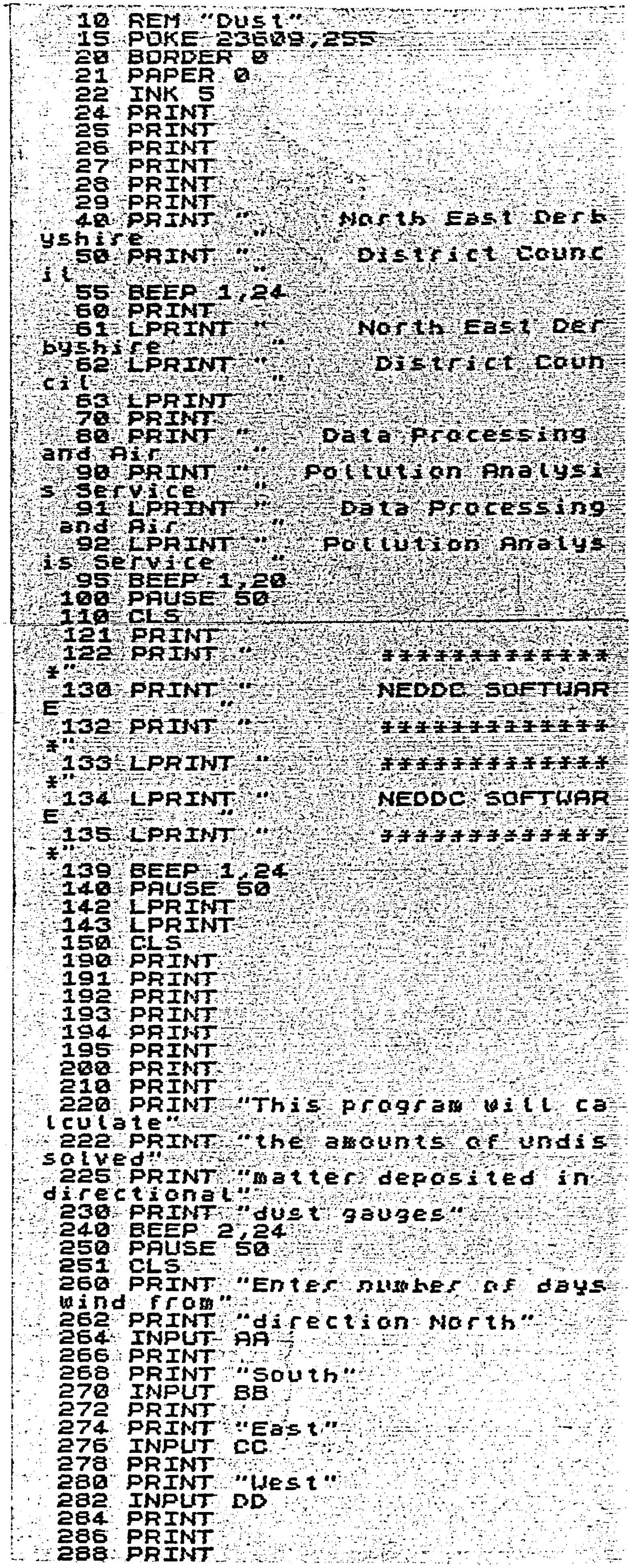
$$\frac{1}{\sqrt{2}} = 0.71$$

The initial programme was amended. 0.5 was replaced by 0.71 on lines 1460, 1470, 1480 and 1490 (see prog. 2).

PROG. 1.

INITIAL

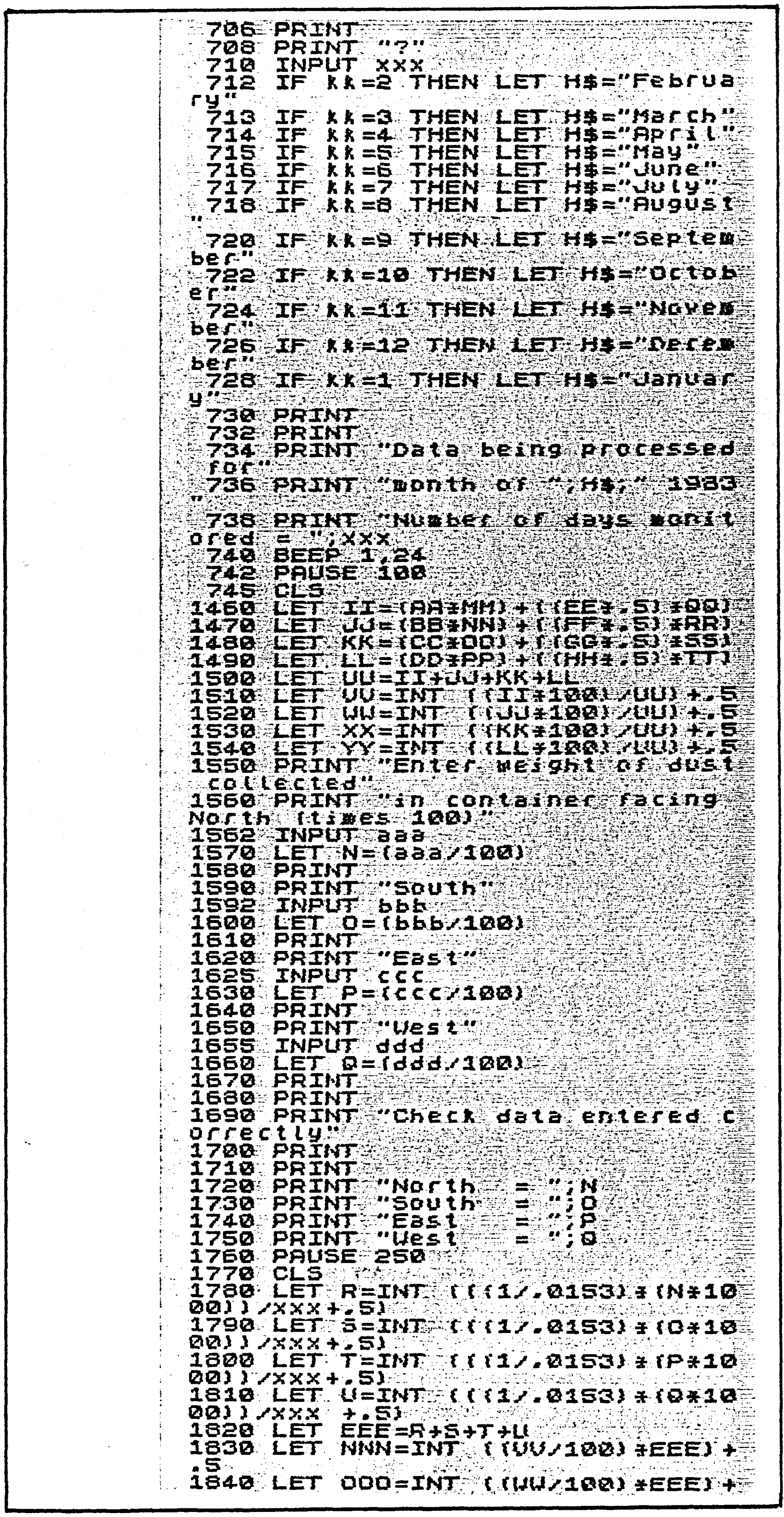
PROGRAMME.



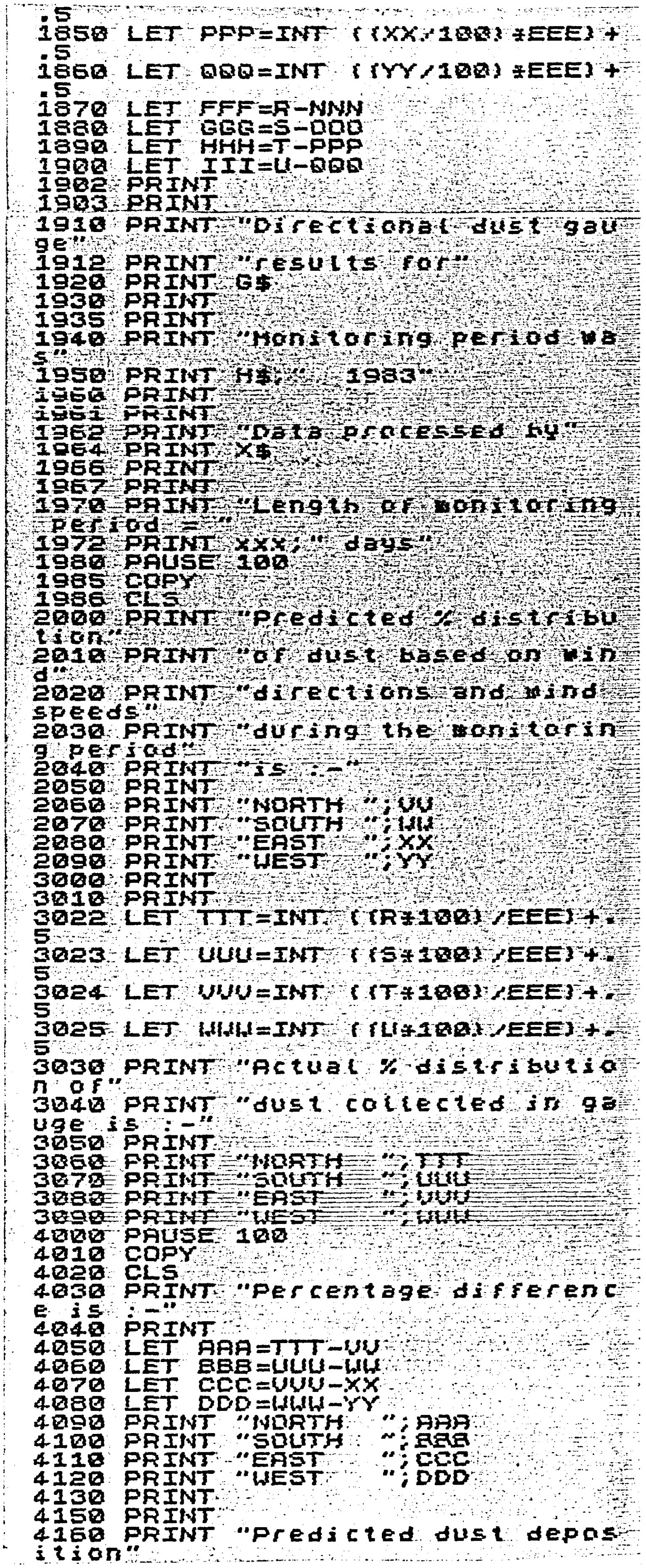
```
  10 REM "Dust"
  15 POKE 23609,255
  20 BORDER 0
  21 PAPER 0
  22 INK 5
  24 PRINT
  25 PRINT
  26 PRINT
  27 PRINT
  28 PRINT
  29 PRINT
  40 PRINT "      North East Derb
yshire  "
  50 PRINT "      District Counc
il    "
  55 BEEP 1,24
  60 PRINT
  61 LPRINT "     North East Der
byshire   "
  62 LPRINT "     District Coun
cil      "
  63 LPRINT
  70 PRINT
  80 PRINT "   Data Processing
and Air   "
  90 PRINT "  Pollution Analysi
s Service  "
  91 LPRINT "   Data Processing
 and Air    "
  92 LPRINT "  Pollution Analys
is Service   "
  95 BEEP 1,20
 100 PAUSE 50
 110 CLS
 121 PRINT
 122 PRINT "        ************
*"
 130 PRINT "        NEDDC SOFTWAR
E    "
 132 PRINT "        ************
*"
 133 LPRINT "       ************
*"
 134 LPRINT "       NEDDC SOFTWAR
E    "
 135 LPRINT "       ************
*"
 139 BEEP 1,24
 140 PAUSE 50
 142 LPRINT
 143 LPRINT
 150 CLS
 190 PRINT
 191 PRINT
 192 PRINT
 193 PRINT
 194 PRINT
 195 PRINT
 200 PRINT
 210 PRINT
 220 PRINT "This program will ca
lculate"
 222 PRINT "the amounts of undis
solved"
 225 PRINT "matter deposited in
directional"
 230 PRINT "dust gauges"
 240 BEEP 2,24
 250 PAUSE 50
 251 CLS
 260 PRINT "Enter number of days
 wind from"
 262 PRINT "direction North"
 264 INPUT AA
 266 PRINT
 268 PRINT "South"
 270 INPUT BB
 272 PRINT
 274 PRINT "East"
 276 INPUT CC
 278 PRINT
 280 PRINT "West"
 282 INPUT DD
 284 PRINT
 286 PRINT
 288 PRINT
```

```
 290 PRINT "Check data entered c
orrectly"
 292 PRINT
 294 PRINT "North = ";AA
 296 PRINT "South = ";BB
 298 PRINT "East  = ";CC
 300 PRINT "West  = ";DD
 302 PAUSE 250
 304 CLS
 306 PRINT "Enter number of days
wind from"
 308 PRINT "a compass point cont
aining North"
 310 INPUT EE
 312 PRINT
 314 PRINT "South"
 316 INPUT FF
 318 PRINT
 319 PRINT "East"
 320 INPUT GG
 322 PRINT
 324 PRINT "West"
 326 INPUT HH
 332 PRINT "Check data entered c
orrectly"
 334 PRINT
 336 PRINT
 338 PRINT "North = ";EE
 340 PRINT "South = ";FF
 342 PRINT "East  = ";GG
 344 PRINT "West  = ";HH
 346 PAUSE 250
 348 CLS
 350 PRINT "Enter average wind s
peed"
 352 PRINT "from direction North
"
 354 INPUT MM
 356 PRINT
 358 PRINT "South"
 360 INPUT NN
 362 PRINT
 364 PRINT "East"
 366 INPUT OO
 368 PRINT
 370 PRINT "West"
 372 INPUT PP
 374 PRINT
 376 PRINT
 378 PRINT "Check data entered c
orrectly"
 380 PRINT
 382 PRINT
 384 PRINT "North = ";MM
 386 PRINT "South = ";NN
 388 PRINT "East  = ";OO
 390 PRINT "West  = ";PP
 392 PAUSE 250
 394 CLS
 396 PRINT "Enter average wind s
peed"
 398 PRINT "from direction mid-p
oints"
 400 PRINT "containing North"
 402 INPUT QQ
 404 PRINT
 406 PRINT "South"
 408 INPUT RR
 410 PRINT
 412 PRINT "East"
 414 INPUT SS
 416 PRINT
 418 PRINT "West"
 420 INPUT TT
 422 PRINT
 424 PRINT
 426 PRINT "Check data entered c
orrectly"
 432 PRINT "North = ";QQ
 434 PRINT "South = ";RR
 436 PRINT "East  = ";SS
 438 PRINT "West  = ";TT
 440 PAUSE 250
 442 CLS
 588 PRINT "ENTER THE OPERATORS
NUMBER"
 596 PRINT "1. N.R.Tranmer"
 598 PRINT "2. D.R.Peaty"
 600 PRINT "3. A.Hobley"
```

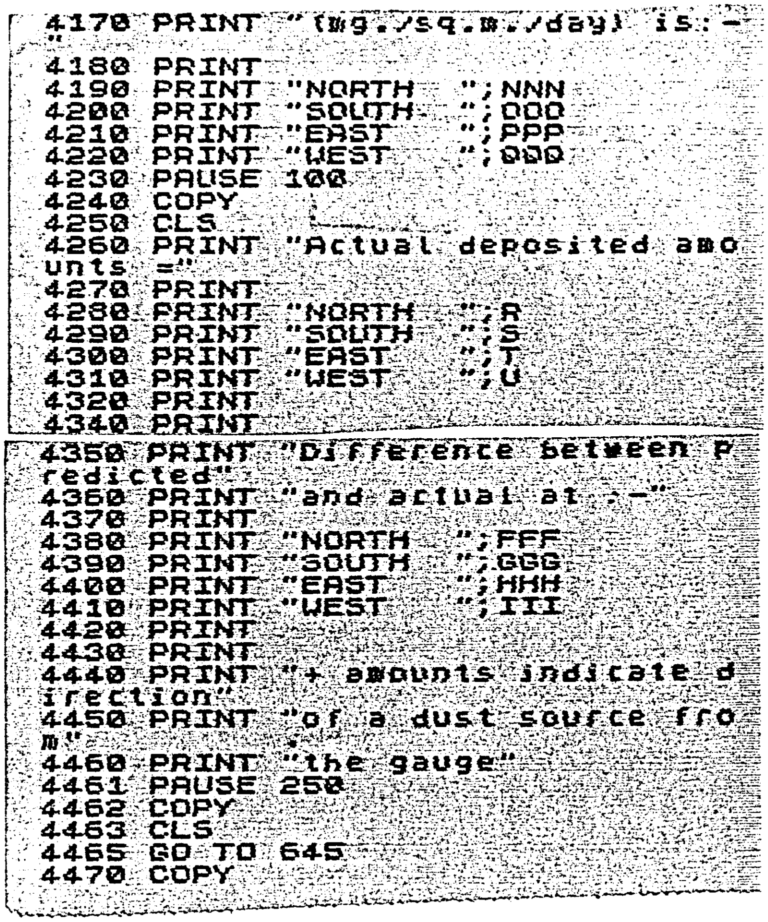
```
 608 PRINT "?"
 610 BEEP 2,24
 612 INPUT rrr
 614 IF rrr=1 THEN LET X$="N.R.T
ranmer"
 616 IF rrr=2 THEN LET X$="D.R.P
eaty"
 618 IF rrr=3 THEN LET X$="A.Hob
ley "
 628 PRINT "Data processed by"
 630 PRINT X$
 632 BEEP 1,20
 634 PAUSE 50
 640 CLS
 645 PRINT "ENTER NUMBER OF GAUG
E SITE"
 647 PRINT
 648 BEEP 1,24
 650 PRINT "1  Lings one."
 652 PRINT "2  Lings two."
 654 PRINT "3  Lings three."
 655 PRINT "4  Lings four."
 656 PRINT "5  Lings five."
 657 PRINT "6  Lings six."
 658 PRINT "7  Lings seven."
 659 PRINT "8  Hut Lane, H.Moor"
 660 PRINT "9  Mansfield Rd., H.
Moor"
 661 PRINT "10 Grange Fm., Grass
moor"
 662 PRINT "11 Furn.Hill. one"
 663 PRINT "12 Furn.Hill. two"
 664 PRINT "13 Furn.Hill. three"
 666 INPUT oo
 667 IF oo=1 THEN LET G$="108 Al
ma Rd, N.Wingfield       LINGS
ONE"
 669 IF oo=2 THEN LET G$="36 Ver
non Rise, Grassmoor      LINGS
TWO"
 670 IF oo=3 THEN LET G$="8 Birk
in Lane, T/Normanton     LINGS
THREE"
 672 IF oo=4 THEN LET G$="251 Ch
esterfld. Rd., T/Norm.   LINGS
FOUR"
 673 IF oo=5 THEN LET G$="112 Ch
esterfld. Rd.,Holmewood  LINGS
FIVE"
 674 IF oo=6 THEN LET G$="299 Wi
lliamthorpe Rd., N.Wing. LINGS
SIX"
 675 IF oo=7 THEN LET G$="12 Huc
klow Ave., N.Wingfield   LINGS
SEVEN"
 676 IF oo=8 THEN LET G$="Hut La
ne, High Moor."
 677 IF oo=9 THEN LET G$="Mansfi
edl Rd., High Moor."
 678 IF oo=10 THEN LET G$="Grang
e Fm."
 679 IF oo=11 THEN LET G$="Furn.
Hill one"
 680 IF oo=12 THEN LET G$="Furn.
Hill two"
 681 IF oo=13 THEN LET G$="Furn.
Hill three"
 687 PRINT "Gauge located at "
 688 PRINT G$
 690 BEEP 1,24
 692 PAUSE 100
 693 CLS
 694 PRINT "ENTER THE NUMBER OF
THE"
 695 PRINT "MONTH OF THE MONITOR
ING PERIOD"
 696 PRINT
 698 PRINT "?"
 699 INPUT kk
 700 PRINT
 701 PRINT
 702 PRINT "ENTER NUMBER OF DAYS
IN THE"
 704 PRINT "MONITORING PERIOD"
```



```
 706 PRINT
 708 PRINT "?"
 710 INPUT xxx
 712 IF kk=2 THEN LET H$="Februa
ry"
 713 IF kk=3 THEN LET H$="March"
 714 IF kk=4 THEN LET H$="April"
 715 IF kk=5 THEN LET H$="May"
 716 IF kk=6 THEN LET H$="June"
 717 IF kk=7 THEN LET H$="July"
 718 IF kk=8 THEN LET H$="August
"
 720 IF kk=9 THEN LET H$="Septem
ber"
 722 IF kk=10 THEN LET H$="Octob
er"
 724 IF kk=11 THEN LET H$="Novem
ber"
 726 IF kk=12 THEN LET H$="Decem
ber"
 728 IF kk=1 THEN LET H$="Januar
y"
 730 PRINT
 732 PRINT
 734 PRINT "Data being processed
 for"
 736 PRINT "month of ";H$;" 1983
"
 738 PRINT "Number of days monit
ored = ";xxx
 740 BEEP 1,24
 742 PAUSE 100
 745 CLS
1460 LET II=(AA*MM)+((EE*.5)*QQ)
1470 LET JJ=(BB*NN)+((FF*.5)*RR)
1480 LET KK=(CC*OO)+((GG*.5)*SS)
1490 LET LL=(DD*PP)+((HH*.5)*TT)
1500 LET UU=II+JJ+KK+LL
1510 LET VV=INT ((II*100)/UU)+.5
1520 LET WW=INT ((JJ*100)/UU)+.5
1530 LET XX=INT ((KK*100)/UU)+.5
1540 LET YY=INT ((LL*100)/UU)+.5
1550 PRINT "Enter weight of dust
 collected"
1560 PRINT "in container facing
North (times 100)"
1562 INPUT aaa
1570 LET N=(aaa/100)
1580 PRINT
1590 PRINT "South"
1592 INPUT bbb
1600 LET O=(bbb/100)
1610 PRINT
1620 PRINT "East"
1625 INPUT ccc
1630 LET P=(ccc/100)
1640 PRINT
1650 PRINT "West"
1655 INPUT ddd
1660 LET Q=(ddd/100)
1670 PRINT
1680 PRINT
1690 PRINT "Check data entered c
orrectly"
1700 PRINT
1710 PRINT
1720 PRINT "North  = ";N
1730 PRINT "South  = ";O
1740 PRINT "East   = ";P
1750 PRINT "West   = ";Q
1760 PAUSE 250
1770 CLS
1780 LET R=INT (((1/.0153)*(N*10
00))/xxx+.5)
1790 LET S=INT (((1/.0153)*(O*10
00))/xxx+.5)
1800 LET T=INT (((1/.0153)*(P*10
00))/xxx+.5)
1810 LET U=INT (((1/.0153)*(Q*10
00))/xxx +.5)
1820 LET EEE=R+S+T+U
1830 LET NNN=INT ((VV/100)*EEE)+
.5
1840 LET OOO=INT ((WW/100)*EEE)+
```

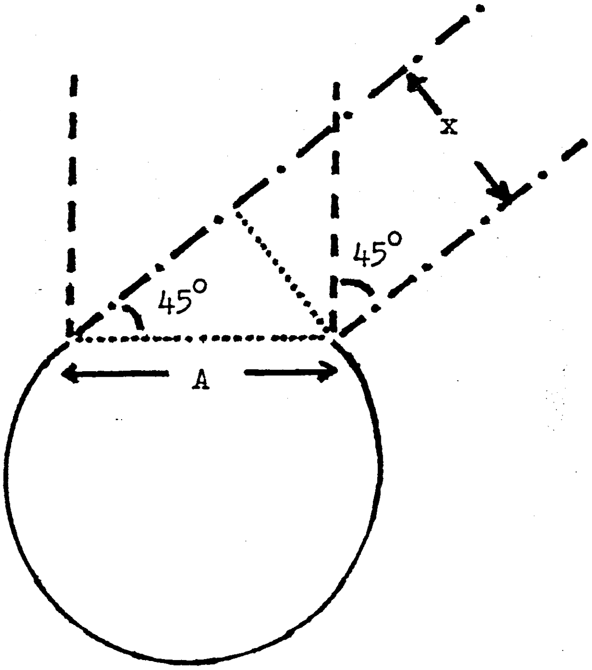


```
.5
1850 LET PPP=INT ((XX/100)*EEE)+
.5
1860 LET QQQ=INT ((YY/100)*EEE)+
.5
1870 LET FFF=R-NNN
1880 LET GGG=S-OOO
1890 LET HHH=T-PPP
1900 LET III=U-QQQ
1902 PRINT
1903 PRINT
1910 PRINT "Directional dust gau
ge"
1912 PRINT "results for"
1920 PRINT G$
1930 PRINT
1935 PRINT
1940 PRINT "Monitoring period wa
s"
1950 PRINT H$;" 1983"
1960 PRINT
1961 PRINT
1962 PRINT "Data processed by"
1964 PRINT X$
1966 PRINT
1967 PRINT
1970 PRINT "Length of monitoring
 period = "
1972 PRINT xxx;" days"
1980 PAUSE 100
1985 COPY
1986 CLS
2000 PRINT "Predicted % distribu
tion"
2010 PRINT "of dust based on win
d"
2020 PRINT "directions and wind
speeds"
2030 PRINT "during the monitorin
g period"
2040 PRINT "is :-"
2050 PRINT
2060 PRINT "NORTH ";VV
2070 PRINT "SOUTH ";WW
2080 PRINT "EAST  ";XX
2090 PRINT "WEST  ";YY
3000 PRINT
3010 PRINT
3022 LET TTT=INT ((R*100)/EEE)+.
5
3023 LET UUU=INT ((S*100)/EEE)+.
5
3024 LET VVV=INT ((T*100)/EEE)+.
5
3025 LET WWW=INT ((U*100)/EEE)+.
5
3030 PRINT "Actual % distributio
n of"
3040 PRINT "dust collected in ga
uge is :-"
3050 PRINT
3060 PRINT "NORTH   ";TTT
3070 PRINT "SOUTH   ";UUU
3080 PRINT "EAST    ";VVV
3090 PRINT "WEST    ";WWW
4000 PAUSE 100
4010 COPY
4020 CLS
4030 PRINT "Percentage differenc
e is :-"
4040 PRINT
4050 LET AAA=TTT-VV
4060 LET BBB=UUU-WW
4070 LET CCC=VVV-XX
4080 LET DDD=WWW-YY
4090 PRINT "NORTH   ";AAA
4100 PRINT "SOUTH   ";BBB
4110 PRINT "EAST    ";CCC
4120 PRINT "WEST    ";DDD
4130 PRINT
4150 PRINT
4160 PRINT "Predicted dust depos
ition"
```



```
4170 PRINT "(mg./sq.m./day) is:-
"
4180 PRINT
4190 PRINT "NORTH  ";NNN
4200 PRINT "SOUTH  ";OOO
4210 PRINT "EAST   ";PPP
4220 PRINT "WEST   ";QQQ
4230 PAUSE 100
4240 COPY
4250 CLS
4260 PRINT "Actual deposited amo
unts ="
4270 PRINT
4280 PRINT "NORTH  ";R
4290 PRINT "SOUTH  ";S
4300 PRINT "EAST   ";T
4310 PRINT "WEST   ";U
4320 PRINT
4340 PRINT
4350 PRINT "Difference between p
redicted"
4360 PRINT "and actual at :-"
4370 PRINT
4380 PRINT "NORTH  ";FFF
4390 PRINT "SOUTH  ";GGG
4400 PRINT "EAST   ";HHH
4410 PRINT "WEST   ";III
4420 PRINT
4430 PRINT
4440 PRINT "+ amounts indicate d
irection"
4450 PRINT "of a dust source fro
m"
4460 PRINT "the gauge"
4461 PAUSE 250
4462 COPY
4463 CLS
4465 GO TO 645
4470 COPY
```

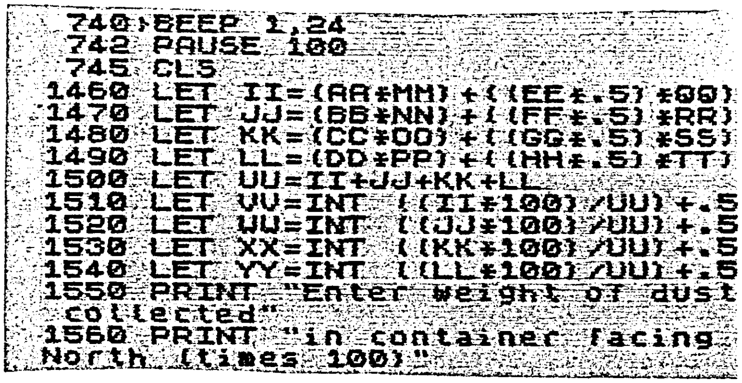
FIG. 10 . AVAILABLE SLIT WIDTH OF ADJACENT COLLECTING HEADS WHEN WIND FROM A HALF COMPASS POINT.



$$\frac{x}{A} = \sin 45^\circ = \frac{1}{\sqrt{2}} = 0.71$$

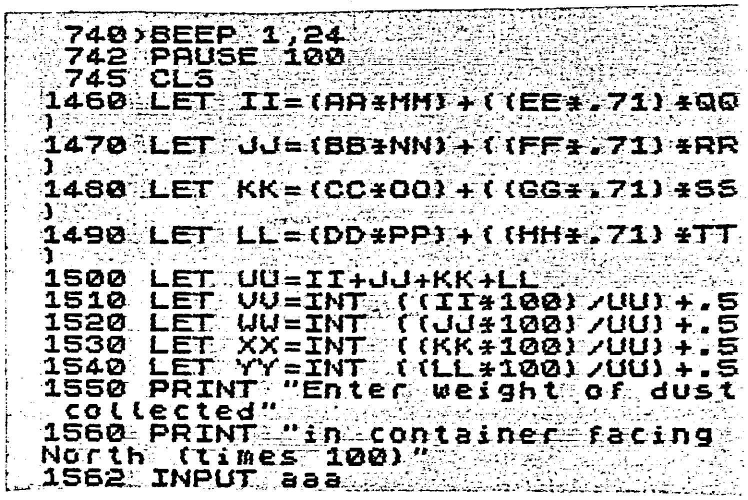
PROG. 2 . AMENDMENT OF PROGRAMME FOR GAUGE CONFIGURATION.

a. Initial



```
 740>BEEP 1,24
 742 PAUSE 100
 745 CLS
1460 LET II=(AA*MM)+((EE*.5)*QQ)
1470 LET JJ=(BB*NN)+((FF*.5)*RR)
1480 LET KK=(CC*OO)+((GG*.5)*SS)
1490 LET LL=(DD*PP)+((HH*.5)*TT)
1500 LET UU=II+JJ+KK+LL
1510 LET VV=INT ((II*100)/UU)+.5
1520 LET WW=INT ((JJ*100)/UU)+.5
1530 LET XX=INT ((KK*100)/UU)+.5
1540 LET YY=INT ((LL*100)/UU)+.5
1550 PRINT "Enter weight of dust
 collected"
1560 PRINT "in container facing
North (times 100)"
```

b. Amended.



```
 740>BEEP 1,24
 742 PAUSE 100
 745 CLS
1460 LET II=(AA*MM)+((EE*.71)*QQ
)
1470 LET JJ=(BB*NN)+((FF*.71)*RR
)
1480 LET KK=(CC*OO)+((GG*.71)*SS
)
1490 LET LL=(DD*PP)+((HH*.71)*TT
)
1500 LET UU=II+JJ+KK+LL
1510 LET VV=INT ((II*100)/UU)+.5
1520 LET WW=INT ((JJ*100)/UU)+.5
1530 LET XX=INT ((KK*100)/UU)+.5
1540 LET YY=INT ((LL*100)/UU)+.5
1550 PRINT "Enter weight of dust
 collected"
1560 PRINT "in container facing
North (times 100)"
1562 INPUT aaa
```

(iv) Refinement of Wind Speed and Direction Input

Lancaster[73] had suggested that the performance of his proposed model would be improved by considering wind directions every hour rather than every twelve hours. The meteorological data that had been applied to the developing model had been obtained from the British Coke Research Association Laboratories, Wingerworth, Chesterfield. This had consisted of daily average wind directions and mean wind speeds. In December, 1982, the laboratories closed and an alternative supply of meterological data was obtained from the Meteorological Office, Watnall, Nottingham.

Although this source was further away (approximately 20 miles), it was decided to develop the model to allow the input of this data which consisted of average six hourly wind directions and wind speeds.

The wind direction data was presented in ten degree divisions of compass point bearing and the programme had to be altered to allow its input.

By a further investigation of the cross sectional configuration of the gauge, the available slit widths of one or more collecting heads at any given wind bearing, were calculated and the weighting factors for the collecting heads are shown in Table 27.

The alterations to the programme are shown in Prog. 3 and the additional and changed defined and programme variables are as follows:-

AA, AB, AC .... BJ

= number of $\frac{1}{4}$ days wind from identified wind bearing multiplied by average wind speed.

TABLE 26. SLIT WIDTHS FOR DIFFERENT COMPASS BEARINGS.

Wind Direction (degress)	Available Slit Width, 50 units max. NORTH	EAST	SOUTH	WEST
0	50.00	-	-	-
10	49.24	8.68	-	-
20	46.98	17.10	-	-
30	43.30	25.00	-	-
40	38.30	32.14	-	-
50	32.14	38.30	-	-
60	25.00	43.30	-	-
70	17.10	46.98	-	-
80	8.68	49.24	-	-
90	-	50.00	-	-
100	-	49.24	8.68	-
110	-	46.98	17.10	-
120	-	43.30	25.00	-
130	-	38.30	32.14	-
140	-	32.14	38.30	-
150	-	25.00	43.30	-
160	-	17.10	46.98	-
170	-	8.68	49.24	-
180	-	-	50.00	-
190	-	-	49.24	8.68
200	-	-	46.98	17.10
210	-	-	43.30	25.00
220	-	-	38.30	32.14
230	-	-	32.14	38.30
240	-	-	25.00	43.30
250	-	-	17.10	46.98
260	-	-	8.68	49.24
270	-	-	-	50.00
280	8.68	-	-	49.24
290	17.10	-	-	46.98
300	25.00	-	-	43.30
310	32.14	-	-	38.30
320	38.30	-	-	32.14
330	43.30	-	-	25.00
340	46.98	-	-	17.10
350	49.24	-	-	8.68

PROG. 3 . AMENDMENT FOR REFINED WIND DIRECTION INPUT.

```
 260 PRINT "Enter column(C) for
0 degrees"
 261 INPUT AA
 265 PRINT "10 o"
 266 INPUT AB
 270 PRINT "20 o"
 271 INPUT AC
 275 PRINT "30 o"
 276 INPUT AD
 280 PRINT "40 o"
 281 INPUT AE
 285 PRINT "50 o"
 286 INPUT AF
 290 PRINT "60 o"
 291 INPUT AG
 295 PRINT "70 o"
 296 INPUT AH
 300 PRINT "80 o"
 301 INPUT AI
 305 PRINT "90 o"
 306 INPUT AJ
 310 PRINT "100 o"
 311 INPUT AK
 315 PRINT "110 o"
 316 INPUT AL
 320 PRINT "120 o"
 321 INPUT AM
 325 PRINT "130 o"
 326 INPUT AN
 330 PRINT "140 o"
 331 INPUT AO
 335 PRINT "150 o"
 336 INPUT AP
 340 PRINT "160 o"
 341 INPUT AQ
 345 PRINT "170 o"
 346 INPUT AR
 350 PRINT "180 o"
 351 INPUT AS
 352 CLS
 355 PRINT "190 o"
 356 INPUT AT
 360 PRINT "200 o"
 361 INPUT AU
 365 PRINT "210 o"
 366 INPUT AV
 370 PRINT "220 o"
 371 INPUT AW
 375 PRINT "230 o"
 376 INPUT AX
 380 PRINT "240 o"
 381 INPUT AY
 385 PRINT "250 o"
 386 INPUT AZ
 390 PRINT "260 o"
 391 INPUT BA
 395 PRINT "270 o"
 396 INPUT BB
 400 PRINT "260 o"
 401 INPUT BC
 405 PRINT "290 o"
 406 INPUT BD
 410 PRINT "300 o"
 411 INPUT BE
 415 PRINT "310 o"
 416 INPUT BF
 420 PRINT "320 o"
 421 INPUT BG
 425 PRINT "330 o"
 426 INPUT BH
 430 PRINT "340 o"
 431 INPUT BI
 435 PRINT "350 o"
 436 INPUT BJ
```

PROG. 3 . <u>continued</u>.

```
 440 LET BK=(AA*50)+(AB*49.24)+(
AC*46.98)+(AD*43.3)+(AE*38.3)+(A
F*32.14)+(AG*25)+(AH*17.1)+(AI*8
.68)+(BC*8.68)+(BD*17.1)+(BE*25)
+(BF*32.14)+(BG*38.3)+(BH*43.3)+
(BI*46.98)+(BJ*49.24)
 441 LET BL=(AJ*50)+(AK*49.24)+(
AL*46.98)+(AM*43.3)+(AN*38.3)+(A
O*32.14)+(AP*25)+(AQ*17.1)+(AR*8
.68)+(AB*8.68)+(AC*17.1)+(AD*25)
+(AE*32.14)+(AF*38.3)+(AG*43.3)+
(AH*49.98)+(AI*49.24)
 445 LET BM=(AK*8.68)+(AL*17.1)+
(AM*25)+(AN*32.14)+(AO*38.3)+(AP
*43.3)+(AQ*46.98)+(AR*49.24)+(AS
*50)+(AT*49.24)+(AU*46.98)+(AV*4
3.3)+(AW*38.3)+(AX*32.14)+(AY*25
)+(AZ*17.1)+(BA*8.68)
 446 LET BN=(AT*8.68)+(AU*17.1)+
(AV*25)+(AW*32.14)+(AX*38.3)+(AY
*43.3)+(AZ*46.98)+(BA*49.24)+(BB
*50)+(BC*49.24)+(BD*46.98)+(BE*4
3.3)+(BF*38.3)+(BG*32.14)+(BH*25
)+(BI*17.1)+(BJ*8.68)
 450 LET BO=BK+BL+BM+BN
 455 LET BP=INT ((BK/BO)*100)+.5
 456 LET BQ=INT ((BL/BO)*100)+.5
 457 LET BR=INT ((BM/BO)*100)+.5
 458 LET BS=INT ((BN/BO)*100)+.5
 459 CLS
```

BK = Weighting factor, north

BL = " east

BM = " south

BN = " west

BO = Sum of weighting factors

BP = % of weighting factor, north

BQ = " east

BR = " south

BS = " west

(g) PERFORMANCE OF THE DEVELOPING MODEL

Data from two directional dust gauges situated at the boundary of the Lings opencast coal extraction site were used to assess the performance of the developing model. The gauges selected were Lings One and Lings Seven, see fig. 11.

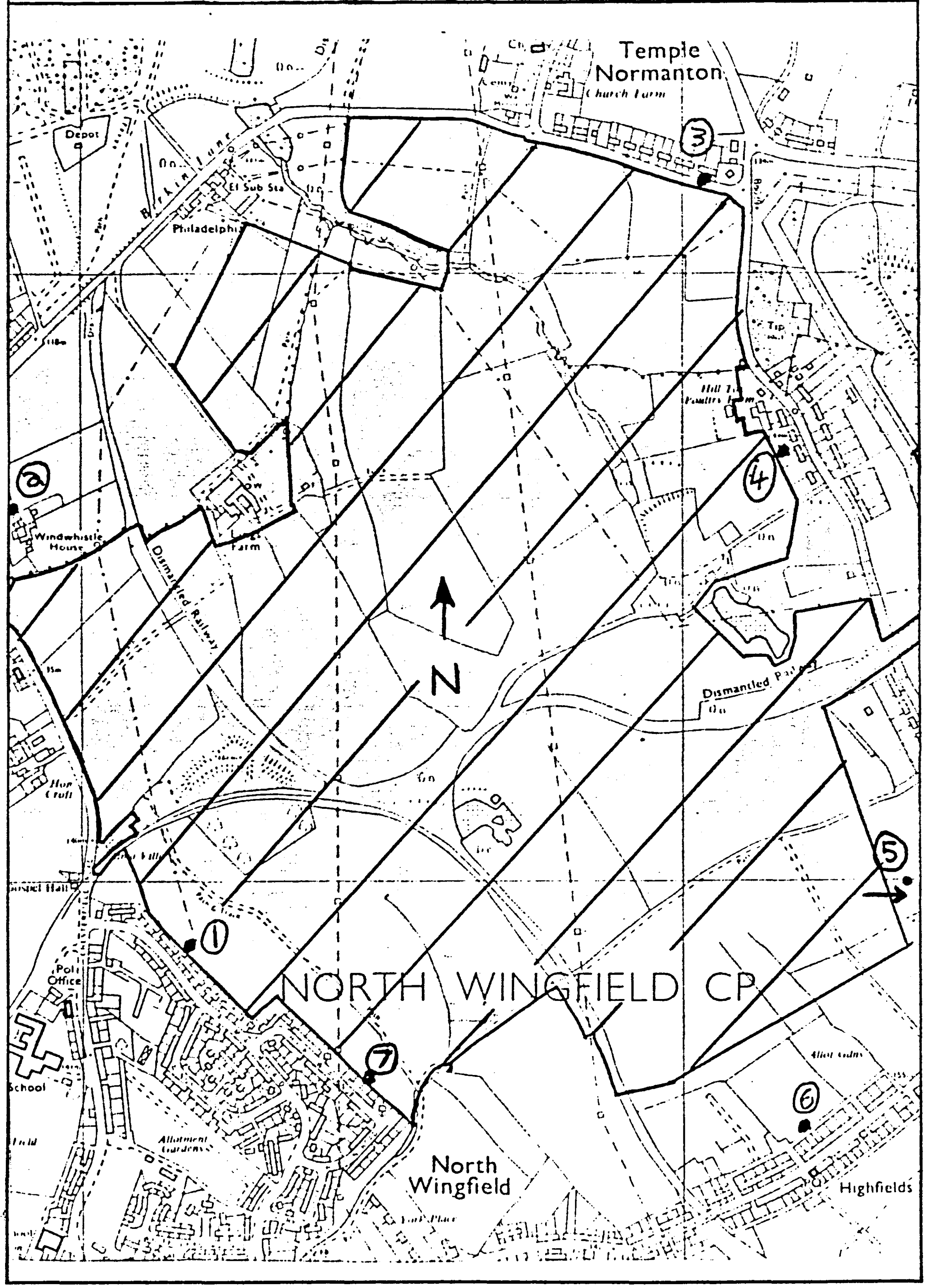
The following six stages of the developing model were applied to the amounts of dust collected by the gauges.

a. Available slit widths for winds from half compass points = 0.5 and average wind speeds for full and half compass points were ascribed a value of one.

b. Same as in a., but average wind speeds from the Meteorological Stations were used.

c. Available slit widths for winds from half compass points = 0.71 and average wind speeds for full and half compass points were ascribed a value of one.

FIG. 11 . DIRECTIONAL DUST GAUGE MONITORING STATIONS AROUND THE LINGS OPENCAST SITE.



d. Same as in c., but average wind speeds from the Meteorological Stations were used.

e. Varying slit width availabilities for winds in 10° divisions of compass point bearing, all average wind speeds ascribed a value of one.

f. Same as in e., but average wind speeds from the Meteorological Stations were used.

The differences between actual and predicted depositions for the six stages of the developing model at these gauge sites for November and December 1982, are shown on Table 28.

For Lings One and Seven, the directions of open cast coal extraction workings were, for both gauges, to the north and east.

The amounts of material collected by these two gauges give little indication of directions of dust sources (see Table 29). Without the application of the model it would be difficult to assess the dust climate and the environmental impact of these workings.

To enable an assessment of the developing model to be made the cumulative differences between actual and predicted depositions of dust (north and east) at the two sites for November and December 1982 were calculated. They are shown on Table 30.

The highest cumulative dust deposition using data from Watnall was obtained using stage b., and for data from Sheffield was stage f. By combining the cumulative dust depositions obtained using the Watnall and Sheffield data, stage f. produced the highest cumulative dust deposition.

TABLE- 28. PERFORMANCE OF THE DEVELOPING MODEL.

Site	Stage of developing model.	Difference between actual and predicted depositions (Actual - Predicted). mg.m^{-2}.day^{-1}			
		North	South	East	West
		* '	* '	* '	* '
Lings One Nov. 1982	a.	11.5 (21.5)	-20.5 (-27.5)	45.5 (53.5)	-35.5 (-48.5)
	b.	19.5 (25.5)	-27.5 (-22.5)	57.5 (64.5)	-52.5 (-70.5)
	c.	11.5 (23.5)	-20.5 (-31.5)	43.5 (51.5)	-33.5 (-43.5)
	d.	19.5 (25.5)	-27.5 (-24.5)	55.5 (64.5)	-48.5 (-65.5)
	e.	19.5 (25.5)	-27.5 (-24.5)	45.5 (45.5)	-37.5 (-46.5)
	f.	23.5 (34.5)	-31.5 (-27.5)	51.5 (60.5)	-43.5 (-67.5)
Lings Seven Nov. 1982	a.	21.5 (26.5)	-9.5 (-23.5)	-2.5 (21.5)	-8.5 (-24.5)
	b.	24.5 (29.5)	-21.5 (-20.5)	22.5 (29.5)	-25.5 (-40.5)
	c.	19.5 (27.6)	-11.5 (-26.5)	-0.5 (19.5)	-8.5 (-21.5)
	d.	24.5 (29.5)	-21.5 (-21.5)	21.5 (29.5)	-24.5 (-37.5)
	e.	24.5 (29.5)	-22.5 (-21.5)	15.5 (15.5)	-17.5 (-23.5)
	f.	27.5 (36.5)	-25.5 (-23.5)	19.5 (26.5)	-21.5 (-39.5)
Lings One Dec. 1982	a.	40.5 (17.5)	-0.5 (-20.5)	44.5 (38.5)	-81.5 (-35.5)
	b.	44.5 (20.5)	-12.5 (-26.5)	46.5 (38.5)	-76.5 (-33.5)
	c.	38.5 (18.5)	-6.5 (-20.5)	42.5 (38.5)	-74.5 (-35.5)
	d.	42.5 (20.5)	-15.5 (-24.5)	44.5 (36.5)	-70.5 (-35.5)
	e.	36.5 (26.5)	-19.5 (-20.5)	42.5 (40.5)	-59.5 (-47.5)
	f.	40.5 (33.5)	-25.5 (-33.5)	44.5 (38.5)	-59.5 (-36.5)
Lings Seven Dec. 1982	a.	41.5 (20.5)	-18.5 (-35.5)	67.5 (62.5)	-88.5 (-47.5)
	b.	44.5 (23.5)	-28.5 (-39.5)	69.5 (62.5)	-83.5 (-46.5)
	c.	39.5 (21.5)	-23.5 (-35.5)	65.5 (62.5)	-82.5 (-47.5)
	d.	42.5 (23.5)	-31.5 (-38.5)	67.5 (60.5)	-78.5 (-47.5)
	e.	38.5 (28.5)	-34.5 (-35.5)	65.5 (64.5)	-69.5 (-58.5)
	f.	41.5 (34.5)	-39.5 (-46.5)	67.5 (62.5)	-69.5 (-49.5)

* Watnall meteorological data

' Sheffield meteorological data

TABLE 29. AMOUNTS OF DEPOSITED MATTER IN THE LINGS ONE AND SEVEN DIRECTIONAL DUST GAUGES.

Site	Month/Year	Deposited Matter (g)			
		North	South	East	West
Lings One	Nov/1982	0.02	0.03	0.04	0.02
Lings Seven	Nov/1982	0.02	0.02	0.02	0.02
Lings One	Dec/1982	0.02	0.02	0.02	0.02
Lings Seven	Dec/1982	0.02	0.01	0.03	0.01

N.B. Direction of workings for both gauges were to the north and east.

TABLE 30. CUMULATIVE DIFFERENCES IN DUST DEPOSITION.

Stage of developing model.	Cumulative difference ($mg.m^{-2}.day^{-1}$) *	'	Total (*+')
a	270	262	532
b	329	294	623
c	260	263	523
d	318	290	608
e	288	276	564
f	316	327	643

* Watnall weather data.

' Sheffield weather data.

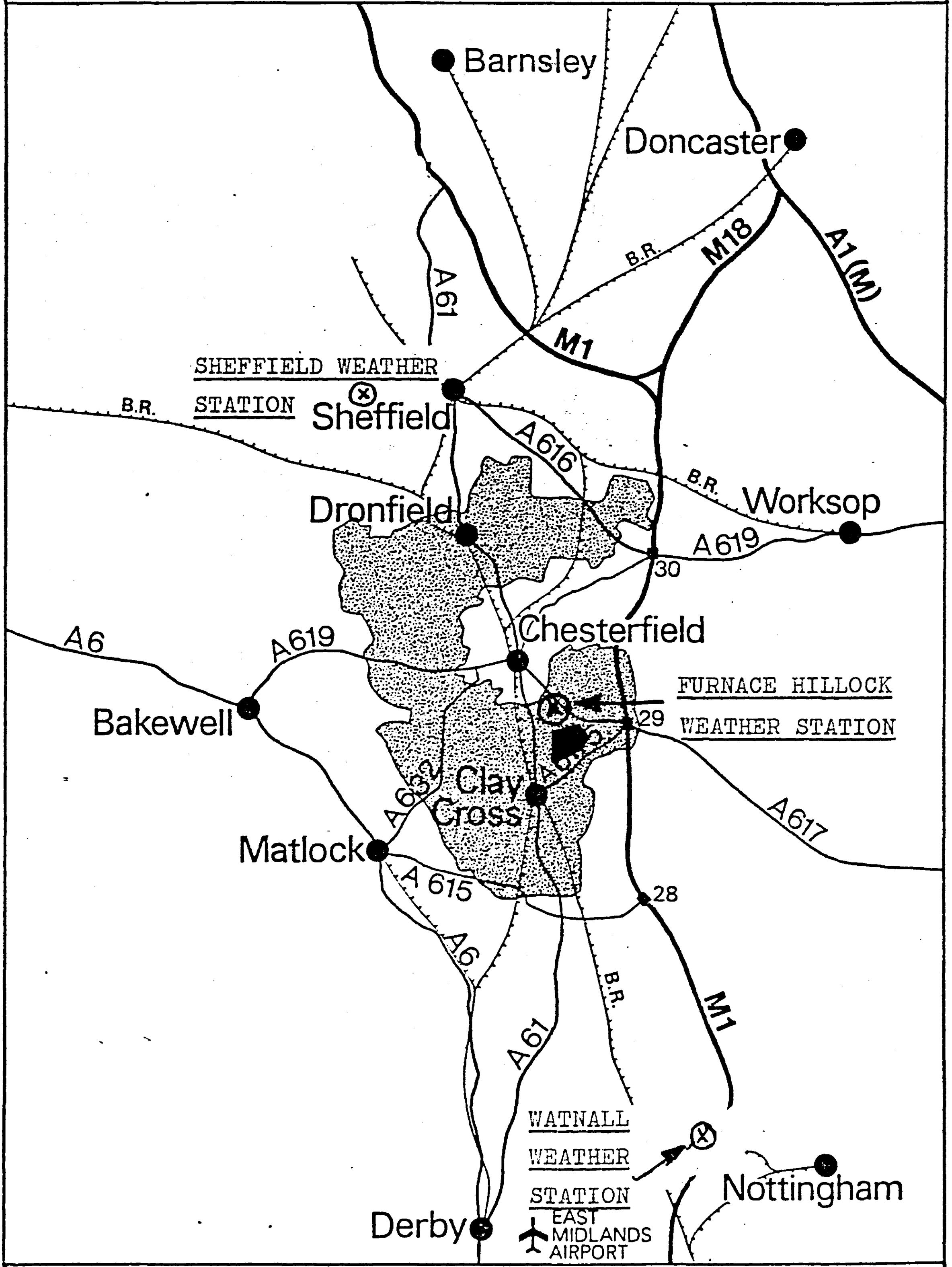
The significance of this conclusion may be further investigated by carrying out similar calculations for more monitoring stations over a longer time period. However, it is valid to expect that by refining the input data to the model that a more accurate assessment of the dust climate may be made (given that there are relationships between wind and speed and dust deposition, wind direction and direction of dust source, and wind direction and vertical collection area of the gauge tube), although the enhancement achieved by successive model refinements decreases, particularly after stage b. when an attempt was made to introduce realistic wind speeds.

(h) LOCALISED AUTOMATIC WEATHER STATION DATA

The model which was applied to amounts of collected dust in directional dust gauges used data obtained from remote weather stations. Commencing November 1983 data became available from an automatic weather station located at the Furnace Hillock Opencase Site (see Fig. 12). The instruments at this station provide hourly integrated measurements of wind speed and wind direction.

To investigate the effect of using localised weather data instead of data from remote stations, several sets of results were recalculated using the automatic weather station data. The results are shown on Table 31. It was not possible to recalculate all the results because of frequent malfunctions with instrumentation at the Furnace Hillock station which produced incomplete monthly data sets.

FIG. 12. LOCATION OF WEATHER STATIONS.



▨ N.E.D.D.C. AREA

■ LINGS OPENCAST SITE

TABLE 31. RECALCULATED RESULTS USING AUTOMATIC WEATHER STATION DATA.

Month Year	Site	Difference between actual and predicted depositions (mg.m^{-2}.day^{-1}).							
		North		South		East		West	
		*	'	*	'	*	'	*	'
Nov.	Lings 1	18.5	(11.5)	8.5	(7.5)	4.5	(-5.5)	30.5	(-14.5)
1983	Lings 2	6.5	(1.5)	-0.5	(-1.5)	8.5	(2.5)	-14.5	(-3.5)
	Lings 3	15.5	(1.5)	-5.5	(-8.5)	24.5	(3.5)	31.5	(1.5)
	Lings 4	12.5	(3.5)	-0.5	(-2.5)	17.5	(5.5)	-28.5	(-7.5)
	Lings 5	15.5	(7.5)	3.5	(2.5)	2.5	(-9.5)	-20.5	(-2.5)
	Lings 6	6.5	(1.5)	-0.5	(-1.5)	8.5	(2.5)	-14.5	(-3.5)
	Lings 7	18.5	(11.5)	-9.5	(-10.5)	22.5	(12.5)	-30.5	(-14.5)
	F. Hill.	59.5	(14.5)	-17.5	(-25.5)	97.5	(30.5)	-131.5	(-27.5)
Jan.	Lings 1	-20.5	(51.5)	49.5	(-53.5)	112.5	(83.5)	-142.5	(-82.5)
1984	Lings 2	-11.5	(31.5)	41.5	(-18.5)	56.5	(39.5)	-87.5	(-52.5)
	Lings 3	-246.5	(155.5)	615.5	(47.5)	123.5	(-42.5)	-492.5	(-160.5)
	Lings 4	-60.5	(60.5)	203.5	(32.5)	54.5	(4.5)	-197.5	(-97.5)
	Lings 5	-11.5	(102.5)	129.5	(-31.5)	111.5	(64.5)	-229.5	(-135.5)
	Lings 7	23.5	(92.5)	31.5	(-65.5)	74.5	(46.5)	-130.5	(-73.5)
	F. Hill.	75.5	(24.5)	-56.5	(-65.5)	146.5	(68.5)	-156.5	(-35.5)
Sept.	Lings 1	-50.5	(-35.5)	20.5	(3.5)	9.5	(20.5)	20.5	(13.5)
1984	Lings 2	-36.5	(-13.5)	57.5	(32.5)	52.5	(68.5)	-73.5	(-83.5)
	Lings 4	-76.5	(-51.5)	75.5	(46.5)	24.5	(42.5)	-23.5	(-34.5)
	Lings 5	-27.5	(-7.5)	36.5	(13.5)	29.5	(43.5)	-38.5	(-47.5)
	Lings 7	-18.5	(-4.5)	23.5	(8.5)	35.5	(45.5)	-41.5	(-47.5)
	F. Hill.	-334.5	(-213.5)	411.5	(271.5)	273.5	(360.5)	-350.5	(-402.5)
Oct.	Lings 1	6.5	(20.5)	14.5	(-23.5)	31.5	(30.5)	-52.5	(-28.5)
1984	Lings 2	20.5	(36.5)	11.5	(-30.5)	49.5	(47.5)	-81.5	(-54.5)
	Lings 4	-117.5	(-25.5)	308.5	(60.5)	101.5	(91.5)	-293.5	(-135.5)
	Lings 5	2.5	(26.5)	35.5	(-31.5)	46.5	(44.5)	-84.5	(-41.5)
	Lings 6	6.5	(20.5)	14.5	(-23.5)	49.5	(48.5)	-70.5	(-46.5)
	F. Hill.	75.5	(6.5)	-56.5	(-56.5)	146.5	(77.5)	-156.5	(-27.5)

* Furnace Hillock weather data.

' Remote weather data.

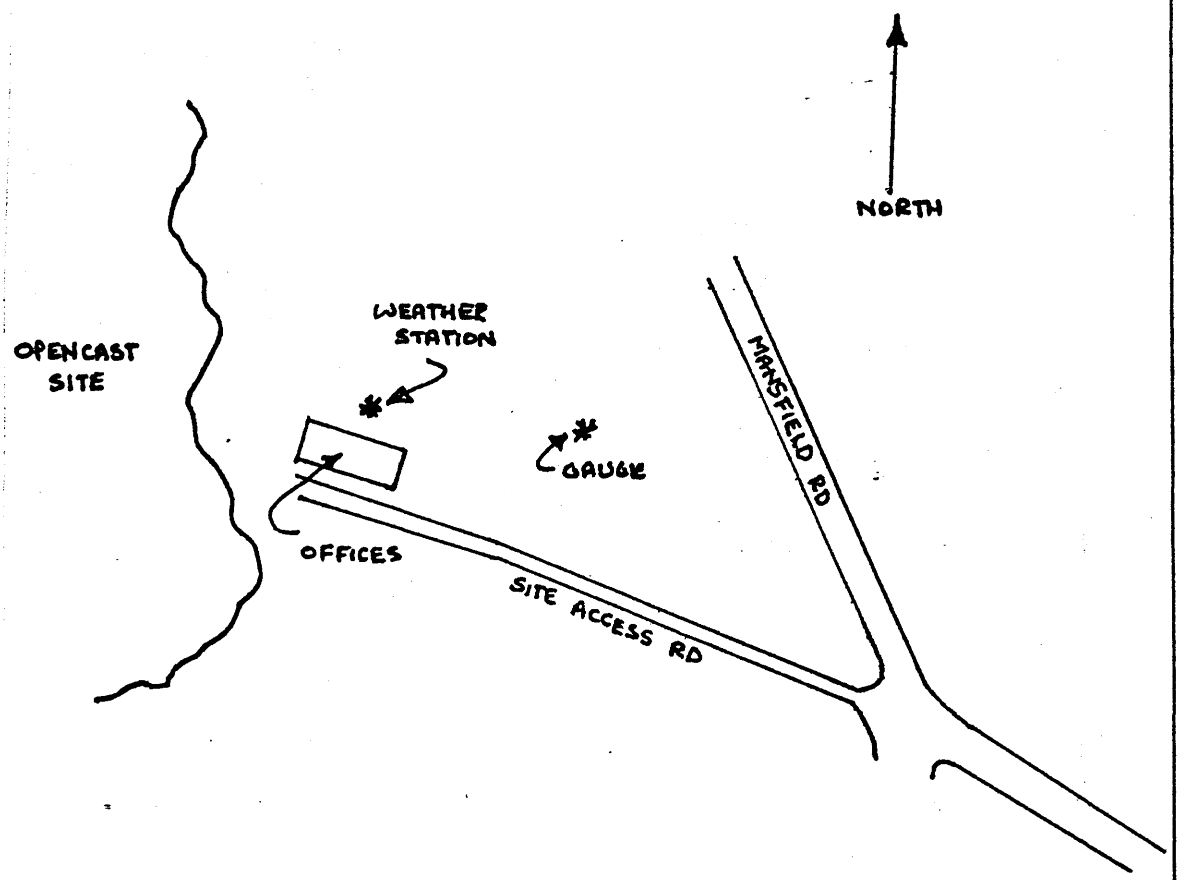
One interesting set of results was obtained from a directional dust gauge located near the automatic weather station at Furnace Hillock. The direction of the opencast site workings from the gauge was to the west and this was assumed to be the predominant dust source. The computer model however indicated that there were significant dust sources to the north, south, and east. To the north and east of the gauge, is the main Chesterfield to Mansfield Road which in addition to normal vehicular traffic is also used by large coal lorries using the site. To the south is the main access road the site (see Fig. 13). It may be concluded that dust generated by vehicles using the Mansfield Road and site access road area, over the monthly monitoring period, was at higher levels than the open cast coal extraction workings.

The two sets of computed results for the Furnace Hillock and Lings Opencast Site directional dust gauges using remote and localised weather data were compared. The model tended to under estimate the increased dust deposition amounts when using remote weather station data. However, the model did indicate similar directions of dust sources when the two sets of weather data were used.

(i) DIRECTIONAL DUST GAUGE MONITORING AND MODELLING IN NORTH EAST DERBYSHIRE

There are many diverse sources of dust which from time to time affect local inhabitants within North East Derbyshire. The installation of directional dust gauges and the application of the model to collected amounts of dust will provide a technique for the identification of dust sources. The main application of this proposed monitoring and modelling technique will be to monitor the environmental impact of open cast coal extraction.

FIG. 13. FURNACE HILLOCK OPENCAST SITE.



This technique will not indicate whether or not a dust nuisance is being caused as the monthly sampling period integrates total amounts of collected dust. For example, if the total amount of dust collected over one month occurred during one day, the potential for nuisance would be higher than if it accumulated gradually over the monthly period.

Experience gained during this part of the research project would suggest that the following criteria should be satisfied when using this technique.

a. The directional dust gauge will only provide information about the dust climate at the position at which it is located. They should, therefore, be sited as close as possible to houses (or other dust sensitive premises), without prejudicing other criteria outlined below.

b. Care should be taken in the siting of the gauges to provide open elevations in all directions to allow contributions from other potential dust sources other than those which are suspected.

c. Where there is a choice of weather station data for use with the model, localised rather than remote should be used. If this is not possible, mean data from two or more remote stations should be used.

d. The directional dust gauge site should, as far as is practicable, be tamper-proof. Large private gardens and school playing fields make ideal sites.

4. SMOKE AND SULPHUR DIOXIDE POLLUTION MONITORING BEHAVIOUR AND MODELLING IN THE N.E.D.D.C. AREA

(a) THE NATURE OF THE AIR ENVIRONMENT

The air is a layer of gases which reaches from the earth's surface to the beginning of space. Most important to life is the troposphere which varies between five and ten miles in depth, above the earth's surface. This layer and the earth's outer crust is usually defined as the biosphere. In this thin finite layer, life exists. It comprises of nitrogen and oxygen (a ratio of approximately 4:1), about 300 p.p.m. carbon dioxide and small amounts of other gases. Before green plants evolved the ratio of oxygen to carbon dioxide was essentially reversed. Organisms which thrived in a low oxygen environment slowly disappeared as the ratio of oxygen: carbon dioxide gradually evolved to what it currently is. Oxygen, which now drives most biological systems, was an air pollutant several million years ago.

In the habitat of terrestrial biological systems, the temperature changes continuously. In the lower, denser, atmosphere air temperature falls with rising altitudes. The rate of change depends on water vapour content and short period gain or loss of thermal energy at all altitudes.

Climatic systems are driven by nuclear generated radiant energy from the sun. The atmosphere directly absorbs about 15% of the energy received from the sun, 42% reflects back into space and 43% is absorbed by the earth's surface. The surface converts short wave light energy to long wave heat energy. The long wave heat energy warms the troposphere and mobilises it.

The earth rotates on its axis and orbits the sun, giving rise to turbulence which produces wind patterns. Linear speeds vary from about

7,800 km. hr^{-1} at the equator to zero at the poles. This motion moves the troposhere in six major zones, each with its prevailing wind motion or direction. The width of the zones varies with the season. Air masses can move independently of the motion of the earth's surface, if they move in unison a calm is produced, if the air moves in any other direction, wind is generated. In addition, large air masses move independently of one another; polar continental and maritime masses from northern and southern hemispheres, tropical continental and maritime masses from the equator. Solar energy received by the earth varies, causing changes in the dominance of the temperate latitudes by warm and cool air masses. This is perceived as alternate warm or cool weather, with occasional periods of stagnation producing drought or rainfall. Topography and the proximity of bodies of water can affect local climates.

The above discussion illustrates, in a very general way, how weather patterns are formed and allows a perception of how pollutants emitted into the troposphere might be dispersed and transported.

(b) INCREASE IN POLLUTION EMISSIONS

Pollution by oxides of sulphur and particulates is a problem that has been growing since the Industrial Revolution. Because of the use of fossil fuels to generate electricity, the quantities of oxides of sulphur emitted to atmosphere have increased several times in the last twenty to thirty years.

Oxides of sulphur and particulates are associated with health effects, especially various types of respiratory diseases, although the exact casual relationships are not fully understood.

Because it is expected that the demand for energy will continue to grow, and in this country especially, the demand is expected to be met by an increased burning of coal, it is important that atmospheric concentrations of the pollutants produced be carefully monitored. Because much of the increased emission will be from sources outside major centres of population e.g. coal fired power stations and at high level, sulphur compounds and particulates will affect atmospheric pollution levels not only on a local scale but also on a regional and global scale.

(c) SOURCES AND POLLUTION BEHAVIOUR

(i) Sources

Several global estimates of natural and man made sulphur emissions have been made by several researchers. These are shown on Table 32. Robinson and Robbins[75] estimate that fossil fuel combustion accounts 75 to 85 per cent of man made sulphur emissions, and industrial processes, such as iron and steel production, make up the residual. Natural emissions include those from volcanoes and biological decay; sea spray is not included in the estimates as most of it returns directly to the oceans. All of the estimates have large uncertainties, but it is interesting to note that the relevant contribution from man made sources have increased with the later study results.

Both natural and man made sources are distributed irregularly over the earth. The geographical distribution of man made sources corresponds closely to the degree of industrialisation in various regions of the world. Kellogg eg al.[78] estimate that 93.5 per cent of sulphur dioxide pollution is produced in the Northern Hemisphere,

TABLE 32. EMISSIONS OF SULPHUR INTO THE ATMOSPHERE (Tg S.yr^{-1})

Reference	Natural emissions.	Man-made emissions.	Percentage man-made of total.
Eriksson[76]	280	40	13
Junge[77]	230	40	15
Robinson and Robbins[75]	90	64	42
Kellog *et al*.[78]	92	50	35
Friend[79]	108	65	38
Granat *et al*.[80]	35	65	65

and the remaining 6.5 per cent in the Southern Hemisphere. Granat <u>et al</u>.[80] concluded that for north-western Europe, an area of about one per cent of the Earth's surface, accounted for an estimated 13 Tg $S.yr^{-1}$, approximately 20 per cent of the global total.

(ii) Pollution transport and diffusion

Pollutant behaviour is governed by the physical and chemical environment (e.g. wind speed, solar radiation, neighbouring chemical species). Turbulent diffusion, photo-oxidation, scavenging by precipitation, etc, define its pathway through the atmosphere. Much is known about individual processes, but the real difficulty lies in quantifying the composite pathway.

Pollutants are transported through the atmosphere by the mean wind, and mixed, or dispersed, by turbulent fluctuations in the wind. The vertical structure of the lower troposphere is important to pollutant transport. Wind speed increases with height as the effect of surface roughness diminishes. Thus, the higher a pollutant's effective injection height (stack height plus plume rise), the greater the transport wind speed it experiences. Atmospheric temperature decreases with height above the surface; however, the actual variation of temperature above the surface, at a given time and place, defines the stability of the atmosphere, and thus the amount of vertical mixing. Pollutants emitted into an unstable atmospheric layer are mixed throughout the layer; on the other hand, pollutants emitted into a stable atmospheric layer are mixed very little.

The structure of the near-surface layer experiences a diurnal variation which affects pollutant transport and diffusion.

At night, surface long-wave radiation cools the near surface air and causes the formation of a ground-based stable layer, or inversion. Pollutants emitted into this layer undergo little mixing or dilution, while those emitted above it may be slowly mixed through a large depth of the atmosphere above the ground based inversion without reaching the surface. In the morning, as solar radiation heats the surface and causes convective mixing, the stable layer is eroded and pollutants mix throughout progressively greater depths of the atmosphere, frequently up to one or two kilometres, depending on the time of year and meteorological conditions. The following night, the cycle is repeated - pollutants well-mixed from the previous day remain above the newly formed surface inversion, and new pollutants are injected into the lower stable layers. Although this description is rather simplistic, it does indicate the complexity of the atmospheric processes controlling pollutant behaviour and the difficulty in modelling these processes.

Pollutants can be transported over large distances under a variety of meteorological conditions. Plumes emitted into a stable atmosphere undergo little vertical or horizontal diffusion and can travel intact for several hundred kilometres before being dispersed. However, when emissions from diverse sources over a broad area accumulate in stable air associated with anti-cyclonic conditions of eastern North America or western Europe, the pollutants become well mixed by day-time convection, and are slowly transported in the southerly flows to the west of the high pressure centres, to affect areas several hundreds of kilometres across for days at a time.

(iii) Transformation

The chemistry of sulphur dioxide in the atmosphere is complex. There are many possible gas-phase reactions and reactions involving liquid droplets and solid particulates by which sulphur dioxide may be transformed into sulphate.

Reaction rates for gas-phase oxidation of sulphur dioxide range from a few tenths of a per cent to a few per cent per hour. For the western Europe summer, Eggleton and Cox[81] suggest values of 0.5 to 5% hour^{-1} in sunlight, depending on the degree of pollution of the atmosphere, with the lower figure relating to clean air. Calvert et al.[82] also found rates up to 4% hour^{-1} in sunny, summer, urban conditions. The most important mechanisms are those involving the oxidation of sulphur dioxide by other short lived pollutants which have been photochemically generated[81]. Because these reactions are dependent on solar radiation, their importance decreases significantly in winter and at night.

Although the liquid-phase oxidation of sulphur dioxide has been extensively studied, there is still considerable disagreement in the literature concerning the rates of reaction. Uncatalyzed oxidation is thought to be relatively unimportant in the atmosphere, compared with other possible liquid-phase reactions[83]. Catalysed oxidation in the presence of metals (e.g. iron, manganese) is important in urban plumes and perhaps urban fogs where their concentrations are sufficiently high, but probably not in cleaner, rural air. Liquid-phase oxidation involving the strong oxidising agents ozone and hydrogen peroxide may also be very important; however, reaction rates and atmospheric concentrations of these two substances are not well known.

The effect of atmospheric ammonia is to retard the increase in acidity of the solution resulting in further dissolution and liquid-phase oxidation of sulphur dioxide. It is also important in the final transformation of sulphuric acid to ammonium sulphate. Liquid-phase oxidation reactions are generally thought to be of comparable importance to the gas-phase reactions.

Measurements indicate the sulphur dioxide is both adsorbed and oxidised on the surface of solid particles. Carbon is believed to be a particularly effective surface. No unambiguous rate data is available and the importance of these reactions to the overall conversion of sulphur dioxide is difficult to assess.

(iv) Deposition

Pollutants are removed from the atmosphere by a number of deposition processes: during dry periods by sedimentation, surface adsorption and impaction; and during precipitation by a cloud and below cloud scavenging. The relative importance of these processes depends both on the climate of a region and on the physical and chemical properties of the specific compounds present. Deposition processes are relatively well understood and have been measured in the laboratory and under certain field conditions; however, modelling them realistically still poses considerable difficulty.

Direct surface uptake of sulphur dioxide is the most important dry removal process for atmospheric sulphur. Turbulent motions bring the gas in contact with the Earth's surface where it is adsorbed, dissolved or undergoes chemical reaction. The uptake may be limited either by the efficiency of the gas-phase transfer to the surface, or by the resistance imposed by the underlying surface. The oceans, other non-acid moist surfaces, some crops and forest species at certain growth stages are good sinks; whereas dry, snow-covered surfaces and acid soils, for example, are less efficient.

Dry deposition of sulphate particles is much less important than that of sulphur dioxide. Sulphate particles are predominantly in the sub-micrometre range, and their removal by gravitation sedimentation is slow. Scavenging by forests is thought to be an effective deposition mechanism, but little quantitative information is available.

Dry deposition measurements are difficult to make. Approaches being used include specialised micro-meteorological measurement techniques, chemical tracer experiments and plume budget studies. These various techniques give comparable results[34]; dry deposition typically accounts for the removal of atmospheric sulphur at rates up to a few per cent per hour.

Deposition by precipitation is the result of both in cloud and below cloud capture of sulphur dioxide and particulate sulphur. In cloud processes include sulphate particles serving as condensation nuclei, coagulation, and diffusional uptake of sulphur dioxide. Below cloud processes include interception of particles by falling drops and diffusional uptake of sulphur dioxide.

Wet deposition is much more easily measured than is dry deposition. Several precipitation chemistry networks exist in various parts of the world for the routine measurement of wet deposition. Sulphur deposition, usually in sulphate form, is determined from measurements of sulphate concentration in precipitation samples and precipitation amount. Typically, the removal rate of particulate sulphate is of the order of forty per cent per hour, and for sulphur dioxide, an order of magnitude less. The overall efficiency of wet removal depends on many factors: precipitation type, intensity, duration, frequency, the relative amounts of sulphur dioxide and sulphate present, and the size distribution of particulate sulphate.

Wet and dry deposition appear to be of comparable importance on an annual basis. Dry deposition is more important closer to source areas where concentrations are higher and tends to go on continually. Wet deposition occurs periodically. Garland and Branson[85] have estimated that, over the United Kingdom, the dry deposition of sulphur is approximately 2.3 times the wet deposition on an annual basis. Granat _et al._[80] found that the dry deposition rate over western Europe to be 0.7 to 1.4 times that of wet deposition. In regions where major emission sources are more distant, such as Scandanavia, Dovland _et al._[86] have shown that wet deposition is more important than dry. For southern Norway, in particular, where orographic precipitation contributes very significantly to the wet deposition, wet deposition is approximately 2.5 times the dry deposition.

(d) METHODS OF MONITORING SMOKE AND SULPHUR DIOXIDE

(i) Smoke

In general, it is not practicable to discriminate on the basis of either particle or size or chemical composition when assessing particulate matter for routine monitoring purposes. The characteristics of the sample are determined by the types of sources in the vicinity, the weather conditions, and sampling procedure adopted. The main methods in use are briefly described and discussed below.

a. Smoke measurement: O.E.C.D. filter soiling method

Air is drawn through a white filter paper, usually over periods of 24 h., and the darkness of the stain obtained measured by reflectometer. Reflectance values are converted to equivalent international smoke units, usually expressed in $\mu g.m^{-3}$. It involves a simple apparatus and is suitable for continous operation. It is widely used in Europe and the low intake velocity ensures that the samples are restricted to the respirable size range. It is often combined with sulphur dioxide measurement by acidimetric method. The results are influenced primarily by black material.

b. Smoke measurement: American Society for Testing and Materials filter soiling method

Similar to O.E.C.D. filter soiling method, but samples are collected on a filter paper tape which is moved on automatically to provide a series of stains over intervals of 2-6 h.[87]. The results usually assessed by transmittance, and expressed in coefficient of haze (COH) units[88]. Reflectance has sometimes been used expressing the results in reflectance units of dirt shade (RUDS)[89]. The flow rate is a little higher that in O.E.C.D. method but the sample is still effectively within respirable size range. It is used in U.S.A. and inter-relationships between COH units and RUDS have been investigaated[90]. It is suitable for continuous operation.

c. Determination of total suspended particulates, gravimetric high volume

Air is drawn through a glass fibre filter sheet, usually with a turbine blower, and the amount collected is determined by weighting under controlled temperature and humidity conditions. The most widely used instrument of this type is the high volume sampler[91], but instruments based on rotary pumps with a membrane rather than a glass fibre filter have been used[92]. It is widely used in U.S.A.. It is liable to collect particles well beyond the respiratory size range and this may bias results, particularly in dry, dusty locations. It is not very suitable for continuous operation and samples are commonly collected over 24 h. periods every sixth day. The samples are large enough for a wide range of chemical analyses.

d. Indirect determination of mass concentration: beta ray sampler

A series of samples are collected on a filter paper strip over selected periods (usually 30 min), and mass of material collected determined by attenuation of beta radiation from a built-in source[93]. The instrument is relatively expensive and is used for monitoring purposes mainly in the Federal Republic of Germany. It is valuable for studying short term variations in total suspended particulates.

e. Light scattering

Consists of direct determination of suspended particulate matter as aerosols by light scattering, either counting and sizing individual particles[94] or integrating light scattered from a given volume of air[95]. It is used to some extent in Japan for monitoring suspended particulate matter. It requires careful calibration and the results are not necessarily comparable with those from direct weighings.

f. Size selective sampling: modified cascade impactor

Particles entering the instrument are separated into several roughly size graded fractions by impaction. The amounts of material collected are determined by direct weighing[96]. This method is mainly applicable to the sampling of dusts in industrial environments.

g. Electrostatic precipitators

Particles are charged as they pass through metal tubes where a large potential gradient exists between the wall and a needle along centre. Particles are deposited on the wall and amounts determined by direct weighing[97]. It is not suitable for outdoor measurements, but useful in occupational environments.

h. Personal samplers

Air is drawn through small glass fibre filters using a battery operated pump. The instrument can be worn by individuals[98] and the particulates are assessed by weighing, or analysed for specific constituents. The method is applicable primarily to industrial environments to assess exposures in a series of working shifts. An elutriator can be added to exclude large particles.

When considering measurements of suspended particulate matter, it is essential to specify the method used and to recognise that results obtained in one set of circumstances will not necessarily be applicable to others. The main difficulty has arisen in attempts to apply findings based on smoke measurements that relate only to the dark coloured material characteristic of the incomplete combustion of coal or other hydrocarbon fuels, to situations involving total suspended particulates assessed more directly in terms of weight. Because the former have been used in much of the early epidemiological work and the latter are now used for monitoring purposes in many countries, some kind of conversion from one type of measurement to the other would be desirable, but there is no generaly applicable conversion factor. Comparative evaluation of the two methods has been undertaken[99, 100], but the results emphasize that they measure different qualities of the particulate matter and that they should not be compared with one another.

From a study in central London, Commins and Waller[101] showed that the additional material collected by the high volume sampler had little effect on smoke measurements and that for their particular series, the total suspended particulate results were approximately 100 $\mu g.m^{-3}$ higher than the corresponding smoke figures. Regression equations have been calculated for their series and have shown a large proportional difference between total particulate and smoke figures at low values, but relatively little difference at high values (more than 500 μg smoke.m^{-3}).

Because of the differing principles involving in the methods of determining amounts of smoke and total suspended particulates it may be concluded that the results obtained using one method are not comparable to those obtained using a different method.

(ii) Sulphur dioxide

Ambient atmospheric concentrations of sulphur dioxide have been determined for many years, throughout the the world, using several different techniques. The selection and evaluation of which method to use depends to a great extent on the objectives envisaged, which must include consideration of the concentration and range of levels to be measured. These objectives will determine the demands to be made on the accuracy and specificity, the period of time during which measurement can be made, the overall time and facilities to be made available for analysis, and the desirability to automate the method. Quite often these factors are interdependent, for example, the need for greater specificity must involve a method of high complexity, and consequently be a determining factor in the facilities necessary. At times the only interest is to observe changes in air concentration levels when a simple method is quite adequate for this purpose.

If sulphur dioxide were the only air contaminant and providing the samples were of adequate size, each of the methods outlined below would give comparable results. In normal urban atmospheres, however, other pollutants are present and although the sampling procedure can be arranged to minimise interference from particulate matter by filtering air first, errors can still arise due to the presence of various gases and vapours. The main methods used are briefly outlined below.

a. Pararosaniline method[102]

Sulphur dioxide is absorbed into a solution of potassium tetrachl-oromercurate (TCM) and the complex formed reacts with pararosaniline and formaldehyde to produce a red-purple colour which is assessed colorimetrically. It is suitable for sampling periods ranging from 30 min to 24 h; and the samples should be analysed soon after collection. It is specific for sulphur dioxide and possible interference from oxides of nitrogen and some metals can be eliminated[103]. It is widely used in U.S.A. and the limit of detection of the method is $0.2 \mu g\ SO_2.10\ ml\ absorbent^{-1}$.

b. Acidimetric method

Sulphur dioxide is absorbed in dilute hydrogen peroxide solution and the sulphuric acid formed is titrated against a standard alkali. The apparatus is simple and is often combined with a smoke filter. It is suitable for sampling periods of 24 h., or less in some circumstances. It is used in the United Kingdom[104] and the limit of detection is $60\ \mu g.100\ ml\ absorbent^{-1}$.

c. Conductivity measurements

Sulphur dioxide is sampled in deionised water containing hydrogen peroxide where it is oxidised to sulphuric acid. The increase in conductivity is measured with a conductivity bridge[105]. The apparatus is simple and it is suitable for sampling periods of the order of 24 h. It usually incorporates a filter to remove particulate matter. It is less reliable than acidimetric method, and is not widely used in manual form. However, the measurement principle is often used in automatic instruments[106] and is applicable also to simple portable instruments for spot checks in urban or industrial environments[107], and to personal samplers for assessing occupational exposures[108]. The limit of detection is $20\ \mu g.50\ ml\ absorbent^{-1}$.

d. Detector tube measurements

Air is drawn through tubes containing an indicator which is sensitive to sulphur dioxide and the concentration is assessed from length of the stain[109]. They are portable and no power supply is required and are widely used for spot checks in occupational environments, or in other situations where the concentrations may be high (from about 3,000 $\mu g.m^{-3}$ upwards). There accuracy is typically ± 25%.

e. Iodine method

Sulphur dioxide is absorbed in a solution of iodine which is contained in a wash bottle with a fritted bubbler and solution is titrated with thiosulphate[110]. The method is applicable to occupational environments, but is not now widely used.

f. Flame Photometry

These instruments are particularly valuable for following short term variations in concentration, but the difficulties may occur in assessing average concentrations, unless the instrument is linked with data processing equipment. The instruments are expensive, and must be under the control of experienced operators.

Limits of detection vary, but are in the order of 15 $\mu g.m^{-3}$.

g. Sulphation rate

Sulphur compounds in the air react with an exposed cylinder or plate covered with a paste containing lead peroxide and lead sulphate is formed. The amount of sulphation is determined by precipitation with barium chloride[129]. The apparatus is simple and requires no power supply and the sampling period long (30 days). Results are expressed in $SO_3.100\ cm^{-2}.day^{-1}$, indicating the rate of reaction of sulphur compounds with surfaces.

(e) SMOKE AND SULPHUR DIOXIDE MONITORING IN THE N.E.D.D.C. AREA

(i) Historical

A publication entitled "The Measurement of Air Pollution", (H.M.S.O., 1958) described analytical procedures for the measurement of deposited particulate matter (dust-fall), suspended particulate matter (smoke), volumetric concentrations of sulphur dioxide and sulphurous pollution by reaction with lead dioxide. Data from the measurements made using these methods by local authorities and others in co-operation with central Government provided an adequate, if aproximate basis for the Clean Air Act of 1956. These procedures have since been revised and are described in various British Standard Specifications[38,37].

To guide the application of the Clean Air Act 1956, and assess the benefits accruing from it, a scientifically planned National Survey of Smoke and Sulphur Dioxide was designed during 1960-61; this incorporated the existing observations but added further sampling sites to ensure a true statistical basis. Apart from these specific aims the National Survey was intended to lead to a better understanding of the causes, distribution and effects, particularly effects on human health, of air pollution. It was therefore decided that observations should be confined to measurements which could be expressed in terms of volumetric concentations. Further, since day to day fluctuations in concentration may be large and even a few days of high pollution, such as the 1952 London 'smog', were known to be associated with illness and death, measurements requiring sampling periods in excess of 24 h. were considered unsuitable.

When the survey came into operation in the winter of 1961-2 specifications of the apparatus and methods were circulated to all the co-operating organisations as careful, uniform work was essential if the results from the different sites throughout the country were to be comparable. Detailed instructions were necessary as most of the local authority staff making measurements had no training in analytical techniques.

Since 1962 improvements in the methods have been introduced following research on the analytical and sampling techniques involved.

It is against this historical background that the methods of determining atmospheric concentrations of smoke and sulphur dioxide used in the N.E.D.D.C. area have been established. The method used for the collection of data are identical to those used throughout the United Kingdom and provide input to the National Survey which is co-ordinated by the Warren Spring Laboratory, Stevenage.

(ii) Apparatus

Sampling instrument (Fig. 4)

Inlet funnel

Made of hard glass or plastic, the diameter of the mouth being 4 cm, and the diameter of stem (internal) 6.5 mm.

Filter clamps

The size of clamps required will depend on the amount of smoke at the site, and its variability. The sizes available are 10, 5, 2.5 and 1.25 cm diameter. The 1.25 cm clamps are only used at rural sites.

Dry gas meter

The specified meters can be read to 1 litre and are tested for air pollution work. Accurate to ± 3% at a flow rate of 100 $1.hr^{-1}$.

Electric suction pump

Nominal rating of 1.5 $1.min^{-1}$.

Drechsel bottles

The bottles are 125 ml capacity and made of borosilicate glass, not soda glass as its alkali content interferes with estimation of sulphur dioxide.

P.V.C. tubing

For connecting pump, gas meter, drechsel heads, filter clamps and sampling funnel. Internal diameter 6.5 mm. Rubber tubing is unsuitable as it absorbs sulphur dioxide; polythene tubing is unsuitable as it attracts smoke particles electrostatically.

Selection of sampling site

If the site is to be representative of the local area around it, then some of the points which must be considered are listed below

a. The site should not be atypical of the surrounding area, e.g., the inlet funnel should not be situated in a closed courtyard.

b. The site should not be subject to extraneous sources of emissions, e.g. individual chimneys, bonfires or smoke from road traffic.

c. The inlet funnel should not be sited so low that particulates can be blown from the ground into it, or so high as to not give indications of ground level concentrations.

(iii) Experimental - smoke

a. Smoke Stain

The smoke filter unit consist of two heavy brass cylinders which are carefully machined to provide an air tight seal when a Whatman No. 1 filter paper is placed between them. Each half of the filter clamp is drilled and an outlet tube tapped in. A satisfactory stain is obtained when the incoming air enters the lower filter clamp and filter paper is mounted horizontally. The filter paper should be inserted with the smooth side facing the incoming air, and after exposure should be removed without touching the stain.

The upper and lower filter clamps should be accurately aligned, or the resulting stain will not be circular, the edges ill-defined, and the concentration of smoke obtained from it will be inaccurate, possibly by as much as 40%.

If the concentration of smoke is to be obtained with reasonably accuracy it is essential that the stain should produce a reflectometer reading in the range 40 to 90. During normal conditions, the readings should be above 70 so that sudden increases in pollution can be accommodated within the acceptable limits. With dark stains, the particles form more than one layer so that the concentration obtained represents only a minimum value, and the flow rate is affected by the accumulation of material. Different sized filter clamps are used to ensure that readings are obtained in the recommended range.

b. Reflectometer

The assessment of smoke stains is carried out using reflectometer, an instrument in which a steady light from a lamp is directed on to the smoke stain and the reflected light is received by a photo-sensitive element. The electrical response from the element is fed to a micro-ammeter. A high reading corresponds to a white surface and a low reading to a dark surface. The instrument is calibrated with standard white and grey tiles.

c. Calculation of smoke concentrations

Smoke concentrations are derived from recorded observations of stain darkness by use of the British Standard Smoke Calibration Curve[36] applied to readings obtained with the reflectometer. The following formula represents this curve to within ± 1.3% over the normal working range of reflectometer readings of 90 to 40.

$$C_{sm} = \frac{F}{V}(91{,}679.22 - 3{,}332.046.R + 49.618884.R^2 - 0.35329778.R^3 + 0.0009863435.R^4)$$

where

C_{sm} = concentration of smoke ($\mu g.m^{-3}$)

V = volume of air (ft^3)

R = reflectometer reading

F = factor depending on size of clamp used i.e.

12.5 mm = 0.288
25.0 mm = 1.00
50.0 mm = 3.68
100.0 mm = 12.80

(iv) Experimental - sulphur dioxide

a. Reagents

All reagents were obtained from B.D.H. Chemicals, Poole, Dorset.

Hydrogen Peroxide, 100 vol. AnalaR grade, diluted to 1 vol with distilled water.

B.D.H. "4.5" indicator.
Sodium tetraborate, N/250. AnalaR grade.
Sulphuric acid, N/250. AnalaR grade.

b. Procedure

Conditioned Drechsel bottles are used. The inlet tube from the Drechsel head should extend to within approximately 10 mm of the bottle base. 50 ml of 1 vol hydrogen peroxide, buffered to pH 4.5 is placed in the Drechsel bottle prior to exposure. Carbon dioxide forms a weak carbonic acid; this interference is removed by choosing 4.5 as the end point. A saturated solution of carbon dioxide has a pH of 4.5 and dilute solutions having this pH are not appreciably changed in pH by addition or removal of carbon dioxide. If the instrument is allowed to run without attention for more than one day, and especially if there is sufficient heating of the bubbler to cause undue evaporation, the amount of hydrogen peroxide solution should be increased.

After exposure, the contents of the Drechsel bottle are placed in a 150 ml conical flask. Two or three drops of B.D.H. "4.5" indicator are added. The solution usually shows a pink, or pinkish-grey colouration (if the solution is alkaline, a blue colouration is prroduced). The solution is titrated until a neutral grey end point is reached, the amount of titre, to the nearest 0.01 ml is recorded.

The concentration of sulphur dioxide is obtained using the volume of air sampled and the amount of titre added. Tables are supplied by Warren Springs Laboratory from which the integrated atmospheric concentration over the period of exposure can be read.

The formula from which they are derived is as follows:-

$$C_{SO_2} = \frac{4520 \, . \, T}{V}$$

where

C_{SO_2} = concentration of sulphur dioxide (ug.m^{-3})

T = volume of titre (ml)

V = volume of air (ft^3)

(v) Smoke and sulphur dioxide monitoring network

a. Current monitoring network

The North East Derbyshire District Council at January 1984 maintains seven smoke and sulphur dioxide monitoring stations. Their locations within the administrative area are shown in fig. 14 detailed site description forms are included in Appendix C and periods of operation shown in Table 33.

FIG. 14. CURRENT SMOKE AND SULPHUR DIOXIDE NETWORK.

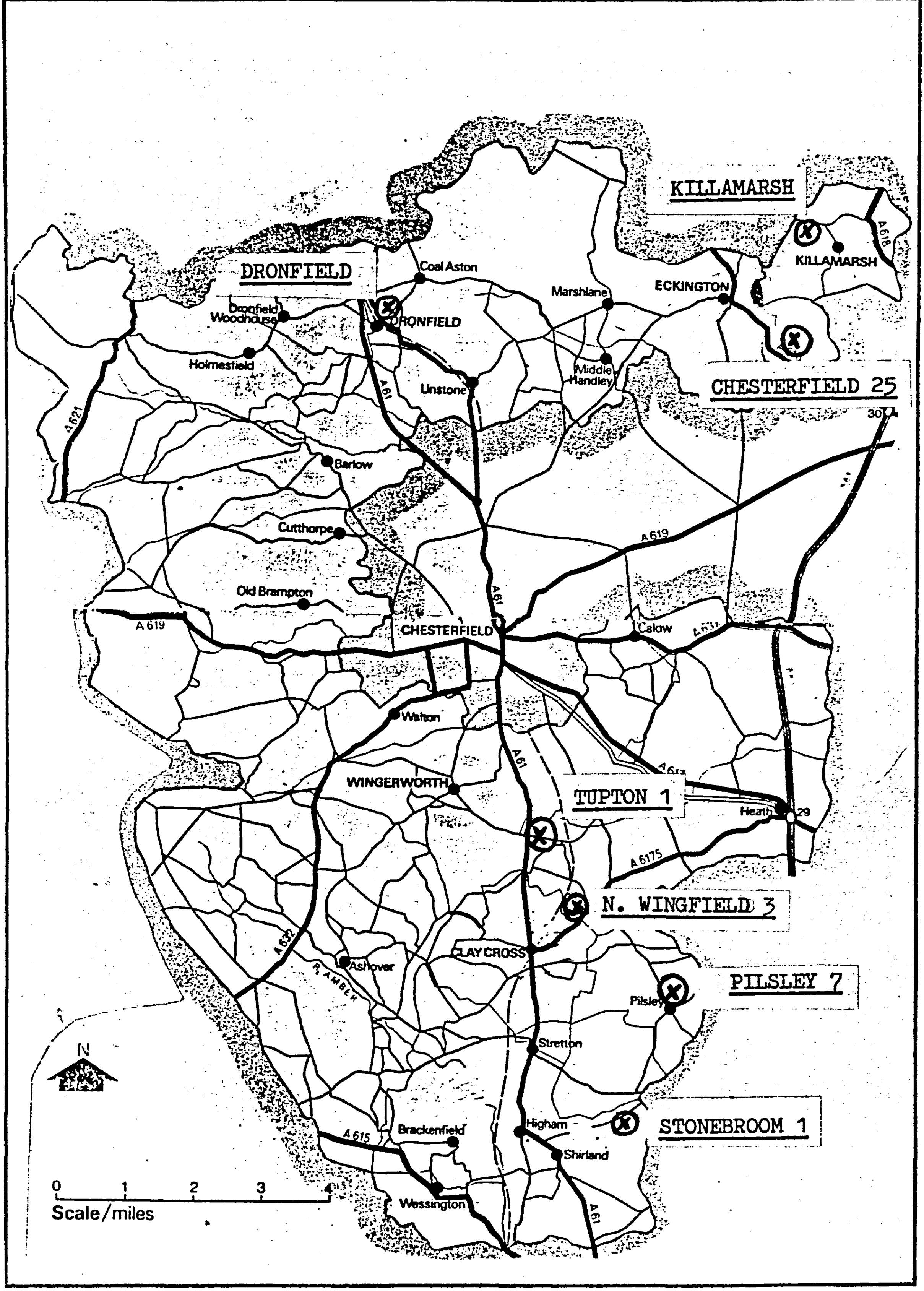


TABLE 33. CURRENT MONITORING NETWORK SITES.

SITE	GAUGE LOCATION	DATE INSTALLED
Tupton 1	Tupton County Infants & Junior School, Queen Victoria Road, Tupton.	1. 1. 71.
Pilsley 7	Pilsley County Junior & Infant School, Station Road, Pilsley.	8. 12. 72.
Chesterfield 25	British Steel Corporation, Renishaw Foundry Offices, Main Road, Renishaw.	15. 1. 74.
Stonebroom 1	Stonebroom County Junior School, High Street, Stonebroom.	29. 1. 80.
North Wingfield 3	North Wingfield Church, St. Lawrence Road, North Wingfield.	8. 11. 76.
Dronfield	Stonelow Depot (N.E.D.D.C.), Shireoaks Road, Dronfield.	5. 1. 82.
Killamarsh	24 Sherwood Road, Norwood, Killamarsh.	15. 12. 81.

b. Other monitoring sites

In the past, data was collected at several other sites in the area. They were established mainly to monitor improvements in air quality following the introduction of smoke control areas and were subsequently withdrawn. Their locations within the administrative area are shown in fig. 18, detailed site description forms (if available) are included in Appendix D and periods of operation shown in Table 33.

(vi) Monitoring results

Monthly averages for smoke and sulphur dioxide levels measured at the present and past monitoring stations are included in Appendix C and D respectively.

(f) POLLUTION BEHAVIOUR IN THE N.E.D.D.C. AREA

(i) Introduction

Before developing an atmospheric pollution model for the N.E.D.D.C area, an initial examination of available atmospheric pollution monitoring results was carried out to investigate how pollutant concentrations fluctuate, how results from the several stations correlate and how they correlate with meteorological data. As outlined in (c) above, there are several inter-related factors which affect the concentrations of smoke and sulphur dioxide. Some of these factors are:

a. non-uniform eemission rates (irregular distribution of sources and of source heights; daily, weekly and annual cycles of emissions; long-term changes in source locations and strengths);

FIG. 15. PAST MONITORING SITES.

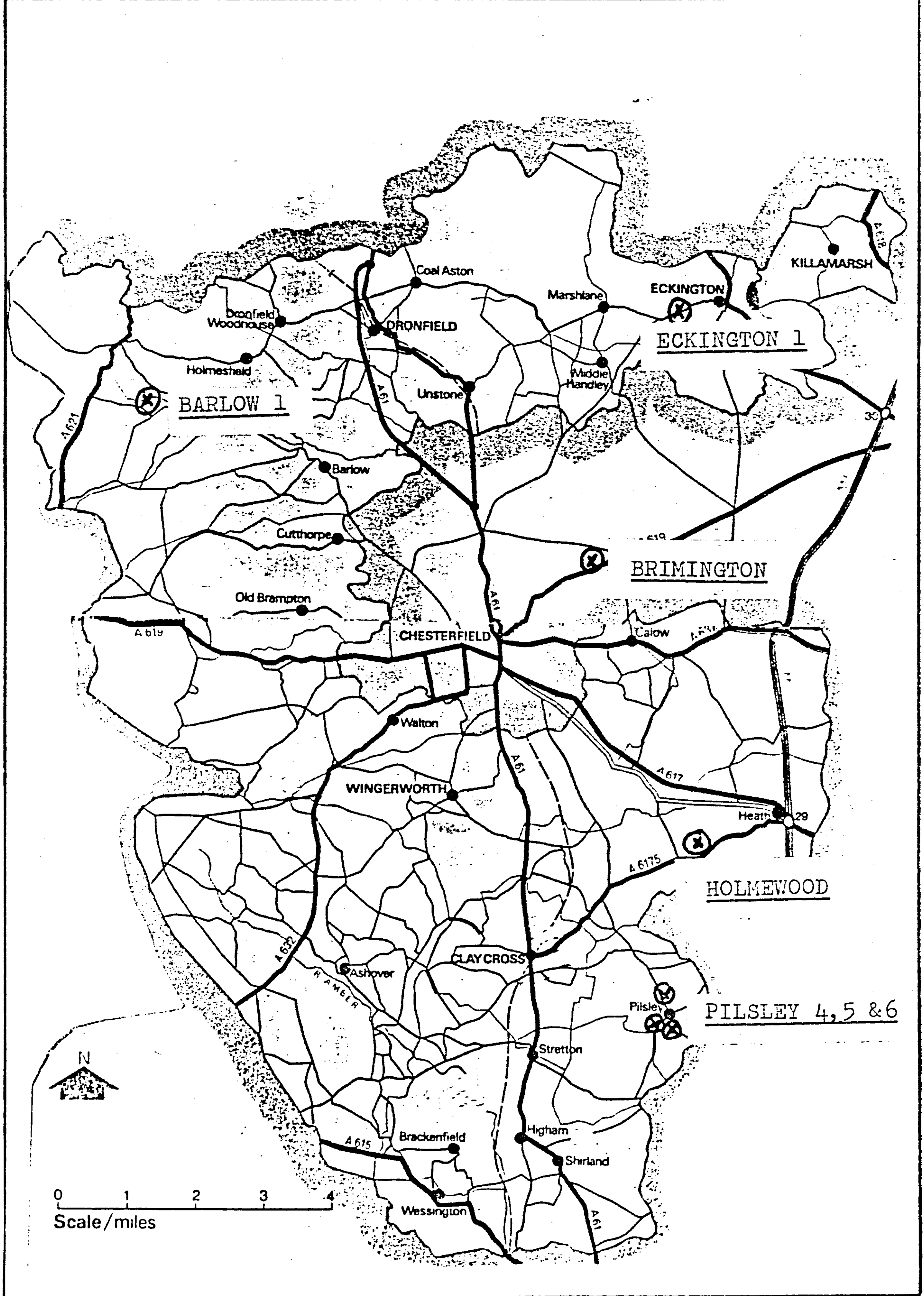


TABLE 34. PAST MONITORING SITES.

SITE	GAUGE LOCATION	MONITORING PERIOD
Pilsley 4	Morton Road, Pilsley.	1.1.74. to 31.6.75.
Pilsley 5	Hardstoft Road, Pilsley.	1.1.74. to 31.6.75.
Pilsley 6	Rupert Street, Pilsley.	1.1.74. to 31.6.75.
Barlow 1	Smeekley Borehole, Fox Lane, Holmesfield.	1.8.78. to 29.6.81.
Holmewood	Station Road, Holmewood.	3.8.76. to 1.6.81.
Brimington	High Street, Brimington.	1.4.67. to 31.3.74.
Eckington 1	Gosber Road, Eckington.	1.1.65. to 31.6.74.

b. large-scale meteorological factors (daily and annual weather cycles; synoptic weather patterns; long-term climatic oscillations and trends);

c. modulations in the large-scale meteorological factors owing to local topography and urban effects;

d. variations in the rates of chemical transformations and deposition (diurnal cylcles, precipitations scavenging, uptake by vegetation, etc.);

e. random fluctuations (due to atmospheric turbulence, etc.).

(ii) Data preparation

Prior to investigating the various correlations which may exist between determined daily atmospheric smoke and sulphur dioxide concentrations and meteorological parameters, a data base of three year's results was established on the IBM 4341 computer at the Computer Services Department, Sheffield City Polytechnic. The computer has the following configuration.

4341 group 1 cental processor
4 megabytes of main storage
3 x 3370 disk drives (3 x 570 megabytes fixed)
2 x 3340 disk drives (2 x 70 megabytes exchangeable)
2 x 4320 magnetic tape drives, 9 track, 1600/6250 bpi
1 x 3203 lineprinter (1100 lpm, 132 print positions)
1 x Memorex 1270 Communications controller

When fully configured this machine is able to support 120 concurrently operating terminals. The operating system that runs on the

IBM 4341 is called Virtual Machine/System Product (VM/SP). This control programme manages the physical resourses of the configuration and allows simultaneous access by many users. For each user VM/SP simulates a complete computer system with processing capability, disk space and certain peripherals. Each registered user is allocated a unique code which gives them a unique virtual machine.

Within the user's virtual machine, the operating system which will be running is called Conversational Monitor System (CMS). It is a single user system and the user's resources are completely protected from all other active virtual machines. The user can create, modify, execute, save and delete programmes using a powerful editor. A range of languages (BASIC, FORTRAN, COBOL, PASCAL, ASSEMBLER) and packages (PAFEC, SPSS, GLIM, SCRIPT, etc.) are available.

Daily determined atmospheric concentrations of smoke and sulphur dioxide obtained from the five monitoring stations located at Tupton (code 1), Pilsley (code 2), North Wingfield (code 3), Renishaw (code 4) and Holmewood (code 5), for 1977, 1978 and 1979 were entered on programming sheets. Several meteorological parameters for the same period were also entered on programming sheets. These parameters are listed below.

Average wind direction for that day
Wind direction at 1400 hours on the previous day
" " " 2200 " " " " "
" " " 0600 " " " " "
" " " 1000 " " " " "
Average wind speed for that day

Wind speed at 1400 hours on the previous day
"   "   " 2200   "   "   "   "   "
"   "   " 0600   "   " that day
"   "   " 1000   "   "   "   "
Rainfall for that day (mm)
Relative Humidity
Amount of sunshine (hrs.)
Maximum daily temperture (^{o}C)
Minimum "   "   "
Average "   "   "

Samples of programme sheets displaying the spacing of data are included in Appendix E.

The data was transferred to punched cards and then to a permanent disk on the IBM 4341 computer. The three files opened for the data had the following filenames and contents.

TRAN1 DATA - Meteorological data, 1977, '78 and '79
TRAN2 DATA - Pollution results, stations 1 - 5, 1977
TRAN3 DATA - "   "   "   " 1978 & '79.

The files were merged to (TRAN4 SPSS) using a Fortran programme which is included in Appendix E. This assembled data formed the basis for some of the initial examinations of the pollution data.

In addition to the data base established on the IBM 4341 computer containing determined pollution levels at five monitoring stations for the years 1977, 1978 and 1979, further sets of data (see Appendices C & D) containing results from 1965 to 1984 were examined.

(iii) Fluctuations in daily pollutant concentrations

Concentrations of a pollutant measured continuously at an urban monitoring station may show considerable variability. Variations may be large near known emission sources but decrease downwind; the pollutants eventually become well mixed throughout the lower atmosphere. The data base was interrogated and the % relative standard deviations for determined smoke and sulphur dioxide levels (1977, 1978 and 1979) at the five monitoring stations obtained. They are shown on Table 35.

None of the monitoring stations are sited in close proximity to known emission sources and all satisfy the suggested sampling site criteria detailed in (e) (ii) above. The percentage relative standard deviations of the monitored pollution levels at the five sites do not indicate that any monitoring site's results have a significantly higher variability. It may be concluded that the monitoring gauges sited at these locations are not being affected by nearby emission sources.

(iv) Weekly emission cycles

Emission rates may be different on Saturdays and Sundays compared to other days. Depending upon the land use of the area being monitored, they may be more or less on these two days than for the rest of the week. In an industrial area they may be less, but in a residential area, where most people will be at home at the weekend they may be more.

To determine whether weekly emission cycles are reflected in monitored pollution levels for North East Derbyshire the available

TABLE 35. PERCENTAGE RELATIVE STANDARD DEVIATIONS OF DETERMINED SMOKE AND SULPHUR DIOXIDE CONCENTRATIONS.

Site	Code	1977		1978		1979	
		smoke	SO_2	smoke	SO_2	smoke	SO_2
Tupton	1	56.8	103	77.1	122	76.5	109
Pilsley	2	53.5	95.7	58.3	118	56.3	96.9
N.Wingfield	3	54.5	98.7	66.8	117	76.3	106
Renishaw	4	60.9	91.4	65.1	99.5	57.5	89.9
Holmewood	5	53.9	87.6	61.8	94.1	58.5	79.3

data was examined. The monitoring results for a summer month (July) and a winter month (January) at various volumetric gauge sites are shown on Figures 16 and 27.

Little evidence is shown which would suggest that there was a weekly cycle in monitored pollution levels. This may be due to a number of inter-related and contributory factors:-

a. although the areas in which monitoring gauges are situated are predominantly residential, there are industrial emission sources which may be contributing to the determined levels;

b. reduced weekday emissions from domestic premises may be off set to an unknown extent by industrial emissions and at the weekends the situation may be reversed;

c. the idealised emission behaviour pattern suggested in the next but one paragraph above does not predominate in North East Derbyshire. Shift working, weekday emission contributions from households containing retired or unemployed members and seven day industrial activity will dampen the cycle;

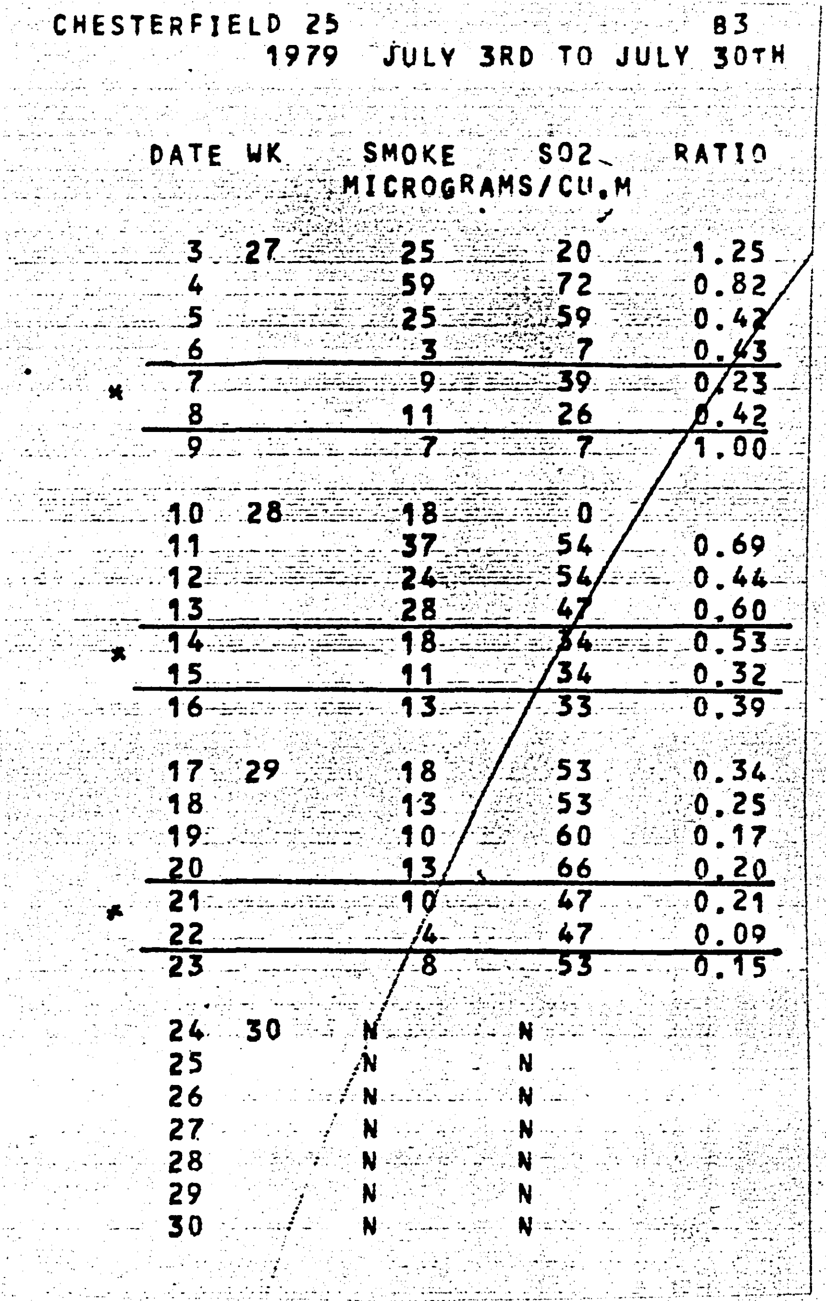
d. reductions and alterations in fuel usage, for example, programmed central heating and the reduced necessity to use coal fires to generate hot water may result in a reduced fluctuation in emission rates.

FIG. 16. DAILY MONITORING RESULTS.

```
CHESTFRFIELD 25                               B3
        1980  JAN 1ST TO JAN 28TH

    DATE WK    SMOKE      SO2      RATIO
            MICROGRAMS/CU.M

      1  01      95        69      1.38
      2          45        50      0.90
      3         116       138      0.84
      4          60        82      0.73
  *   5          48        57      0.84
      6          14        25      0.56
      7          17        31      0.55

      8  02      47        49      0.96
      9          37        49      0.76
     10          63        77      0.82
     11         219       211      1.04
  *  12         251       239      1.05
     13         209       162      1.29
     14         173       246      0.70

     15  03      63       105      0.60
     16          60       105      0.57
     17          87       120      0.73
     18         130       127      1.02
  *  19         130       225      0.58
     20          87        98      0.89
     21          79        98      0.81

     22  04      42        71      0.59
     23          27        64      0.42
     24          75        85      0.88
     25          48        64      0.75
  *  26          75       113      0.66
     27         130       134      0.97
     28         118       134      0.88
```

* Saturday and Sunday.

FIG. 17. DAILY MONITORING RESULTS.



CHESTERFIELD 25 83
1979 JULY 3RD TO JULY 30TH

DATE	WK	SMOKE	SO2	RATIO
		MICROGRAMS/CU.M		
3	27	25	20	1.25
4		59	72	0.82
5		25	59	0.42
6		3	7	0.43
* 7		9	39	0.23
8		11	26	0.42
9		7	7	1.00
10	28	18	0	
11		37	54	0.69
12		24	54	0.44
13		28	47	0.60
* 14		18	34	0.53
15		11	34	0.32
16		13	33	0.39
17	29	18	53	0.34
18		13	53	0.25
19		10	60	0.17
20		13	66	0.20
* 21		10	47	0.21
22		4	47	0.09
23		8	53	0.15
24	30	N	N	
25		N	N	
26		N	N	
27		N	N	
28		N	N	
29		N	N	
30		N	N	

N No readings

* Saturday and Sunday.

FIG. 18. DAILY MONITORING RESULTS.

BARLOW 1 02
1980 JAN 1ST TO JAN 28TH

DATE	WK	SMOKE MICROGRAMS/CU.M	SO2 MICROGRAMS/CU.M	RATIO
1	01	6	12	0.50
2		4	35	0.11
3		23	82	0.28
4		10	24	0.42
* 5		7	6	1.17
6		3	12	0.25
7		7	18	0.39
8	02	32	62	0.52
9		32	68	0.47
10		41	98	0.42
11		55	105	0.52
* 12		65	117	0.56
13		76	80	0.95
14		32	74	0.43
15	03	21	78	0.27
16		20	90	0.22
17		25	120	0.21
18		54	96	0.56
* 19		21	156	0.13
20		25	60	0.42
21		12	54	0.22
22	04	5	18	0.28
23		10	18	0.56
24		5	24	0.21
25		21	36	0.58
* 26		4	66	0.06
27		3	42	0.07
28		9	90	0.10

* Saturday and Sunday.

FIG. 19. DAILY MONITORING RESULTS.

BARLOW 1 02

1980 JULY 1ST TO JULY 28TH

	DATE	WK	SMOKE MICROGRAMS/CU.M	SO2	RATIO
	1	27	1	37	0.03
	2		2	6	0.33
	3		8	18	0.44
	4		3	30	0.10
*	5		2	37	0.05
	6		3	24	0.13
	7		12	37	0.32
	8	28	6	37	0.16
	9		4	30	0.13
	10		2	24	0.08
	11		3	24	0.13
*	12		2	37	0.05
	13		2	24	0.08
	14		9	30	0.30
	15	29	5	30	0.17
	16		5	12	0.42
	17		6	24	0.25
	18		4	12	0.33
*	19		3	24	0.13
	20		2	24	0.08
	21		5	18	0.28
	22	30	4	31	0.13
	23		4	31	0.13
	24		3	43	0.07
	25		5	49	0.10
*	26		10	43	0.23
	27		22	37	0.59
	28		3	43	0.07

* Saturday and Sunday.

FIG. 20. DAILY MONITORING RESULTS.

PILSLEY 1 D2/E

1979 JAN 2ND TO JAN 29TH

	DATE	WK	SMOKE	SO2	RATIO
			MICROGRAMS/CU.M		
	2	01	10	36	0.28
	3		66	142	0.46
	4		146	231	0.63
	5		73	142	0.51
*	6		126	166	0.76
	7		31	59	0.53
	8		31	18	1.72
	9	02	24	35	0.69
	10		17	41	0.41
	11		11	52	0.21
	12		30	111	0.27
*	13		44	151	0.29
	14		131	169	0.78
	15		65	52	1.25
	16	03	108	94	1.15
	17		35	129	0.27
	18		19	59	0.32
	19		28	65	0.43
*	20		33	117	0.28
	21		47	182	0.26
	22		42	229	0.18
	23	04	26	57	0.46
	24		30	125	0.24
	25		20	62	0.32
	26		46	148	0.31
*	27		86	176	0.49
	28		100	284	0.35
	29		34	102	0.33

* Saturday and Sunday.

FIG. 21. DAILY MONITORING RESULTS.

PILSLEY 1 D2/E
1979 JULY 3RD TO JULY 30TH

	DATE	WK	SMOKE	SO2	RATIO
			MICROGRAMS/CU.M		
	3	27	11	40	0.28
	4		38	79	0.48
	5		14	74	0.19
	6		11	45	0.24
*	7		8	40	0.20
	8		4	34	0.12
	9		6	28	0.21
	10	28	7	45	0.16
	11		18	62	0.29
	12		15	62	0.24
	13		12	51	0.24
*	14		7	51	0.14
	15		6	45	0.13
	16		8	40	0.20
	17	29	5	57	0.09
	18		3	51	0.06
	19		4	74	0.05
	20		3	45	0.07
*	21		4	45	0.09
	22		2	62	0.03
	23		4	51	0.08
	24	30	7	40	0.18
	25		5	40	0.13
	26		7	40	0.18
	27		20	120	0.17
*	28		11	80	0.14
	29		2	28	0.07
	30		3	28	0.11

* Saturday and Sunday.

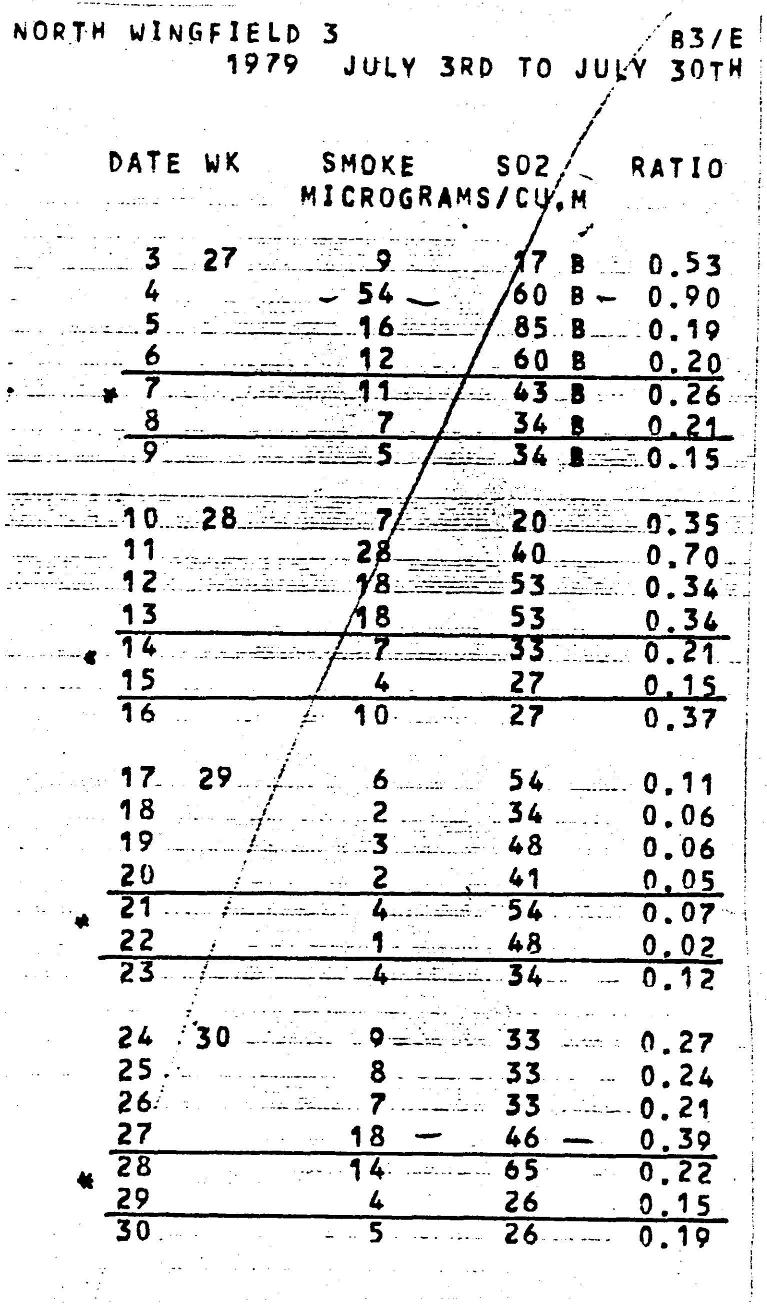
FIG. 22. DAILY MONITORING RESULTS.

NORTH WINGFIELD 3 B3/F
1980 JAN 1ST TO JAN 28TH

DATE	WK	SMOKE	SO2	RATIO
		MICROGRAMS/CU.M		
1	01	29	65	0.45
2		42	65	0.65
3		91	146	0.62
4		34	73	0.47
* 5		26	33	0.79
6		7	16	0.44
7		14	57	0.25
8	02	42	87	0.48
9		54	100	0.54
10		173	100	1.73
11		173	214	0.81
* 12		165	207	0.80
13		79	254	0.31
14		51	154	0.33
15	03	34	91	0.37
16		44	124	0.35
17		73	162	0.45
18		94	169	0.56
* 19		46	201	0.23
20		29	104	0.28
21		44	84	0.52
22	04	9	52	0.17
23		12	52	0.23
24		25	58	0.43
25		16	58	0.28
* 26		55	168	0.33
27		31	135	0.23
28		72	129	0.56

* Saturday and Sunday.

FIG. 23. DAILY MONITORING RESULTS.



NORTH WINGFIELD 3 B3/E
1979 JULY 3RD TO JULY 30TH

DATE	WK	SMOKE MICROGRAMS/CU.M	SO2		RATIO
3	27	9	17	B	0.53
4		54	60	B	0.90
5		16	85	B	0.19
6		12	60	B	0.20
* 7		11	43	B	0.26
8		7	34	B	0.21
9		5	34	B	0.15
10	28	7	20		0.35
11		28	40		0.70
12		18	53		0.34
13		18	53		0.34
* 14		7	33		0.21
15		4	27		0.15
16		10	27		0.37
17	29	6	54		0.11
18		2	34		0.06
19		3	48		0.06
20		2	41		0.05
* 21		4	54		0.07
22		1	48		0.02
23		4	34		0.12
24	30	9	33		0.27
25		8	33		0.24
26		7	33		0.21
27		18	46		0.39
* 28		14	65		0.22
29		4	26		0.15
30		5	26		0.19

* Saturday and Sunday.

FIG. 24. DAILY MONITORING RESULTS.

```
TUPTON 1                                    R
            1980  JAN 1ST TO JAN 28TH

            DATE WK    SMOKE    SO2    RATIO
                   MICROGRAMS/CU.M

              1  01      N        N
              2          N        N
              3          N        N
              4          N        N
              5          N        N
              6          N        N
              7          N        N

              8  02      46       31    1.48
              9          41     ALK
             10          65       98    0.66
             11         158      135    1.17
     *       12         165      165    1.00
             13         151      159    0.95
             14         158      177    0.89

             15  03      42      105    0.40
             16          47       81    0.58
             17          73      124    0.59
             18          90      137    0.66
     *       19          47      180    0.26
             20          26       99    0.26
             21          37       74    0.50

             22  04       8       20    0.40
             23           7       46    0.15
             24          14       39    0.36
             25          10       39    0.26
     *       26          59      105    0.56
             27          29      111    0.26
             28          69      118    0.58
```

N No readings

* Saturday and Sunday.

FIG. 25. DAILY MONITORING RESULTS.

TUPTON 1
1979 JULY 3RD TO JULY 30TH

	DATE	WK	SMOKE	SO2	RATIO
			MICROGRAMS/CU.M		
	3	27	7	6	1.17
	4		27	42	0.64
	5		15	42	0.36
	6		10	36	0.28
*	7		5	24	0.21
	8		4	12	0.33
	9		3	N	
	10	28	6	24	0.25
	11		25	71	0.35
	12		18	54	0.33
	13		16	36	0.44
*	14		7	36	0.19
	15		9	24	0.38
	16		5	24	0.21
	17	29	3	29	0.10
	18		1	29	0.03
	19		2	ALK	
	20		3	47	0.06
*	21		4	52	0.08
	22		1	47	0.02
	23		3	23	0.13
	24	30	8	17	0.47
	25		6	17	0.35
	26		6	17	0.35
	27		17	35	0.49
*	28		14	41	0.34
	29		3	12	0.25
	30		3	17	0.18

* Saturday and Sunday.

FIG. 26. DAILY MONITORING RESULTS.

STONEBROOM 1 83
1981 DEC 30TH TO FEB 2ND

	DATE	WK	SMOKE	SO2	RATIO
			MICROGRAMS/CU.M		
	30	01	66	76	0.87
	31		41	83	0.49
	1		62	62	1.00
	2		38	55	0.69
*	3		29	62	0.47
	4		50	69	0.72
	5		44	48	0.92
	6	02	72	103	0.70
	7		160	34	4.71
	8		76	14	5.43
	9		41	55	0.75
*	10		8	27	0.30
	11		20	68	0.29
	12		41	82	0.50
	13	03	4	48	0.08
	14		15	68	0.22
	15		3	61	0.05
	16		15	75	0.20
*	17		15	54	0.28
	18		18	88	0.20
	19		35	75	0.47
	20	04	24	48	0.50
	21		120	151	0.79
	22		29	41	0.71
	23		94	96	0.98
*	24		99	96	1.03
	25		12	48	0.25
	26		43	48	0.90
	27	05	19	62	0.31
	28		20	83	0.24
	29		20	131	0.15
	30		19	117	0.16
*	31		22	124	0.18
	1		24	96	0.25
	2		20	103	0.19

* Saturday and Sunday.

FIG. 27. DAILY MONITORING RESULTS.

STONEBROOM 1 B3
1980 JULY 1ST TO JULY 28TH

	DATE	WK	SMOKE	SO2	RATIO
			MICROGRAMS/CU.M		
	1	27	22	54	0.41
	2		7	54	0.13
	3		35	54	0.65
	4		33	75	0.44
*	5		13	48	0.27
	6		7	41	0.17
	7		20	54	0.37
	8	28	13	46	0.28
	9		8	66	0.12
	10		7	52	0.13
	11		10	53	0.19
*	12		8	46	0.17
	13		4	39	0.10
	14		8	52	0.15
	15	29	14	59	0.24
	16		21	59	0.36
	17		21	53	0.40
	18		37	66	0.56
*	19		27	46	0.59
	20		18	39	0.46
	21		10	33	0.30
	22	30	23	66	0.35
	23		23	79	0.29
	24		10	66	0.15
	25		11	59	0.19
*	26		16	59	0.27
	27		34	66	0.52
	28		23	79	0.29

* Saturday and Sunday.

(v) Spatial correlation analysis

By correlating daily integrated pollution levels recorded at one monitoring station, referred to as a reference site, with corresponding daily values of other stations over a limited period of time, a series of point correlation coefficients can be obtained. From these point values a pollution correlation field can be constructed.

Elsom[111] constructed a pollution correlation field for Greater Manchester, based on 66 stations. It provided an assessment of the degree to which pollution levels at the various monitoring stations mutually respond to "factors which operate simultaneously over large areas". The Greater Manchester study showed that the majority of coefficients were of high value, demonstrating that day to day changes in pollution levels are primarily controlled by regional controls rather than local controls such as emission sources near monitoring stations. He implied that the major part of the variation in day to day changes in smoke and sulphur dioxide levels were due to prevailing weather conditions favouring or discouraging the build up of pollution levels at all stations i.e. temperature, wind speed and precipitation.

To investigate whether variations in day to day pollution levels were due to prevailing weather conditions the data base containing daily determined levels of smoke and sulphur dioxide, and daily meteorological measurements was interrogated. The various data files were merged to produce a file of 5,475 lines, each of which containing nineteen variables. The variables are listed below.

Variable 1 - Monitoring station code number

2 - Daily smoke concentration

3 - Daily sulphur dioxide concentration

4 - Average wind direction for the day

5 - Wind direction 1400 hours previous day

6 - " 2200 " "

7 - " 0600 " that day

8 - " 1000 " "

9 - Average wind speed for the day (Knots)

10 - Wind speed 1400 hours previous day

11 - " 2200 " "

12 - " 0600 " that day

13 - " 100 " "

14 - Precipitation (mm)

15 - Relative humidity

16 - Hours of sunshine

17 - Maximum daily temperature (^0C)

18 - Minimum " " "

19 - Average " " "

Negative correlation coefficients of 0.40 for sulphur dioxide and average daily temperature, 0.42 for smoke and average temperature, 0.23 for average wind speed and sulphur dioxide, 0.24 for average wind speed and smoke, 0.09 for precipitation and sulphur dioxide and 0.02 for precipitation and smoke were computed.

The significant correlation coefficients which Elsom's work suggests do not exist in the North East Derbyshire data. Significant correlations do however, exist between daily smoke and sulphur dioxide concentrations (0.70) and maximum daily temperature and hours of sunshine (0.54).

Elsom[111] concluded that, in the case of the Greater Manchester study, spatial correlation analysis revealing high correlation coefficients provided a technique for "optimising the monitoring network". Where high correlation coefficients exist between results from adjacent monitoring stations a technique may be developed of predicting pollution levels, with varying degrees of confidence, at different sites in the area using data from one reference station.

The data base was again interrogated and the correlation coefficients of determined daily sulphur dioxide and smoke levels for the five monitoring stations were computed. The results are shown in Table 36. From these results it may be concluded that the daily determined sulphur dioxide and smoke levels at station number three show higher correlation coefficients with the results from the other stations and may be selected as the reference station in developing a predictive model.

(g) MONITORING AND MODELLING STRATEGIES FOR THE N.E.D.D.C. AREA

(i) Introduction

The Clean Air Act 1956 gave Local Authorities powers to declare part or the whole of their area to be a smoke control area in which emissions of smoke from dwellings are prohibited. Section 12 of the Act makes provision for adapting unsuitable heating and cooking appliances in smoke control areas, with financial help from Local Authorities, who in turn are assisted by Central Government.

TABLE 36. CORRELATION COEFFICIENTS, SULPHUR DIOXIDE AND SMOKE FOR THE FIVE MONITORING SITES.

SULPHUR DIOXIDE

Monitoring station	1	2	3	4	5
1	1.0	0.73	0.74	0.58	0.65
2	0.73	1.0	0.76	0.60	0.75
3	0.74	0.76	1.0	0.75	0.76
4	0.58	0.60	0.75	1.0	0.69
5	0.65	0.75	0.76	0.69	1.0

SMOKE

Monitoring station	1	2	3	4	5
1	1.0	0.89	0.92	0.82	0.65
2	0.89	1.0	0.91	0.83	0.72
3	0.92	0.91	1.0	0.88	0.73
4	0.82	0.83	0.88	1.0	0.70
5	0.65	0.72	0.73	0.70	1.0

The cost of the approved adaptation is apportioned as to the owner or occupier of the dwelling 30%, Local Authority 30% and Central Government 40%. This 70% grant is not available to commercial or industrial premises, although provision is made to assist charitable institutions, churches and chapels. Changes in fuel usage and types of adaptations carried out in a typical smoke control area (Pilsley No. 14) are summarised on Table 37.

North East Derbyshire District Council and its predecessors have progressively declared smoke control areas which now affect the majority of the populated parts of the area (see Figure 28 and Table 38). To monitor improvements in air quality following the declaration of a smoke control area pollution gauges were installed at various locations in North East Derbyshire. These monitoring sites were located at Pilsley (Pilsley No. 14), Tupton (Tupton No. 11) and at Heath Road, Holmewood (Holmewood No. 24) (see Figs. 14 and 15 below). As can be seen from graphs displayed on Figs. 29 to 31 to reductions in monitored smoke and sulphur dioxide levels following the declaration of a smoke control area were significant.

Reductions in sulphur dioxide levels tend not to be as marked as those for smoke concentrations. This is due to the fact that solid smokeless fuel is manufactured from bituminous coal. Although the process of carbonisation removes the majority of the volatile compounds likely to produce smoke when the fuel is burned, there is no corresponding reduction in the sulphur content of the fuel. The amount of sulphur in coal varies from 0.5 to 3.5% with an average of 1.6%.

TABLE 37. CHANGES IN FUEL USAGE AND TYPES OF ADAPTATION CARRIED OUT IN A TYPICAL SMOKE CONTROL AREA.

Fuel	Before Order		Conversions		After Order	
	Total	% age	Total	% age	Total	% age
Electricity	11	1.1	19	2.4	30	3.1
Gas	101	10.5	177	22.5	278	28.8
Oil	3	0.3	nil	0.0	3	0.3
Coke	64	6.6	589	75.1	653	67.8
Bituminous Coal	785	81.5	nil	0.0	nil	0.0
TOTALS:	964	100.0	785	100.0	964	100.0

Source - North East Derbyshire District Council records.

FIG. 28. DECLARED SMOKE CONTROL AREAS.

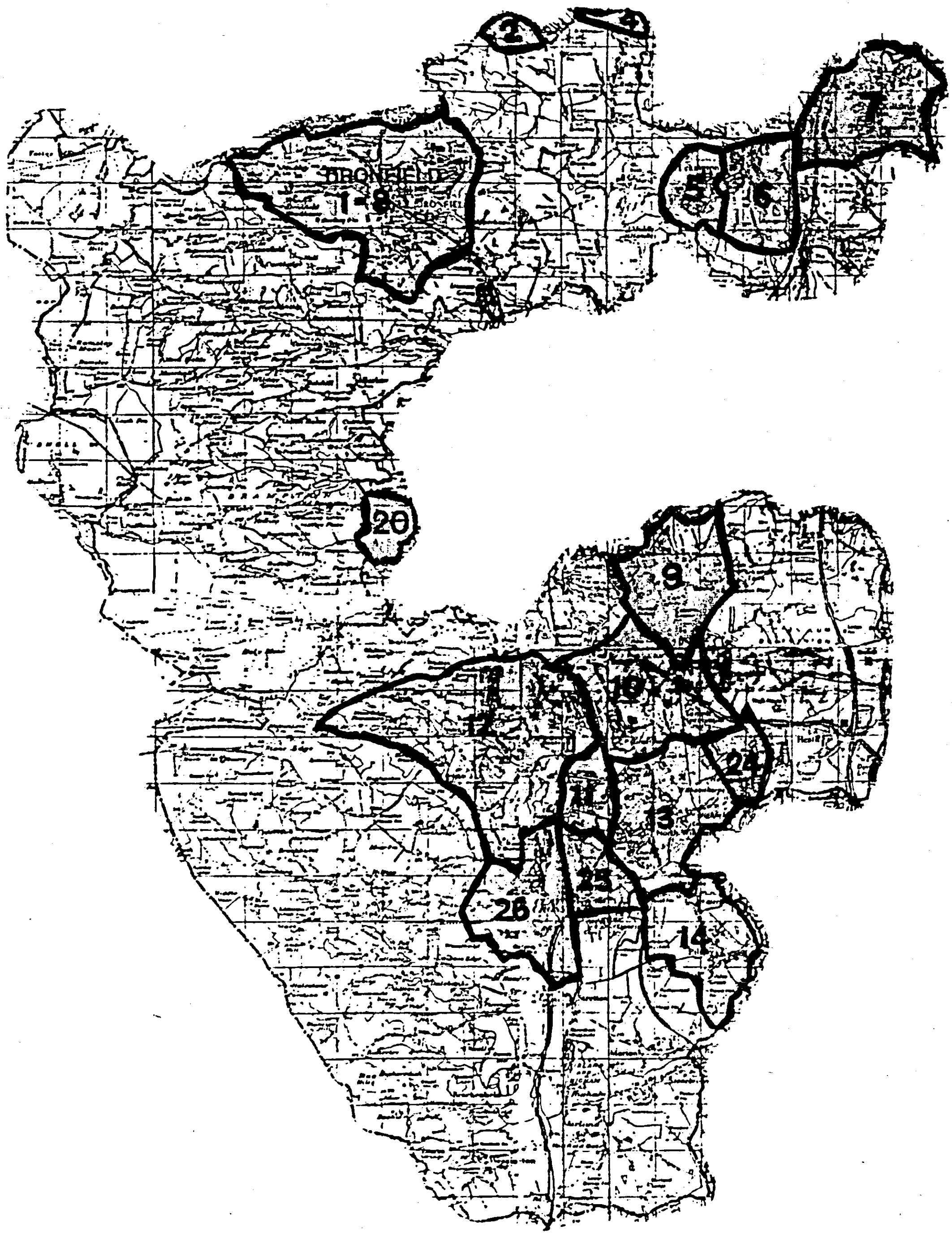
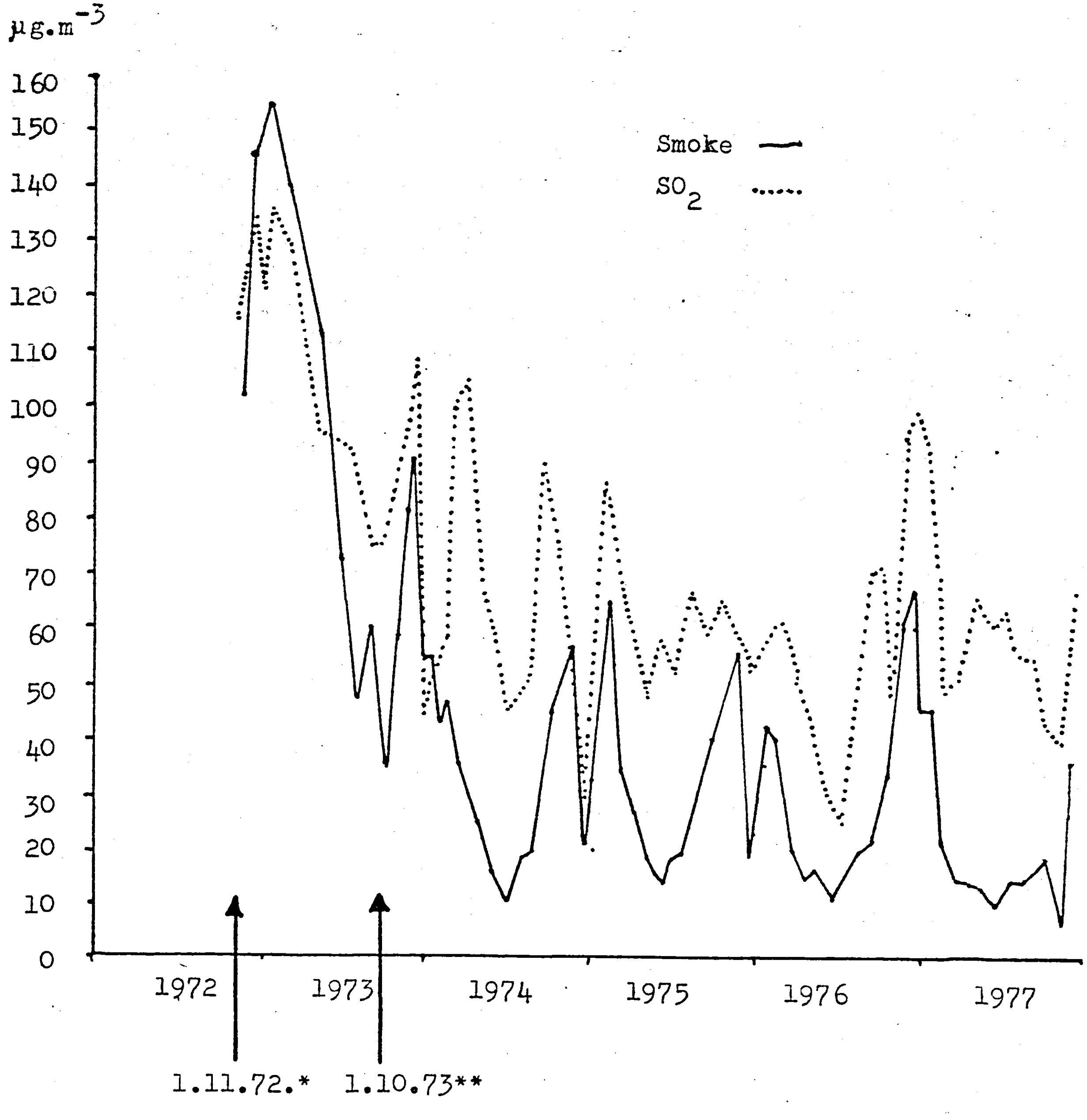


TABLE 38. DECLARED SMOKE CONTROL AREAS.

No. 2 S.C.O.	GLEADLESS
No. 4 S.C.O.	BEIGHTON
No. 5 S.C.O.	ECKINGTON
No. 6 S.C.O.	ECKINGTON
No. 7 S.C.O.	KILLAMARSH
No. 9 S.C.O.	CALOW
No. 10 S.C.O.	HASLAND, GRASSMOOR, PART TEMPLE NORMANTON
No. 11 S.C.O.	TUPTON
No. 12 S.C.O.	WINGERWORTH
No. 13 S.C.O.	NORTH WINGFIELD
No. 14 S.C.O.	PILSLEY
No. 20 S.C.O.	PART BRAMPTON
No. 24 S.C.O.	HOLMEWOOD
No. 25 S.C.O.	CLAY CROSS (EAST)
No. 26 S.C.O.	CLAY CROSS (WEST)
1 - 8	DRONFIELD

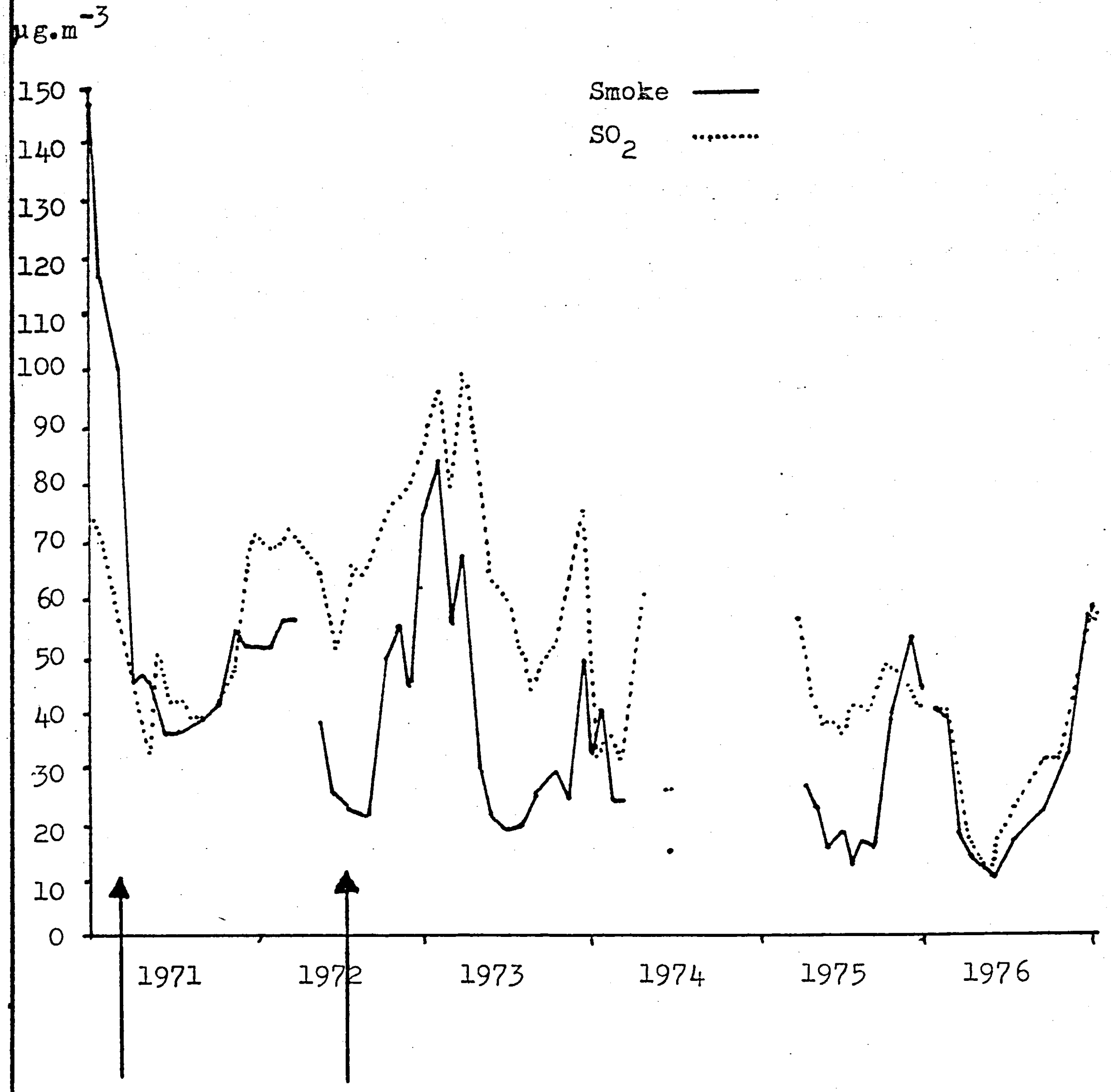
FIG. 29. MONITORING RESULTS - PILSLEY NO. 14.



* Date of confirmation of the smoke control order.

** Operative date of the smoke control order.

FIG. 30. MONITORING RESULTS - TUPTON NO. 11.

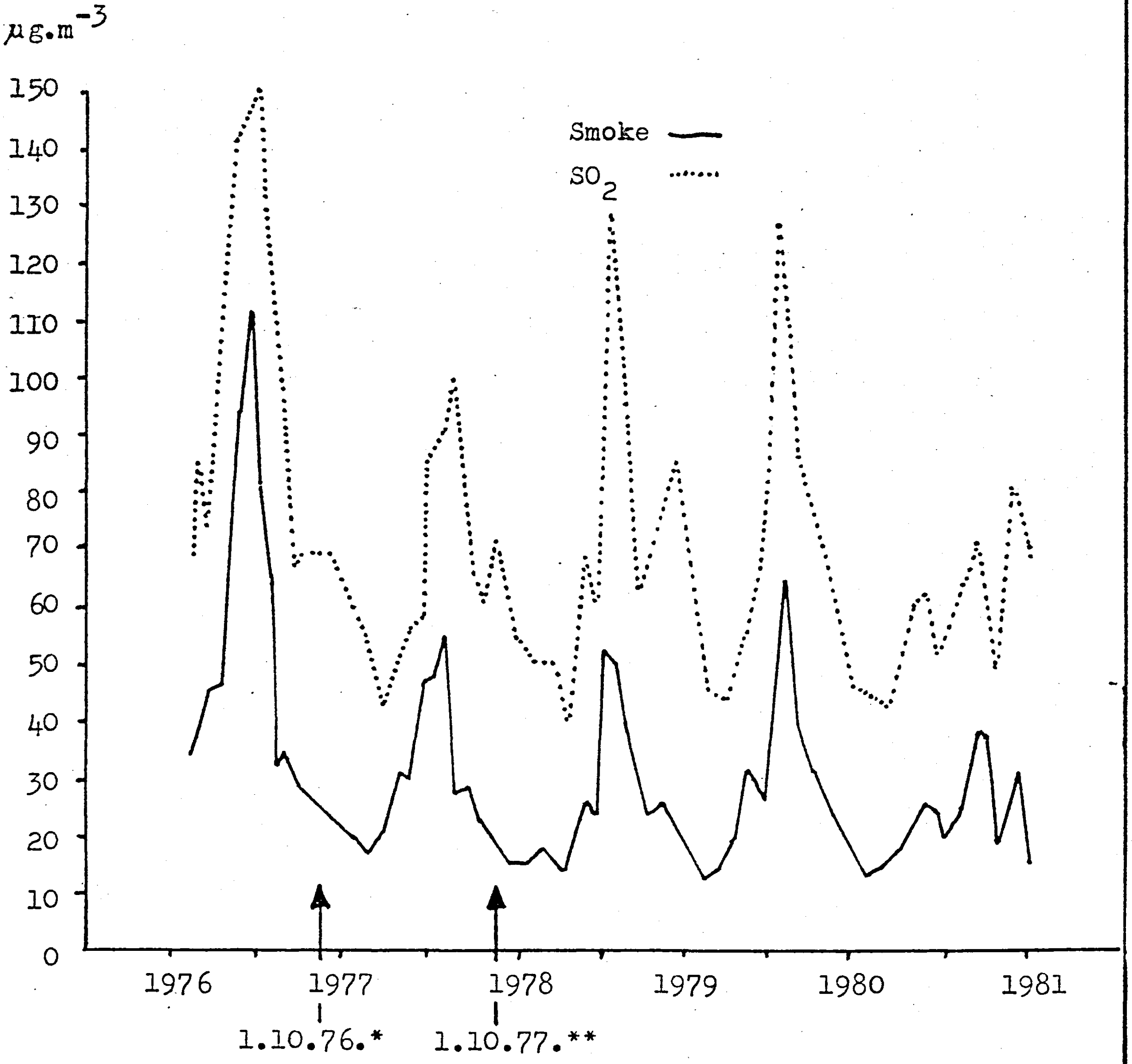


11.2.71.* 1.7.72.**

* Date of confirmation of the smoke control order.

** Operative date of the smoke control order.

FIG. 51. MONITORING RESULTS - HOLMEWOOD NO. 24.



* Date of confirmation of the smoke control order.

** Operative date of the smoke control order.

However, the calorific value of solid smokeless fuel is greater than that of coal. The coal mined in the North Derbyshire coalfield generally falls within Groups 600 to 900 with a net calorific value of between 22,500 to 26,550 kJ.kg^{-1}, whereas coke has a net calorific value of 28,300 kJ.kg^{-1}. The decrease in fuel used therefore, for the same calorific output varies between 20.5% and 8%. In addition to the projected reduction in solid fuel usage due to differences in calorific values, other fuels such as natural gas and electricity, which obviously contain no sulphur, will be used instead of solid fuel.

Another factor which reduces the amounts of solid fuel usage is appliance efficiency. The use of closed room heaters and central heating boilers can increase the heat exchange efficiency (compared to an open coal fire) by as much as 40%.

Whilst the introducton of a smoke control order substantially reduces smoke concentrations, the reduction in sulphur dioxide levels is less and will vary depending upon the types of conversions which are carried out in a particular smoke control area.

Following the implementation of a programme of smoke control in North East Derbyshire little change has occurred in the patterns of fuel usage. Many parts of the area were not linked to the national gas distribution network at the time of the domestic heating appliance conversions and to date only a few properties have had a piped supply provided. Some reductions in fuel usage have been achieved with the installation of thermal insulation. The Building Regulations [112] have progressively required higher standards of thermal insulation and since the mid 1970's grants have been available to bring older houses up to a similar standard.

It may be concluded that since the middle to late 1970's emissions to atmosphere of sulphur dioxide and smoke have not changed significantly. Since the implementation of smoke control area legislation there have been no significant changes in domestic and industrial emission rates.

(ii) European Community Directive on Sulphur Dioxide and Suspended Particulates

Air pollution monitoring is essential to the control of air pollution. There is a need to distinguish between emissions of pollutants and the resulting concentrations in the environment. Emissions are monitored largely for control purposes in order to check that pollution control equipment is operating properly and that the requirements of the controlling authorities are being met. The monitoring of ambient air quality (usually the ground level concentrations of pollutants) is of wider significance. Such measurements provide the basis for control policy: for example, they may indicate areas where domestic smoke control would be desirable, and enable the effectiveness of smoke control, when introduced, to be assessed: or they may provide information for medical authorities for epidemiological studies of the effects of air pollution on health.

High concentrations of sulphur dioxide and smoke were significantly reduced following the implementation of the Clean Air Acts[1]. During the late 1970's it became apparent that there was a need for an air quality standard for sulphur dioxide and smoke.

The adoption of air quality standards provide guidelines as to whether ambient concentrations of pollution in a particular area are satisfactory or whether some form of pollution control action is necessary.

In 1980 the E.C. Council of Ministers adopted a Directive on concentrations of smoke and sulphur dioxide in the atmosphere. The Directive prescribed mandatory maximum values (limit values) for the ground level concentrations of these pollutants which had to be met throughout the Community by 1st April, 1983. These values were intended to act as a protection for human health. Derogations were permitted for specific areas that exceeded the limit values provided for specific areas that exceeded the limit values provided the Member State demonstrated that it was taking the necessary measures to bring pollution concentrations below the limit values as quickly as possible and by 1st April, 1983 at the latest. The Directive also provided a non-mandatory, lower set of values (guide values) which were intended to serve as reference points for the longer term improvement of air quality and for the setting of targets in special zones if necessary. The limit values and guide values are shown in Table 39. The Directive required that monitoring be carried out in areas where the limit values were likely to be approached or exceeded and also required reports to be made to the Commission of the European Community on monitoring and control measures in areas exceeding the limit values.

The Warren Spring Laboratory, in conjunction with other Central Government Departments reviewed results from the National Survey of Smoke and Sulphur Dioxide. District Councils within which there may be an area where the concentrations of smoke and sulphur dioxide were likely to exceed the limit values were identified. Meetings were held

TABLE 39. E.C.. DIRECTIVE LIMIT AND GUIDE VALUES FOR SMOKE AND SULPHUR DIOXIDE.

LIMIT VALUES FOR SMOKE AND SULPHUR DIOXIDE IN MICROGRAMMES PER CUBIC METRE

Reference Period	*Smoke**	*Limit Values for*	*Sulphur dioxide*
Year (Median of daily values)	80 (68)	If smoke less than If smoke more than	40:120 40: 80 (34)
Winter (Median of daily values Oct-March)	130 (111)	If smoke less than If smoke more than	60:180 60:130 (51)
Year (Peak) (98 percentile of daily values)	250 (213)	If smoke less than If smoke more than	150:350 150:250 (128)

GUIDE VALUES FOR SMOKE AND SULPHUR DIOXIDE IN MICROGRAMMES PER CUBIC METRE

Reference Period	*Smoke**	*Sulphur Dioxide*
Year (arithmetic mean of daily values)	40 to 60 (34 to 51)	40 to 60
24 hours (daily mean value)	100 to 150 (85 to 128)	100 to 150

*Limit values for smoke as stated in the Directive relate to OECD method: figures in brackets give equivalents for BSI method as used in the National Survey.

between these District Councils and Warren Spring Laboratory in 1981 and steps to secure compliance were discussed. Areas where the limit values were likely to be exceeded were generally found not to have sufficient coverage by smoke control and the primary method of reducing concentrations below the limit values in such areas was the introduction or extension of smoke control. In some cases neighbouring authorities needed to co-ordinate action on adjacent areas for the greatest benefit to be obtained.

In deciding upon future programmes authorities containing such areas of high concentrations were asked to consider whether they could order their priorities within the general restraint on public expenditure so as complete any necessary extension of smoke control by 1983. Where this was not possible authorities should aim to complete any necessary programme as soon as possible after that date and at the latest by 1993.

In determining the annual allocation of maximum Exchequer conributions the Secretary of State had regard to the need to allow for authorities with areas exceeding the limit values to undertake programmes of smoke control to reduce and eventually eliminate those areas.

In a few areas, generally where smoke control was already substantially complete, the main difficulty lay with concentrations of sulphur dioxide above the limit values. Means of reducing these concentrations, other than by smoke control were considered; for example, the introduction of regulations under section 76 of the Control of Pollution Act 1974, to limit the sulphur content of fuel oil. To date, no regulations have been made. No special arrangements other than smoke control have been introduced.

The National Survey of Smoke and Sulphur Dioxide monitoring network was considered to be adequate for the purposes of supplying information which would enable the Government to discharge its obligation to report progress to the European Commission. The Directive prescribed various technical requirements for the measurement and sampling techniques; the methods currently in use in the National Survey are acceptable.

The guide values in the Directive were to be used as long term goals and were not mandatory. The Directive asked that Member States should in the long term endeavour to move towards these guide values. The Department of the Environment asked local authorities to note this objective and, in those areas where pollution was already below the limit values, were asked to consider whether any further progress towards these guide values was desirable and economically feasible.

The Directive also proposed that where it was necessary to limit or prevent a foreseeable increase in pollution following development, zones may be set up in which the guide values could be used to set limits for those zones lower than the limit values. There was a further provision in the Directive for the creation of zones which needed special environmental protection and for which levels below the guide values could be set. The Government stated that it did not see any areas in which it was either desirable or economically feasible for it to set up either type of zone.

The formulae used in calculating the annual statistics for determining compliance with the E.C. Limit Values are detailed below.

a. Winter median

Daily concentrations from the winter period (October to March) are sorted into ascending order of concentration value, $C_1, C_2, C_3, \ldots\ldots, C_i, \ldots\ldots C_N$.

If N is even,

$$WMD = (C_{N/2} + C_{(N/2 + 1)}) /2, \text{ or}$$

if N is odd,

$$WMD = C_{(N/2 + 0.5)}$$

where

WMD = winter median,

C_i = ith daily concentration in the ascending set, and

N = number of results available for the winter period.

b. Yearly median

Same method as for a. above except that daily concentrations for the whole year, instead of the winter period are used.

c. Percentiles

Daily concentrations are sorted into ascending order of concentraation value, $C_1.C_2, C_3, \ldots\ldots C_i, \ldots\ldots C_n$, and the associated percentile value for each concentration value is found from

$$P_i = \left(\frac{1}{N + 1}\right) 100, \quad P_i = \left(\frac{i}{N + 1}\right) 100,$$

where

P_i = the percentile for the ith concentation in the sorted set, that is, P_i% of the concentrations will be equal to or less than C_i, and

N = number of results available for the year.

The concentration value for percentiles are obtained by linear interpolation between the concentration values for the nearest percentile values on either side.

For example, in the sets

$P_1, P_2, \ldots\ldots P_i, \ldots\ldots\ldots 98.8, 99.3, \ldots\ldots P_N$

$C_1, C_2, \ldots\ldots C_i, \ldots\ldots\ldots 150, 160, \ldots\ldots\ldots C_N$

the 99th percentile would be 154 $\mu g.m^{-3}$.

(iii) Compliance with the E.C. Directive limit values in the N.E.D.D.C. area

The monitored pollution levels in the area from 1977 to 1984 were examined and the annual statistics are shown on Table 40.

Guidelines issued by the Warren Spring Laboratory recommend criteria which should be satisfied in deriving the annual statistics. These criteria were applied to the monitored levels and where the criteria was not satisfied, annual statistics were not calculated.

TABLE 40. ANNUAL STATISTICS FOR DAILY DETERMINED SMOKE AND SULPHUR DIOXIDE LEVELS 1977 TO 1984.

Year	Site	Year (Median of daily values) µg.m^{-3}		Winter (Median of daily values Oct.-March) µg.m^{-3}		98^{th} Percentile µg.m^{-3}	
		Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
1977/8	Tupton	15	37	21	37	106	124
	Pilsley	15	51	22	48	107	174
	N.Wingfield	14	53	22	58	99	191
	Holmewood	24	59	28	63	133	179
	Renishaw	25	52	50	66	176	152
1978/9	Tupton	13	41	19	47	108	184
	Pilsley	16	59	23	63	123	210
	N.Wingfield	*	*	*	*	*	*
	Holmewood	21	59	26	70	117	216
	Renishaw	26	53	42	67	154	206
	Barlow	*	*	9	35	*	*
1979/80	Tupton	14	42	22	48	90	135
	Pilsley	17	57	25	67	87	184
	N.Wingfield	*	*	27	64	*	*
	Holmewood	*	*	30	78	*	*
	Renishaw	31	58	58	75	170	172
	Barlow	6	30	9	36	33	104
1980/81	Tupton	*	*	13	47	*	*
	Pilsley	14	50	17	46	77	115
	N.Wingfield	*	*	*	*	*	*
	Holmewood	*	*	20	52	*	*
	Renishaw	*	*	*	*	*	*
	Barlow	5	27	5	25	29	74
	Stonebroom	22	62	34	66	121	148
1981/2	Tupton	*	*	15	57	*	*
	Pilsley	*	*	21	58	*	*
	Holmewood	*	*	*	*	*	*
	Renishaw	26	49	48	68	163	258
	Barlow	*	*	*	*	*	*
	Stomebroom	*	*	47	67	*	*

TABLE ANNUAL STATISTICS FOR DAILY DETERMINED SMOKE AND SULPHUR DIOXIDE LEVELS 1977 TO 1984 continued.

Year	Site	Year (Median of daily values) $\mu g.m^{-3}$		Winter (Median of daily values Oct.-March) $\mu g.m^{-3}$		98th Percentile $\mu g.m^{-3}$	
		Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
1982/3	Tupton	10	37	12	40	70	149
	Pilsley	*	*	*	*	*	*
	Renishaw	*	*	*	*	*	*
	Stonebroom	21	48	34	55	114	135
1983/4	Tupton	*	*	*	*	*	*
	Pilsley	12	47	17	46	73	148
	Renishaw	*	*	*	*	*	*
	Stonebroom	*	*	*	*	*	*

* insufficient results to compute annual statistics.

For the purposes of securing compliance with the limit values, the Warren Spring Laboratory have introduced a lower set of values which they call "approach levels". They provide an indication that the E.C. limit values are in danger of being breached. They are detailed below.

a. Annual median of daily values ($\mu g.m^{-3}$)

If smoke more than 61.

If smoke less than 31 and sulphur dioxide more than 109.

If smoke more than 30 and sulphur dioxide more than 72.

b. Winter median of daily winter values ($\mu g.m^{-3}$)

If smoke more than 100.

If smoke less than 47 and sulphur dioxide more than 163.

If smoke more than 46 and sulphur dioxide more than 118.

c. Daily Values ($\mu g.m^{-3}$)

Approach (1) if either smoke more than 213, smoke more than 128 and sulphur dioxide more than 250 or smoke less than 129 and sulphur dioxide more than 350 for seven days during the year.

Approach (2) if either smoke moe than 193, smoke more than 116 and sulphur dioxide more than 227 or smoke less than 117 and sulphur dioxide more than 318 on more than seven days during the year.

Approach (3) if the annual 98th percentiles for smoke more than 213, or if smoke more than 128 and sulphur dioxide

more than 250 or if smoke less than 129 and
sulphur dioxide more than 350.

Where the statistics indicate that an approach or breach of the limit values has occurred action is initiated by the Warren Spring Laboratory. Joint discussions are held between the local authority in whose area the monitoring gauge is located and advisors from Warren Spring Laboratory. Results of such meetings range from relocation of the monitoring gauge (where the site is not collecting representative data) to the declaration of a smoke control order.

Since the introduction of the E.C. limit values, only two approaches to a breach have occurred in North East Derbyshire. They occurred in 1981 - 1982 at Renishaw and Stonebroom.

(iv) Predictive model for the N.E.D.D.C. area

Significantly high correlation coefficients between daily smoke and sulphur dioxide results obtained from the five monitoring stations contained in the computer data base have been established (see (f),(v) above). From these calculations the results from station three (North Wingfield) indicate that in constructing a correlation field that this station may be used as the reference station.

The purpose of the model would be to predict that approaches or breaches of the E.C. Limit Values may be occurring in other areas using data obtained from the reference station. Should an approach or breach be predicted, a volumetric gauge would be installed at the station for which an approach or breach is indicated.

The correlation coefficients for daily determined smoke and sulphur dioxide levels at stations one, two, four and five with determined levels at station three are shown below.

Smoke

Station one	- Tupton	0.92
Station two	- Pilsley	0.91
Station four	- Renishaw	0.88
Station five	- Holmewood	0.73

Sulphur dioxide

Station one	- Tupton	0.74
Station two	- Pilsley	0.76
Station four	- Renishaw	0.75
Station five	- Holmewood	0.76

To predict pollution levels at stations 1, 2, 4 and 5 (Y_1,Y_2, Y_4 and Y_5) from pollution levels at stations 3 (X) the regression coefficients of pollution levels at stations 1, 2, 4 and 5 on levels at station 3 may be used.

The regression co-efficients of Y_1,Y_2,Y_4 and Y_5 on X

$$= \frac{\Sigma\ (X-\bar{X})(Y-\bar{Y})}{\Sigma\ (X-\bar{X})^2}$$

Where,

X = pollution level at station 3

$\bar{X}$ = mean pollution level at station 3

Y = pollution level at stations 1, 2, 4 and 5

$\overline{Y}$ = mean pollution level at stations 1, 2, 4 and 5.

The data base was interrogated and the following regression coefficients of pollution levels at the four stations on levels determined at station 3 are shown below.

Smoke

Station one - Tupton	0.929
Station two - Pilsley	0.919
Station four - Renishaw	0.505
Station five - Holmewood	0.504

Sulphur dioxide

Station one - Tupton	1.01
Station two - Pilsley	0.799
Station four - Renishaw	0.656
Station five - Holmewood	0.655

To predict levels of smoke and sulphur dioxide at the four stations using data obtained from station 3 the formula shown below may be used.

$$Y = (\overline{Y} - (b.\overline{X})) + (b.X)$$

where,

Y = predicted value of level of pollution,

$\overline{Y}$ = mean pollution level from previous observations (1977 - 79) at one of the four stations,

X = known pollution level at station 3,

$\overline{X}$ = mean pollution level from previous observations (1977 - 1979) at station 3,

b = regression coefficient of Y on X calculated from previous observations (1977 - 1979).

The regression coefficient produces a best estimate based on a large data set. It will provide information on the linear relationship of two variables.

The determined correlation coefficients may be used to set the range of values that may be predicted using the regression coefficients. The correlation coefficient, r, is the proportion of the variability in one variable that can be accounted for by its linear relationship with the other variable. Therefore, if $r = +0.8$ then $r^2 = +0.64$. It can be said that 64% of the variability in one variable (say X), can be accounted for by its linear relationship with the other variable (Y).

Values of r^2 for the four stations (derived from the correlation coefficients for results from the four stations with those from station 3), are shown below.

Smoke

Station one	- Tupton	0.84
Station two	- Pilsley	0.83
Station four	- Renishaw	0.77
Station five	- Holmewood	0.53

Sulphur dioxide

Station one	- Tupton	0.55
Station two	- Pilsley	0.58
Station four	- Renishaw	0.56
Station five	- Holmewood	0.58

Values of Y derived from the formula:

$$Y = (\bar{Y} - (b.\bar{X})) + (b.X).$$

may be set limits, based on variability that can be accounted for by the linear relationships that exists. These limits are shown below.

Smoke

Station one	- Tupton	+ or - 16%
Station two	- Pilsley	+ or - 17%
Station four	- Renishaw	+ or - 23%
Station five	- Holmewood	+ or - 47%

Sulphur dioxide

Station one	- Tupton	+ or - 45%
Station two	- Pilsley	+ or - 42%
Station four	- Renishaw	+ or - 44%
Station five	- Holmewood	+ or - 42%

(v) Use of the predictive model

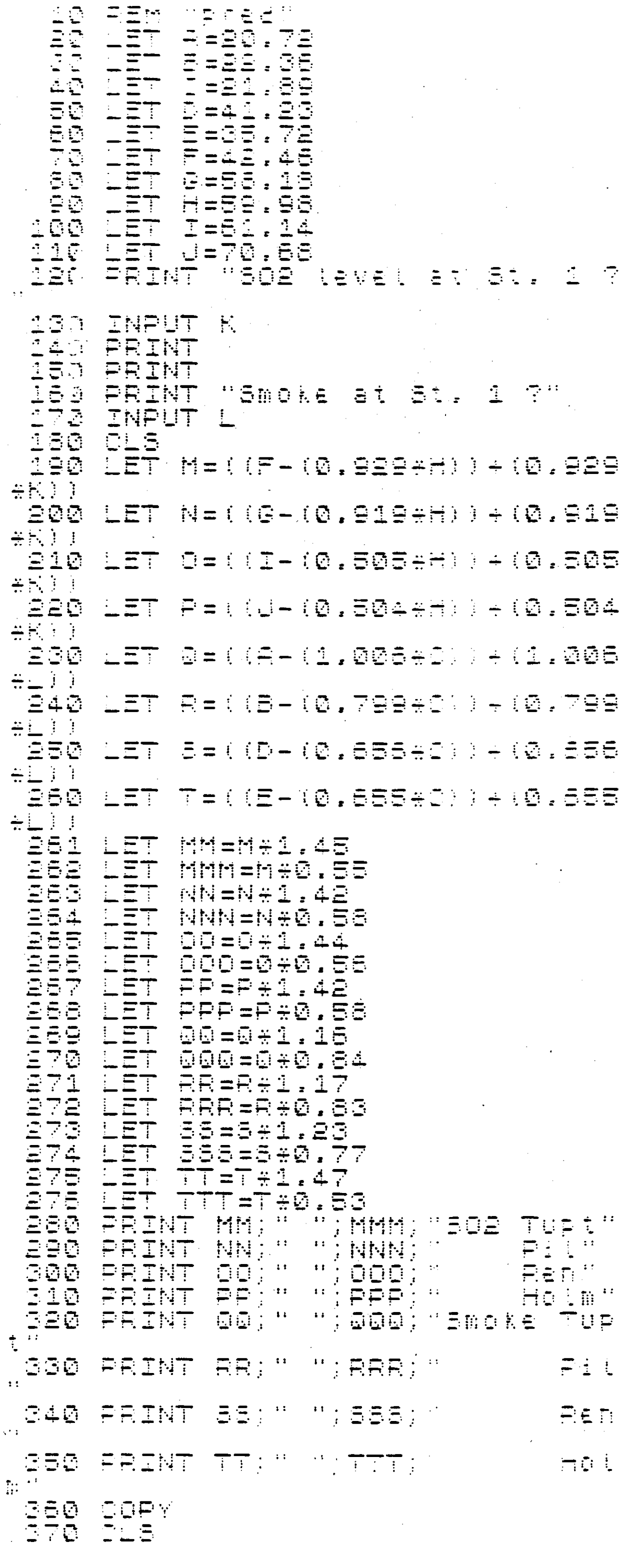
Daily concentrations of smoke and sulphur dioxide are calculated from the amounts of titre added to exposed hydrogen perioxide (sulphur dioxide), the reflectance of the expoed filter paper (smoke) and the daily air flow.

A micro computer based programme to calculate these daily values was written and is shown in Appendix F. An additional sub routine was written for use with data from the North Wingfield (station 3), monitoring site to predict ranges of pollution level which may be occurring at the Tupton, Pilsley, Renishaw and Holmewood sites. This sub routine is shown in Table 41. The sub routine variables are shown below.

MM = predicted max. SO_2 conc. Tupton
MMM = " min. " " "
NN = " max. " " Pilsley
NNN = " min. " " "
OO = " max. " " Renishaw
OOO = " min. " " "
PP = " max. " " Holmewood
PPP = " min. " " "
QQ = " max. smoke conc. Tupton
QQQ = " min. " " "
RR = " max. " " Pilsley
RRR = " min. " " "
SS = " max. " " Renishaw
SSS = " min. " " "
TT = " max. " " Holmewood
TTT = " min. " " "

Due to a rationalisation of the monitoring network which was carried out before this work was completed, the volumetric gauge at

TABLE 41. PREDICTIVE MODEL SUB ROUTINE.



```
  10 REM "pred"
  20 LET A=20.72
  30 LET B=22.35
  40 LET C=21.89
  50 LET D=41.23
  60 LET E=35.72
  70 LET F=42.45
  80 LET G=58.18
  90 LET H=52.98
 100 LET I=61.14
 110 LET J=70.68
 120 PRINT "SO2 level at St. 1 ?
"
 130 INPUT K
 140 PRINT
 150 PRINT
 160 PRINT "Smoke at St. 1 ?"
 170 INPUT L
 180 CLS
 190 LET M=((F-(0.929*H))+(0.929
*K))
 200 LET N=((G-(0.919*H))+(0.919
*K))
 210 LET O=((I-(0.505*H))+(0.505
*K))
 220 LET P=((J-(0.504*H))+(0.504
*K))
 230 LET Q=((A-(1.006*C))+(1.006
*L))
 240 LET R=((B-(0.799*C))+(0.799
*L))
 250 LET S=((D-(0.655*C))+(0.655
*L))
 260 LET T=((E-(0.555*C))+(0.555
*L))
 261 LET MM=M*1.45
 262 LET MMM=M*0.55
 263 LET NN=N*1.42
 264 LET NNN=N*0.58
 265 LET OO=O*1.44
 266 LET OOO=O*0.56
 267 LET PP=P*1.42
 268 LET PPP=P*0.58
 269 LET QQ=Q*1.16
 270 LET QQQ=Q*0.84
 271 LET RR=R*1.17
 272 LET RRR=R*0.83
 273 LET SS=S*1.23
 274 LET SSS=S*0.77
 275 LET TT=T*1.47
 276 LET TTT=T*0.53
 280 PRINT MM;" ";MMM;"SO2 Tupt"
 290 PRINT NN;" ";NNN;"     Pil"
 300 PRINT OO;" ";OOO;"     Ren"
 310 PRINT PP;" ";PPP;"     Holm"
 320 PRINT QQ;" ";QQQ;"Smoke Tup
t"
 330 PRINT RR;" ";RRR;"        Pil
"
 340 PRINT SS;" ";SSS;"        Ren
"
 350 PRINT TT;" ";TTT;"        Hol
m"
 360 COPY
 370 CLS
```

North Wingfield was withdrawn in January, 1984. However the prediction model was tested with available data (not used in the calculation of the regression and correlation co-efficients) and more than 90% of the monitored levels were contained within the higher limit of the predicted range.

It may be concluded that this predictive model will indicate any approaches to a breach of the E.C. Limit Values at Tupton, Pilsley, Renishaw and Holmewood.

(vi) Proposed smoke and sulphur dioxide monitoring and modelling programme

The objective of smoke and sulphur dioxide air quality management in North East Derbyshire is to secure compliance with the E.C. Limit Values. Monitored levels have indicated a reduction in atmospheric concentrations of smoke and sulphur dioxide following the implementation of smoke control orders and a reduced monitoring network and the introduction of a simple predictive model will indicate whether there is an approach occurring to a Limit Value.

The proposed modelling and monitoring network is outlined below.

a. Pilsley - volumetric gauge providing data for the National Survey (Warren Spring Laboratory).
b. Renishaw - as a.
c. Stonebroom - as a.
d. North Wingfield - volumetric gauge providing data for the predictive model to indicate approaches to a breach of the Limit Values at Tupton and

Holmewood. Comparisons of predicted and monitored levels at Pilsley and Renishaw will be used to test the continued validity of the model.

(a) INTRODUCTION

Because of reports of increased acidity in precipitation in Europe and North America, extensive measurement programmes aimed at investigating this subject have been initiated in many countries. In 1980, Warren Spring Laboratory invited a small group of United Kingdom scientists active in acid rain research to review available data for this country. Their terms of reference were as follows:

a. to examine the distribution of acidity in precipitation in the United Kingdom on the basis of existing measurements,

b. to assess the quality of available data for precipitation acidity in northern Europe and to examine the evidence for trends with time;

c. to assess the need for further research.

This group of scientists published their findings[74] in December, 1983.

North East Derbyshire District Council (and its predecessors), have monitored the acidity of rainfall at a number of sites, some of which have been in continuous operation since 1950.

The object of this part of the project is to examine the data collected in the North East Derbyshire Area, compare it to data for the rest of the United Kingdom and to suggest/propose a long term monitoring programme for the measurement of the acidity of precipitation.

(i) Rainfall Acidity

The pH of rainwater does not lie near the neutral value of 7.0

of course, as carbon dioxide in the atmosphere combines with rainwater to form a weak acid solution, sometimes referred to as carbonic acid. The pH of deionised water in equilibrium with carbon dioxide is 5.6 and acid rain is often considered to be rain with a pH lower than this value. Charlson and Rodhe[113] have shown that pH values might range from 4.5 to 5.6 due to the variability of the natural sulphur cycle. Measurements of rainfall acidity are not available for the period prior to the industrial revolution, however, evaluation of data from five remote areas led Galloway et al,[114] to conclude that, in the absence of human activities, the lower limit of the natural mean pH of rainwater is probably 5.0.

(b) MEASUREMENT

(i) Sample Collection

The objective is to collect precipitation immediately prior to its contact with ground surfaces. The transfer to substances to the earths surface via precipitation is called wet deposition. Typical precipitation gauges[42] are also subject to the fallout of large particles, impaction of small particles and adsorption of gases which are collectively called dry deposition. Chemical reactions in the gauge collection bottle may alter the pH of the precipitation sample.

"Wet-only" precipitation gauges have been introduced which only open during periods of precipitation and where the sample is refrigerated to help maintain sample stability. Most of the available United Kingdom data, however, has been obtained from "bulk" or combined wet and dry deposition collectors.

(ii) Sampling Errors

Differences in the composition of the falling rain and collected sample can arise due to number of factors.

a. Contamination of the collection gauge

Sample contamination by particles and gases may increase or decrease the acidity of collected rainfall. Dry deposition of sulphur dioxide gas and sulphate containing particles onto a continuously exposed Pyrex rain collector may contribute between 13% and 35% of the non-marine sulphur collected[115]. Martin and Barber[116] found that similar dry deposition on polythene collectors may account for up to 40% of the sulphur in the collected sample.

Dry deposition of sulphur dioxide gas and sulphate containing particles increases the acidity of the sample. This effect may be reduced by dry deposition of alkaline particles and ammonia. The effects of different collector materials on rainfall sample acidity has been investigated[117] and it was concluded that the use of "plastics" increased sample acidity by about 15%.

b. Collection Procedures

The length of the sampling period also influences measured acidity, shorter periods leading to greater acidity[118], the difference between daily and monthly collections at the same site being about 15%. The differences were attributed to the additional deposition of alkaline particles in the monthly collectors.

c. Comparison of Adjacent Bulk and Wet-Only Collectors

The performance of bulk precipitation collectors and wet-only collectors have been compared by several groups of research workers[119,120,121]. The results of such studies indicate that the differences observed between the two types of collector vary considerably with location and the pollutant species under consideration. In general, bulk collectors are subject to higher dry deposition rates, but this component, as a percentage of the total, for different species, has not been accurately defined.

(c) ACID DEPOSITION IN THE UNITED KINGDOM[74]

The above report published by the Department of the Environment in December, 1983, recognised the inherent sampling errors in previous acid rain monitoring. It concluded that because of differing sampling and analytical methods involved there was insufficient comparative information to allow the application of correction factors to the subsets of data. To allow an examination of the available data to be carried out it applied certain criteria.

(i) Criteria for Data Acceptance

Data from 91 "rural" sites in the United Kingdom were considered initially. The following criteria were applied to the data.

a. Only data from sites with a sampling period of one month or less were used. If more than two months data were missing or if two consecutive months data were missing for any one year at a site then that year was rejected.

b. Evidence of winter alkalinity (defined as weighted mean pH greater than 6.0 for any monthly sample in the period October to March) has been found to be a useful criterion for assessing the influence of local alkaline sources[124]. Sites exhibiting persistent winter alkalinity were rejected.

c. Sites were considered to be unsatisfactory due to local sources of pollutants, for example, domestic fires, sewage treatment works or agricultural practices such as spreading nitrogen containing fertilisers. Guidelines for the location of rural sites have been proposed by Martin et al[118]. While not all the remaining sites entirely met their criteria (100 m from a single house, 1 km from any village, and 10 km from any town or industrial site), some were considered to be representative of the rural area in which they were located and not unduly influenced by local sources.

After application of these criteria 38 sites remained.

(ii) Basic Data Set

The basic data set used in the study consisted of the annual mean acidity values measured at the sites. They were weighted for precipitation according to the formula:

$$c = \frac{\sum c_i p_i}{\sum p_i}$$

c = the weighted mean hydrogen ion concentration,

c_i = the hydrogen ion concentration in an individual sample,

p_i = the corresponding rainwater volume.

The annual mean acidity values for the 38 sites for 1978-1980 are shown in Table 42. A conversion table relating hydrogen ion concentrations in μeq litre^{-1} to pH values is shown in Table 43.

(iii) Measurements in the N.E.D.D.C. Area

Commencing in the early 1950's, many of the local authorities which were amalgamated in 1974 to form the North East Derbyshire District Council, established monitoring sites for the determination of deposited matter. The British Standard Deposit Gauge[42] was used and the results were collated by the Warren Springs Laboratory as part of a National Survey of Deposited Matter.

Many of the gauge sites were established to monitor specific emission sources rather than to provide data on "background" levels.

The sampling errors of the gauge are considerable (see Chapter 3,A (i) above). As part of the routine examination of the contents of the collection bottle a pH determination was carried out.

The sites in the N.E.D.D.C. area were established to monitor fall-out of grit and dust from a number of sources.

(1) Wingerworth Church - Avenue Carbonisation Plant (coke ovens) half a mile to the east.

(2) 107 St. Lawrence Road, North Wingfield - Clay Cross Iron and Foundries Ltd., (hot blast cupola furnace) half a mile to the south-west.

TABLE 42. ANNUAL PRECIPITATION WEIGHTED MEAN ACIDITY AND RAINFALL DATA FOR RURAL SITES 1978 - 1980 (H^+ μ eq litre^{-1})[74].

				1978		1979		1980	
No.	Site Name	Map Reference	Altitude (m)	mm	H^+	mm	H^+	mm	H^+
1	Lerwick	HU 453 397	91	770	39	1000	25	–	
2	Bettyhill	NC 708 624	30	804	33	1014	19	984	16
3	Inverpolly	NC 075 145	30	1189	21	1410	22	1365	20
4	Nigg Bay	NH 795 738	5	–		716	25	835	33
5	Forest of Deer	NJ 976 510	100	–		846	47	895	59
6	Broadford	NG 628 247	15	1808	23	2329	24	2225	17
7	Achnagoichan	NH 914 082	300	–		962	36	873	25
8	Banchory	NO 680 988	140	891	56	775	55	919	65
9	Lochnagar	NO 274 858	500	965	44	909	48	872	65
10	Torlundy	NN 147 773	30	–		1756	23	1915	34
11	Faskally	NN 919 600	150	910	48	851	46	913	57
12	Lephinmore	NS 005 915	300	1831	49	1757	29	1816	32
13	Bush	NT 246 638	250	792	41	779	45	844	58
14	Whiteadder	NT 663 633	230	–		770	46	737	68
15	Eskdalemuir 1	NT 234 028	243	1405	34	1601	41	1538	58
16	Eskdalemuir 2	NT 235 028	242	–		1522	33	1352	63
17	Redesdale	NY 833 954	260	794	56	821	43	804	78
18	Glentrool	NX 358 785	100	1546	38	1527	22	1799	29
19	Cairnsmore of Fleet	NX 530 638	320	–		2000	38	–	
20	Windermere	SD 363 974	100	1219	37	1526	38	1765	50
21	Grimsby 3	TA 245 059	21	–		708	53	717	50
22	Donna Nook	TF 432 992	4	621	51	627	33	643	46
23	Sheffield 79	SK 328 965	225	744	47	644	54	597	67
24	Mablethorpe	TF 509 833	2	566	61	535	34	546	51
25	Croft	TF 513 628	2	–		–		548	44
26	Tattershall	TF 191 559	2	670	66	653	47	740	47
27	Holme-next-the-Sea	TF 714 450	4	546	58	530	39	546	52
28	Kirton	TF 306 377	3	551	65	525	44	549	62
29	Bottesford	SK 797 376	32	525	69	557	46	600	45
30	Skillington	SK 893 246	130	604	64	619	51	653	46
31	Long Sutton	TF 427 222	3	536	58	532	33	589	46
32	Exton	SK 912 107	126	556	53	588	38	563	42
33	Bwa-Banc	SN 721 810	340	–		1421	20	–	
34	Belle Vue	SN 617 737	183	–		1185	21	–	
35	Chilton	SU 468 861	130	629	43	687	40	628	37
36	Bracknell	SU 846 664	70	589	77	–		–	
37	Tillingbourne	TQ 140 435	236	917	71	1181	66	1091	90
38	Goonhilly	SW 724 212	108	–		–		1095	40

TABLE 43. CONVERSION OF pH VALUES TO MICROEQUIVALENTS HYDROGEN ION PER LITRE.

$$\mu \text{ eq } H^{+}.\text{litre}^{-1} = \text{antilog } (6.0 - \text{pH})$$

pH	μ eq H^{+}.litre^{-1}
3.0	1000
3.1	794
3.2	631
3.3	501
3.4	398
3.5	316
3.6	251
3.7	200
3.8	158
3.9	126
4.0	100
4.1	79
4.2	63
4.3	50
4.4	40
4.5	32
4.6	25
4.7	20
4.8	16
4.9	13
5.0	10
5.1	8
5.2	6
5.3	5
5.4	4
5.5	3
5.6	3
5.7	2
5.8	2
5.9	1

(3) Smeekley Borehole, Holmesfield - "background" fallout levels at a location five miles away from any industrial emission source.

(4) Heath School, Heath - coal carbonisation plant at Heath, one mile to the south-west.

(5) 108 Longedge Lane, Wingerworth - Avenue Carbonisation Plant (coke ovens) half a mile to the east.

(6) Crowhole Reservoir, Barlow - "background" fallout levels at a location three and a half miles away from any industrial emission source.

(7) Field Avenue, Renishaw - three blast furnaces situated a quarter of a mile to the north. The furnaces were subsequently replaced by a pair of cold blast cupola furnaces.

(8) New Palace Cinema, Holmewood - Heath coal carbonisation plant.

(9) 150 Main Road, Morton - Morton Colliery boiler house.

(10) Lea Road, Dronfield - two cold blast cupola furnaces a quarter of a mile to the east.

(11) Callywhite Lane, Dronfield - two cold blast cupola furnaces half a mile to the west.

(12) Stonelow Depot, Dronfield - two cold blast cupola furnaces, half a mile to the south-west.

(13) Top Farm, Spinkhill - roadstone plant, half a mile to the south-west.

(14) Smithy Brook Treatment Works, Renishaw - roadstone plant, quarter of a mile to the south.

(15) Mount St. Mary's College, Spinkhill - roadstone plant, half a mile to the south-west.

(16) West Lea, Holmewood - nearby coal carbonisation plant.

(17) Allotment Site, Circular Drive, Renishaw - two cold blast cupola furnaces, quarter of a mile to the north-east.

(18) The Greenway, Wingerworth - Avenue Carbonisation Plant, half a mile to the north.

(19) South Bank, Derby Road, Wingerworth - Avenue Carbonisation Plant, half a mile to the north.

(20) Padley Wood Lane, Pilsley - "background" fallout levels remote from industrial emission sources.

(21) 89 Wingfield Road, Tupton - two hot blast cupolas, one and a half miles to the south.

(22) North Wingfield Road, Grassmoor - opencast coal extraction site, 300 metres to the east.

(23) Corbriggs, Winsick - opencast coal extraction site, two hundred metres to the east.

Applying the criteria for data acceptance outlined in (1) above, sites at Smeekley Borehole, Holmesfield and Crowhole Reservoir, Barlow may be considered as representative rural sites. Data at the first site were collected from August, 1978 to May 1981 and from the second site from September, 1951 to January 1962.

The annual mean acidity values, weighted for precipitation, for these two sites were calculated and are shown on Table 44.

(d) TRENDS IN PRECIPITATION ACIDITY

(i) Measurements in the United Kingdom

Because of short term fluctuations in precipitation composition extended monitoring periods of ten years or longer are necessary to reveal trends. Measurements in the past usually involved inappropriate collection methods and poor analytical precision. These problems tend to become worse with successive evaluation of earlier and earlier data.

The study of precipitation composition throughout Great Britain was reported by the First Alkali Inspector, R. A. Smith, 1872[125]. Smith gave careful consideration to the problems of collecting and analysing precipitation and was aware of the importance of the dry deposition of particles. Because the analytical methods which were used were not described in detail comparisons with present day data are difficult to make. Schwela[126], however has estimated pH values for precipitation from Smith's data. Calculated values for rural areas are in the range pH 5.1 + or - 0.5 (3 - 25 μeq H^+litre^{-1}) and in urban areas pH 3.4 to 3.9 (125 - 400 μeq. H^+litre^{-1}).

Collection and analysis of rainfall has been carried out at Rothamstead, Hertfordshire for the last 120 years. Brindlecombe and Pitmen[127] evaluated the Rothamstead data together with deposit gauge

TABLE 44. ANNUAL PRECIPITATION WEIGHTED MEAN ACIDITY DATA FOR THE TWO RURAL SITES IN N.E.D.D.C. (H^+ µ eq $litre^{-1}$)

Site	Year	H^+
Crowhole Reservoir, Barlow.	1952	0.0
	1953	1.0
	1954	9.6
	1955	0.5
	1956	2.0
	1957	2.1
	1958	16.0
	1959	13.8
	1960	13.4
	1961	16.4
Smeekley Borehole, Holmesfield.	1979	47.0
	1980	42.0

observations at nearby sites. They concluded that the deposition and seasonal variation of chloride and ammonia have remained relatively constant over the last 120 years, whereas nitrate appears to have increased approximately five-fold over the same period[128]. Increased deposition during the spring months suggests that increased nitrate depositions may be associated with the application of nitrogenous fertilisers which have increased during this century. Measurements of pH were started at Rothamstead in 1930. Precipitation weighted H^+ concentrations between 1930 and 1950 averaged about 20 μ eq.litre^{-1}, between 1956 and 1970 averaged about 75 μ eq.litre^{-1} and between 1970 and 1977 averaged 85 μ eq.litre^{-1}. Because of changes of site operational and analytical procedures, the suggestion of a trend must be treated with caution.

(ii) Measurements in the N.E.D.D.C. Area

The data from the two rural sites in the North East Derbyshire District Council area suggest a trend of increasing precipitation acidity (see Table 44 above). The two sites are located in similar areas and are geographically four miles apart. Neither are in close proximity to domestic or industrial emission sources or agricultural activities involving the application of nitrogen containing fertilisers. Analysis of the collected material and especially pH determination was undertaken by different analysts. Samples collected from Crowhole reservoir were analysed by the then Public Analysts, A. H. Allen and Partners, Surrey Street, Sheffield, those from Smeekley Borehole by the County Analyst, Derbyshire County Council, County Offices, Matlock, Derbyshire.

A. H. Allen and Partners moved to new premises at 342 Coleford Road, Darnall, Sheffield in the early 1980's. A member of their staff who was involved with standard Deposit Gauge analyses in the 1950's and 1960's stated that pH determinations at that time were carried out colorimetrically using an indicator. They replaced this method of determination with a pH meter in the middle to late 1960's. He stated that no significant changes in determined pH values were noted when they changed their analytical method.

The County Analyst's Department, Derbyshire County Council have used a pH meter for determinations since 1972. A member of their staff also stated that no significant changes in determined pH values were noted when they changed their analytical method.

(e) FUTURE MONITORING OF PRECIPITATION ACIDITY

Gauges at the two rural sites were removed due to changing monitoring priorities and it is proposed that a gauge be re-instated at the Crowhole Reservoir site. The Smeekley Borehole Site has access difficulties; it is approached by a steep, winding, single carriageway cart track. The previously manned water extraction works is now unoccupied which would pose security problems.

Instead of a bulk collector, a wet-only sampler would be installed at Crowhole Reservoir. The use of a moisture sensor to trigger the removal of a lid to a collection funnel would ensure that "wet deposition" only is collected.

6. FUTURE AIR POLLUTION MONITORING AND MODELLING IN THE N.E.D.D.C. AREA

(a) INTRODUCTION

To fulfil the air quality management function of the North East Derbyshire District Council would involve the establishment of a monitoring network and modelling technique for the determination and prediction of ground level concentrations of sulphur dioxide and smoke in the populated areas of the district, a technique for the evaluation of localised dust sources, determination of trends in precipitation acidity and the monitoring of levels of atmospheric lead.

(b) RECOMMENDATIONS

Based upon the results of this research programme a monitoring regime is proposed.

(i) Ground level concentrations of Sulphur Dioxide and smoke

With the objective of obtaining representative data which would indicate compliance with the E.C. Limit Values a modelling and monitoring network is outlined below.

(a) Pilsley - volumetric gauge providing data for the National Survey (Warren Spring Laboratory).

(b) Renishaw - as a.

(c) Stonebroom - as a.

(d) North Wingfield - volumetric gauge providing data for the predictive model to indicate approaches to a breach of the Limit Values at Tupton and Holmewood. Comparisons of predicted and monitored levels at Pilsley and Renishaw will be used to test the continued validity of the model.

(ii) Evaluation of Localised Dust Sources

With the objective of identifying and evaluating localised sources of dust, directional dust gauges be installed and the amounts of collected material assessed using the developed model. The main application of this monitoring and modelling technique would be to evaluate the environmental impact of open cast coal extraction.

(iii) Precipitation Acidity

With the objection of monitoring long term trends in precipitation acidity, a "wet-only" collector be installed at Crowhole Reservoir, Barlow.

(iv) Atmospheric Lead

Lead filtration gauges will be installed for periods of one year at locations within the N.E.D.D.C. area. Sites will include children's playgrounds and other locations where children may be exposed to atmospheric lead and suspected "hot spots" where industrial emissions may be producing elevated lead in air concentrations. Action may be taken where E.C. Air Quality Standards are breached.

A. ATMOSPHERIC LEAD MONITORING RESULTS.

Atmospheric Lead Monitoring (Schedule of Results)

Gauge Sites:

Renishaw Foundary, Renishaw
Stonelow Road, Dronfield
Sherwood Road, Killamarsh
North Wingfield Road, Grassmoor
Chesterfield Road, Shirland

(1) Renishaw Foundry, Renishaw

Date (week ending date of monitoring period)	Atmospheric Lead Concentration (microgrammes per cubic metre)
2.2.81	0.37
9.2.81	0.30
16.2.81	0.12
23.2.81	0.18
2.3.81	0.31
9.3.81	0.18
16.3.81	0.089
23.3.81	0.0
30.3.81	0.55
6.4.81	0.12
13.4.81	0.24
* 27.4.81	0.09
* 11.5.81	0.092
18.5.81	0.12
1.6.81	0.16
8.6.81	0.0
15.6.81	0.0
22.6.81	0.0
29.6.81	0.0
6.7.81	0.0
13.7.81	0.14
20.7.81	0.17
27.7.81	0.0
3.8.81	0.49
10.8.81	0.64
17.8.81	0.55
24.8.81	0.0
28.8.81	0.91
2.9.81	0.0
7.9.81	0.48
14.9.81	0.18
21.9.81	0.0
28.9.81	0.67
5.10.81	0.89
12.10.81	0.007
19.10.81	0.56
26.10.81	0.77
2.11.81	0.63
9.11.81	1.55

Date (week ending date of monitoring period)	Atmospheric Lead Concentration (microgrammes per cubic metre)
16.11.81	0.40
23.11.81	0.57
30.11.81	0.95
7.12.81	0.32
14.12.81	0.46
21.12.81	0.33
28.12.81	0.59
4.1.82	0.82
11.1.82	0.30
18.1.82	0.92
25.1.82	0.29
1.2.82	0.53
8.2.82	NR
15.2.82	0.68
22.2.82	0.37
1.3.82	0.61
8.3.82	0.59
15.3.82	0.23
22.3.82	0.58
29.3.82	0.86
5.4.82	0.88
8.4.82	0.58
15.4.82	0.57
19.4.82	0.12
26.4.82	0.05
* 10.5.82	0.33
17.5.82	0.94
24.5.82	0.72
7.6.82	0.17
14.6.82	0.05
21.6.82	1.05
28.6.82	0.47
5.7.82	0.95
12.7.82	0.33
19.7.82	1.15
26.7.82	0.88
2.8.82	0.63
9.8.82	0.0
16.8.82	2.0
23.8.82	0.0
6.9.82	Holed Filter
13.9.82	4.03
20.9.82	0.49
27.9.82	Holed Filter
4.10.82	
11.10.82	Holed Filter
18.10.82	0.42
25.10.82	0.31
1.11.82	0.22
8.11.82	1.28

Date (Week ending date of Monitoring Period)	Atmospheric Lead Concentration (Microgrammes per cubic metre)
15.11.82	Holed Filter
22.11.82	0.35
29.11.82	0.33
6.12.82	0.71
13.12.82	0.27
5.1.83	0.15
10.1.83	0.52
17.1.83	0.31
28.2.83	0.63 0
28.3.83	1.3 0
25.4.83	2.5 0
6.6.83	2.24 0
4.7.83	0.4 0
1.8.83	0.3 0
5.9.83	0.21
3.10.83	0.05
31.10.83	0.26
28.11.83	0.38
16.1.84	0.26
30.1.84	Holed Filter
27.2.84	0.3
26.3.84	0.16
30.4.84	0.18
4.6.84	Holed Filter
2.7.84	0.14
30.7.84	0.24
10.9.84	Holed Filter
1.10.84	0.24
29.10.84	0.14
22.1.85	0.52

(2) Stonelow Road, Dronfield

Date (week ending date of monitoring period)	Atmospheric Lead Concentration (microgrammes per cubic metre)
16.10.81	–
26.10.81	0.52
2.11.81	0.68
9.11.81	0.92
16.11.81	0.69
23.11.81	1.15
7.12.81	0.08
14.12.81	0.43
21.12.81	0.32
30.12.81	–
4.1.82	0.66
11.1.82	0.85
18.1.82	0.31
25.1.82	0.15
1.2.82	0.15
8.2.82	0.5
15.2.82	0.38
22.2.82	0.54
1.3.82	0.28
8.3.82	0.8
15.3.82	0.36
22.3.82	0.20
29.3.82	0.49
5.4.82	0.50
8.4.82	1.01
15.4.82	0.47
19.4.82	0.52
26.4.82	0.51
* 10.5.82	0.40
17.5.82	1.25
24.5.82	1.05
7.6.82	0.73
14.6.82	0.28
21.6.82	0.18
28.6.82	0.83
5.7.82	1.05
12.7.82	0.54
19.7.82	0.15
26.7.82	0.61
16.8.82	0.39
23.8.82	0.35
6.9.82	0.27
13.9.82	0.32
20.9.82	0.72
27.9.82	0.21
4.10.82	
11.10.82	0.28
18.10.82	0.31

Date (week ending date of monitoring period)	Atmospheric Lead Concentration (microgrammes per cubic metre)
25.10.82	0.28
1.11.82	0.17
8.11.82	1.23
15.11.82	0.31
22.11.82	0.21
29.11.82	0.4
6.12.82	0.0
13.12.82	0.0
5.1.83	0.42
10.1.83	0.33
17.1.83	0.21
28.2.83	1.68 ø
28.3.83	0.52 ø
25.4.83	3.7 ø
6.6.83	0.1
4.7.83	0.25 ø
1.8.83	0.17 ø
5.9.83	0.14
3.10.83	0.15
31.10.83	0.04
28.11.83	0.11
30.1.84	0.15
27.2.84	0.25
26.3.84	0.4
30.4.84	0.083
4.6.84	0.14
2.7.84	0.19
30.7.84	0.26
10.9.84	0.21
1.10.84	0.32
29.10.84	0.30
22.1.85	0.53

(3) Sherwood Road, Killamarsh

Date	Atmospheric Lead Concentration
(week ending date of monitoring period)	(microgrammes per cubic metre)
21.12.81	0.22
30.12.81	0.36
4.1.82	0.24
11.1.82	0.46
18.1.82	0.79
25.1.82	0.21
8.2.82	0.39
15.2.82	0.38
22.2.82	0.46
1.3.82	0.66
8.3.82	0.32
15.3.82	0.47
(No monitoring 15.3.82 to 19.4.82)	
26.4.82	0.29
* 10.5.82	0.22
17.5.82	0.99
24.5.82	0.15
7.6.82	0.52
14.6.82	0.26
21.6.82	0.15
28.6.82	0.28
5.7.82	0.42
12.7.82	0.05
19.7.82	0.22
26.7.82	0.61
2.8.82	NR
9.8.82	0.34
16.8.82	0.0
23.8.82	0.0
6.9.82	2.15
13.9.82	0.81
20.9.82	0.63
27.9.82	0.38
4.10.82	0.49
11.10.82	0.15
18.10.82	0.07
25.10.82	
1.11.82	0.23
8.11.82	0.61
15.11.82	0.23
22.11.82	0.23
29.11.82	0.22
6.12.82	0.0
13.12.82	0.0
5.1.83	0.15
10.1.83	0.15
17.1.83	0.21
28.2.83	0.27 ✓
28.3.83	1.02 ✓
25.4.83	0.94 ✓

Date (week ending date of monitoring period)	Atmospheric Lead Concentration (microgrammes per cubic metre)
6.6.83	1.35 Ø
4.7.83	0.17 Ø
1.8.83	0.18 Ø
5.9.83	0.5
3.10.83	0.25
31.10.83	0.21
28.11.83	0.12
2.1.84	0.18
30.1.84	0.14
29.2.84	0.10
26.3.84	0.39
30.4.84	0.027
4.6.84	0.42
2.7.84	0.16
30.7.84	0.05
29.8.84	No Result
1.10.84	0.21
29.10.84	0.14
22.1.85	0.37

(4) North Wingfield Road, Grassmoor

Date (week ending date of monitoring period)	Atmospheric Lead Concentration (microgrammes per cubic metre)
6.2.82	-
22.2.82	0.28
1.3.82	0.24
8.3.82	0.21
15.3.82	0.38
22.3.82	0.18
29.3.82	0.75
8.4.82	0.43
15.4.82	0.38
19.4.82	0.64
26.4.82	0.43
* 10.5.82	0.34
17.5.82	0.44
24.5.82	0.15
14.6.82	0.38
21.6.82	0.51
28.6.82	0.65
5.7.82	NR
12.7.82	0.25
19.7.82	0.59
26.7.82	0.38
2.8.82	-
23.8.82	0.78
6.9.82	0.15
13.9.82	0.93
20.9.82	0.47
27.9.82	0.23
4.10.82	0.35
11.10.82	No Stain
18.10.82	0.2
25.10.82	0.24
1.11.82	-
8.11.82	1.34
15.11.82	0.31
22.11.82	0.23
6.12.82	0.17

Gauge removed 6.12.82

(5) Chesterfield Road, Shirland

Date (week ending date of monitoring period)	Atmospheric Lead Concentration (microgrammes per cubic metre)
8.2.82	-
22.2.82	0.27
1.3.82	0.36
8.3.82	0.34
15.3.82	0.22
22.3.82	0.62
29.3.82	0.61
* 19.4.82	0.42
26.4.82	0.48
* 10.5.82	0.30
17.5.82	0.45
24.5.82	0.38
7.6.82	0.43
14.6.82	0.17
21.6.82	0.45
28.6.82	0.61
5.7.82	0.38
12.7.82	0.27
19.7.82	0.65
26.7.82	-
2.8.82	-
16.8.82	0.15
23.8.82	0.25
6.9.82	0.52
13.9.82	0.33
20.9.82	0.29
27.9.82	0.33
4.10.82	0.35
11.10.82	0.21
18.10.82	0.2
25.10.82	
1.11.82	0.13*
8.11.82	0.96
15.11.82	0.32
22.11.82	0.45
29.11.82	0.26
6.12.82	0.28
13.12.82	0.0
5.1.83	0.2
10.1.83	0.1
17.1.83	0.32
28.2.83	0.32 Ø
28.3.83	0.7 Ø
25.4.83	0.13 Ø
6.6.83	0.24

Date (Week Ending Date of Monitoring Period)	Atmospheric Lead Concentration (Microgrammes Per Cubic Metre)
4.7.83	0.22 0
18.7.83	0.23 *
5.9.83	0.13
3.10.83	0.08
14.11.83	0.27
28.11.83	0.44
28.11.83 to 12.12.83	No results
30.1.84	0.07
27.2.84	0.19
26.3.84	0.08
30.4.84	0.12
4.6.84	0.12
2.7.84	0.37
13.8.84	1.67
1.10.84	0.13
29.10.84	0.19
22.1.85	0.34

* = 2 weeks
NR = No Reading
0 = Monthly means

B. METEOROLOGICAL REPORT FORMS.

Furnace Hill Opencast Site - Automatic Weather Station.

```
2327.03.357 1513.07.
2234.00.134 1013.05.
2141.00.214 1013.06.
2047.00.312 1012.07.
1954.04.335 1012.08.
1901.00.145 1012.07.
1807.00.071 1011.08.
1714.00.103 1010.09.
1621.03.292 1010.10.
1527.02.036 1010.11.
1434.04.258 1010.13.
1341.05.289 1010.14.
1247.03.325 1009.14.
1154.04.336 1009.15.
1101.04.338 1009.14.
1007.05.3   1009.12.
0914.06.187 1008.12.
0621.08.229 1008.12.
0727.04.232 1008.11.
0034.06.170 1008.10.
0541.05.175 1007.09.
0447.07.233 1008.10.
0354.15.271 1007.11.
0301.14.265 1007.11.
0207.19.285 1007.11.
0151.21.278 1007.11.
0141.21.774 1007.11.
0114.17.259 1008.11.
0109.23.252 1008.11.
0103.24.259 1008.11.
0058.26.256 1008.11.
0053.23.278 1008.11.
0047.23.257 1008.11.
0042.25.257 1008.12.
0037.25.283 1008.12.
0031.23.276 1006.12.
0025.24.285 1008.12.
0021.23.277 1008.12.
0015.22.258 1008.12.
0010.22.263 1008.12.
```

MON 5TH DEC

Time — Wind Speed m.p.h. — Wind Direction — Pressure — Temp.

WIND RECORDINGS

Taken at the Carbonization Research Centre
of the British Carbonization Research Association

MONTH MARCH 1982

Date	0.600h		10.00h		14.00h		22.00h		Av. for day	Max. for day
	Direction	Speed	Direction	Speed	Direction	Speed	Direction	Speed		
1	SW	14	SW	14	SW	14	SW	4	9	30.3
2	SW	12	W	10	W	13	SW	23	14	35.5
3	SW	14	W	18	W	16	W	12	14	34.7
4	W	14	NW	10	NW	7	CALM	NIL	8	35.5
5	CALM	NIL	W	2	SW	7	SW	6	5	13.9
6	SW	10	SW	16	SW	14	SW	9	11	26.1
7	NE	9	SW	6	CALM	NIL	CALM	NIL	4	13.0
8	CALM	NIL	S	8	SW	14	SW	4	5	23.4
9	SW	9	SW	12	SW	14	SW	19	13	32.1
10	SW	14	W	15	NW	14	NW	23	16	40.7
11	NW	12	W	16	NW	14	W	11	12	32.1
12	SW	17	W	26	W	23	W	10	19	42.5
13	NW	11	NW	13	NW	11	SW	8	9	27.8
14	SW	9	SW	12	SW	11	SW	15	12	31.2
15	SW	14	SW	7	SW	6	SW	6	9	33.8
16	SW	14	SW	6	SW	17	SW	14	14	34.7
17	SW	6	W	10	W	9	W	13	11	27.8
18	NW	6	NW	12	W	14	W	1	10	23.4
19	CALM	NIL	CALM	NIL	SW	11	SW	4	7	19.1
20	NE	6	NE	6	NE	4	CALM	NIL	6	19.1
21	CALM	NIL	SW	5	SW	9	SW	5	5	15.6
22	CALM	NIL	NW	10	W	10	NW	7	7	18.2
23	CALM	NIL	CALM	NIL	SW	4	CALM	NIL	2	11.3
24	CALM	NIL	CALM	NIL	W	5	CALM	NIL	3	13.0
25	CALM	NIL	CALM	NIL	SW	8	CALM	NIL	5	12.2
26	CALM	NIL	CALM	NIL	SW	6	CALM	NIL	3	10.4
27	CALM	NIL	SE	3	SE	3	CALM	NIL	1	8.7
28	CALM	NIL	E	1	CALM	NIL	NW	12	5	22.5
29	NW	10	N	10	N	14	NE	15	12	26.1
30	NE	11	N	13	N	16	NE	9	13	26.1
31	N	2	NE	6	NE	10	NE	6	9	24.3
								Mean		

METEOROLOGICAL DATA - MARCH 1982

taken at the Carbonization Research Centre

of the British Carbonization Research Association

(Observations for Period Ending 10.00 B.S.T.)

Date	Wind		Rainfall (mm)	Mean Humidity at 10.00 B.S.T. (%)	Sun (hrs)	Temperature °C		
	Direction	Av. speed (knots)				Max.	Min.	Av.
1	SW	13	4.7	77	3.4	13.1	6.2	10.1
2	SW	10	2.2	68	0.7	8.7	2.7	5.8
3	W	14	5.0	53	5.0	10.5	5.8	8.4
4	W	14	2.5	-	3.3	9.4	4.3	6.1
5	NW	5	3.1	97	NIL	7.7	-1.3	3.0
6	SW	9	1.9	91	7.6	9.7	3.9	5.7
7	SW	10	19.6	98	NIL	6.6	4.8	6.0
8	S	2	TRACE	95	NIL	6.1	-2.3	2.5
9	SW	7	2.0	79	NIL	6.2	-1.3	1.8
10	SW	15	15.9	75	0.5	9.4	0.8	7.2
11	NW	15	4.5	73	4.2	10.5	1.2	4.8
12	W	15	3.5	66	3.4	7.7	2.1	6.0
13	W	15	0.2	77	6.2	6.2	1.4	3.6
14	SW	10	0.4	85	8.9	8.9	4.7	6.5
15	SW	13	16.3	86	NIL	11.1	4.0	8.0
16	SW	10	1.5	82	NIL	6.7	1.6	3.4
17	SW	13	2.6	86	6.7	8.3	2.5	5.0
18	NW	10	1.0	69	4.4	8.8	3.4	5.6
19	W	8	NIL	82	3.6	8.3	0.6	5.0
20	NE	7	6.5	95	1.4	7.8	2.9	4.8
21	SW	4	1.8	95	2.0	7.1	1.0	3.5
22	SW	7	0.3	73	NIL	8.9	3.0	5.3
23	NW	9	NIL	76	6.3	11.4	-1.0	6.0
24	SW	2	NIL	72	6.8	11.8	1.3	6.7
25	W	3	NIL	72	8.9	14.2	1.1	8.0
26	SW	4	TRACE	65	9.2	16.5	0.2	10.0
27	SE	3	NIL	92	9.0	17.5	-0.5	8.9
28	E	1	NIL	100	4.7	13.0	-0.2	6.7
29	NW	10	NIL	67	0.2	11.9	3.1	7.5
30	N	13	2.8	73	3.3	7.8	3.1	5.2
31	NE	11	TRACE	86	1.5	7.4	2.5	5.0
		TOTAL						
		MEAN						

N.B. The figures in brackets are an accumulated reading over the weekend

\- = No figures recorded

Summary of Meteorological Observations for March 1982 Taken at the British Carbonization Research Association, Chesterfield

Absolute Maximum (26 March)	17.5°C (21.8°C, 1965)*
Mean of Daily Maxima	9.5°C (8.5°C)
Absolute Minimum (8 March)	-2.3°C (-12.4°C, 1969)
Mean of Daily Minima	2.0°C (1.7°C)

	Mean for Month
No. of Days with Rain	21 (16) (1966-81)
No. of Days with Snow	3 (6) (1960-81)
No. of Days with Air Frost	6 (8)
No. of Days with Ground Frost	16 (14)
Total Rainfall (mm)	98.3 (59.6)
Total Sunshine (Hrs)	107.8 (87.7)
Mean Relative Humidity at 10.00 BST (%)	80 (82)

Wind Direction	S	SE	E	NE	N	NW	W	SW	CALM
% Time	1	2	1	8	4	12	16	35	21

Mean Wind Speed	8.8 knots	
Maximum Wind Speed (12 March)	42.5 knots	(57.2 knots, 1968) (1963-81)
Mean Daily Maxima	24.7 knots	

1 mph = 0.8684 knots
1 in = 25.4 mm

*The figures in brackets give the mean or absolute values recorded since 1959.

Metform 3225

METEOROLOGICAL OFFICE

Values of Wind speed & Direction for June 198

at Nottingham Weather Centre Extracted from Daily Register

Day.	0300	0900	1500	2100
1	040/08	030/10	220/02	210/07
2	220/07	200/11	240/05	280/03
3	230/04	170/04	190/08	130/05
4	260/07	250/09	240/10	210/07
5	030/02	040/10	040/16	040/14
6	050/12	050/15	070/16	060/14
7	050/10	060/07	120/10	080/06
8	030/03	290/13	230/07	230/07
9	230/07	240/08	270 12	270 05
10	210/02	230/09	260/09	210/05
11	190 10	220 13	200 11	210 07
12	250 07	240 10	260 10	250 07
13	230 06	230 11	210 11	180 15
14	270 11	270 14	260 14	270 09
15	260 08	300 10	290 12	290 06
16	260 02	230 01	210 03	060 04
17	310 02	360 02	340 05	040 04
18	060 04	050 08	120 06	070 06
19	030 02	040 04	060 11	030 08
20	020 07	040 17	060 15	060 11
21	030 09	040 07	050 10	060 07
22	060 05	040 02	060 05	040 03
23	340 02	030 08	020 08	020 10
24	030 09	030 08	040 08	070 06
25	040 02	270 01	270 04	260 02
26	270 02	260 08	260 08	270 07
27	310 06	330 08	300 08	280 06
28	280 07	280 08	280 12	250 08
29	240 12	280 12	290 12	280 07
30	340 02	270 05	030 05	090 02
~~31~~				
Total				
Mean				

SHEFFIELD CITY MUSEUMS

WESTON PARK METEOROLOGICAL STATION

MAY 1983

Date	Wind Direction & Knots	Dry Bulb °C	Humidity %	Air Max. °C	Air Min. °C	Rainfall mm	Sunshine Hours
1	NE 15	6.0	98	9.0	4.6	29.0	-
2	NW 10	6.0	92	9.6	5.0	1.6	-
3	NW 10	6.8	82	10.0	4.4	tr.	0.3
4	SE 2	9.8	76	13.2	1.8	0.2	6.8
5	SE 7	8.8	97	14.1	6.8	6.5	-
6	SSE 4	12.7	94	18.0	8.7	0.1	7.3
7	SSW 6	11.5	83	16.3	9.9	5.7	2.3
8	NNW 5	10.5	90	14.2	9.2	1.8	3.5
9	SSW 8	8.7	99	12.7	7.0	1.1	3.7
10	S 7	8.1	74	12.5	3.8	0.8	4.6
11	SE 6	5.8	95	13.4	4.7	5.8	5.2
12	S 3	6.2	95	13.7	5.8	2.1	3.0
13	SSW 9	10.8	72	15.3	6.2	2.4	6.5
14	SSW 7	11.0	86	15.0	5.1	3.9	9.0
15	Calm	9.1	92	13.0	5.7	5.5	0.6
16	E 5	12.8	76	17.5	4.9	4.9	7.6
17	SE 7	12.0	76	15.6	7.1	1.3	6.3
18	ESE 2	10.4	90	12.4	8.3	5.2	0.2
19	NNE 1	7.9	90	11.4	6.8	0.1	0.2
20	Calm	8.5	89	13.2	7.1	1.5	0.1
21	NNE 6	8.5	88	11.7	6.9	0.1	0.2
22	WSW 6	11.2	71	13.0	5.4	1.9	2.0
23	Calm	11.3	64	14.7	5.5	-	3.1
24	Calm	11.8	81	16.7	9.3	-	6.9
25	N 3	13.1	73	17.8	5.7	0.2	7.2
26	N 10	9.4	74	13.4	6.9	-	4.1
27	NNW 5	10.1	68	11.2	6.7	6.3	2.4
28	NW 14	7.8	94	9.0	6.0	1.4	-
29	NNW 5	8.1	97	11.5	7.2	0.3	0.6
30	Calm	8.9	93	14.4	7.7	4.1	0.1
31	Calm	14.2	75	19.1	8.8	33.2	7.8
						127.0	101.6

Mean of daily maximum temperatures	13.6
Mean of daily minimum temperatures	6.4
Mean of max. and min. temperatures	10.0

Long term averages for May

Sunshine hours	162	(1941-70)
Rainfall mm	65	(1941-70)
Mean of daily maximum temperatures	15.4	(1941-70)
Mean of daily minimum temperatures	7.2	(1941-70)
Mean of max. and min. temperatures	11.3	

Note: the above are a selection of the readings taken at 09.00 hours G.M.T. Details of Grass Minimum and Earth Temperatures, Snowfall, 24 hour Anemograph Traces, Cloud Cover etc. are available on request.

C. CURRENT SMOKE AND SULPHUR DIOXIDE MONITORING NETWORK.

- site description forms
- monthly determined means

W.S.L. 214 A.P.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH
WARREN SPRING LABORATORY
INVESTIGATION OF ATMOSPHERIC POLLUTION
PARTICULARS OF SITE FOR VOLUMETRIC INSTRUMENT

Authority CHESTERFIELD RURAL DISTRICT COUNCIL

Type of apparatus used (delete as necessary)

~~SMOKE only~~ : ~~SO_2 only~~ : Combined SMOKE/SO_2 (Vol.)

Address of site TUPTON COUNTY INFANTS AND JUNIOR SCHOOL

Short name of site TUPTON

Site is in civil administrative area of CHESTERFIELD (~~C.B./U.D.~~/R.D./ etc.)

National grid reference 3955 6610

Site is 3.2 miles ~~N NE E SE~~ S ~~SW W NW~~ of town or city centre (CHESTERFIELD)

Height of ground above Mean Sea Level 350 feet

Air inlet funnel is 10 feet above ground

Situation of apparatus IN OUTBUILDING OF SCHOOL

Description of surrounding district (open ~~country, park,~~ residential, ~~commercial,~~ manufacturing)

RESIDENTIAL

Particulars of chimneys, housing estates, and other possible sources of pollution

Distance in feet from air inlet funnel			Description of source(s)*	
N.	3000 - 5000	ft	Avenue Coking Plant	250' A
	100 - 750	ft	Dwellings	20' B
NE.	3000 - 5000	ft	Dwellings	50' A
		ft		
E.	5000 - 7000	ft	Dwellings	0 - 100' A
		ft		
SE.	4000 - 5000	ft	Dwellings	0 - 50' A
		ft		
S.	0 - 2,500	ft	Dwellings	0 - 100' A
	6000	ft	Clay Cross Iron Works	200' A
SW.	7000 - 9000	ft	Dwellings	100' A
		ft		
W.	181 - 2000	ft	Dwellings	0 - 25' B
NW.	4,500 - 10,000	ft	Dwellings	0 - 260' A
	2000 - 5000	ft	Dwellings	0 - 50' B

*State distance above air inlet funnel (A), or below air inlet funnel (B) e.g.

N.	300	ft	Factory chimney 180 ft (A)	
	350-6,000	ft	Domestic chimneys 5ft (B) to 15 ft (A)	

Name of person responsible for care of apparatus J. WILSON, CHIEF PUBLIC HEALTH INSPECTOR.

Observations began on TO BEGIN 1/1/71

Remarks

Signed

Date 2/12/70

(3523) Wt 45552/31 15m 9 59 M.P.Ltd Gp. 722.

Tupton Tupton County Infants & Junior
School, Queen Victoria Rd., Tupton.

	1971		1972		1973	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	147	74	52	68	83	96
February	116	70	56	69	57	79
March	100	61	56	72	67	99
April	46	32			29	89
May	47	51	38	66	21	62
June	46	43	25	51	19	59
July	37	43	22	66	20	51
August	37	39	21	63	24	43
September	39	39	50	75	29	47
October	42	48	55	78	24	52
November	54	66	44	61	49	75
December	53	71	74	87	32	32

	1974		1975		1976	
	smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	40	35				
February	23	31			40	47
March	23	60	27	56	39	48
April			22	42	17	35
May			16	37	13	27
June	14	26	18	37	12	15
July			12	36	10	18
August			17	41	17	57
September			16	40	23	61
October			39	48	32	41
November			52	47	57	69
December			43	41	56	76

Tupton Tupton County Infants & Junior School, Queen Victoria Rd., Tupton.

	1977		1978		1979	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	39	61	40	56	50	101
February	40	51	40	75	31	85
March	19	46	18	43	12	42
April	13	42	19	54	19	55
May	12	47	16	61	10	47
June	12	48	9	32	10	47
July	9	40	9	34	8	30
August	11	38	13	33	8	23
September	12	38	9	24	17	34
October	32	31	17	47	30	42
November	16	19	18	41	24	37
December	33	46	46	79	21	41

	1980		1981		1982	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January			17	55	49	130
February	31	65	33	83	28	68
March	22	67			22	57
April					16	54
May					11	41
June	7	32			9	39
July					8	35
August			12	25	7	23
September			14	27	14	32
October			13	36	18	53
November	16	61	23	54	14	37
December	11	42	49	148	32	38

Tupton Tupton County Infants & Junior School, Queen Victoria Rd., Tupton.

	1983		1984	
	Smoke	SO_2	Smoke	SO_2
January	7	27	14	56
February	27	93	**	
March	11	45		
April	11	56		
May	10	56		
June	9	63		
July	11	75		
August	13	57		
September	13	63		
November	24	96		
December	10	41		

* No results available

** Volumetric gauge removed, sampling tube retained.

1.861

DEPARTMENT OF INDUSTRY-WARREN SPRING LABORATORY
NATIONAL SURVEY OF AIR POLLUTION
PARTICULARS OF SITE FOR VOLUMETRIC INSTRUMENT

Authority NORTH EAST DERBYSHIRE DISTRICT COUNCIL

Type of apparatus used (delete as necessary)
~~SMOKE only~~ : ~~SO2 (Vol) only~~ : Combined SMOKE / SO_2 (Vol)

Address of site PILSLEY COUNTY JUNIOR/INFANT SCHOOL - STATION RD. PILSLEY.

Short name of site PILSEY

Site is in civil administrative area of CHESTERFIELD ~~M B~~ / D / etc

National grid reference SK 425 622

Site is 13 km N NE E [✓ SE] S SW W NW of town ~~or city~~ centre (CHESTERFIELD)

Height of ground above Mean Sea Level 152 metres

Air inlet funnel is 3:5 metres above ground

Situation of apparatus OUTBUILDING OVERLOOKING PLAYGROUND.

Description of surrounding district (open country, park, residential, commercial, manufacturing)
RESIDENTIAL/COMMERCIAL/OPEN COUNTRY/ MANUFACTURING.

Particulars of chimneys, housing estates, and other possible sources of pollution

Distance in metres from air inlet funnel			Description of source(s)*
N	0 - 152 m	Housing Estate	6m A to 6m B
	m		
NE	- m		
	m		
E	0 - 1220 m	Housing Estate	4.5m - 9m A
	m		
SE	0 - 183 m	Housing	4.5m - 6m A
	m		
S	0 - 304 m	Housing	4.5m - 6m A
	m		
SW	0 - 1524 m	Housing	4.5m A - 4.5m B
	m		
W	0 - 914 m	Housing	4.5m A - 15m B
	4572 m	Factory Chimneys.	30m B
NW	0 - 3048 m	Housing.	4.5m A - 23m B
	914 m	Factory Chimneys.	15m B

*State distance above air inlet funnel (A), or below air inlet funnel (B) e.g.

N	90 m	Factory chimney 52m (A)
	105 - 1800 m	Domestic chimneys 1m(B) to 5m (A)

Name of person responsible for care of apparatus [illegible]

Observations began on 14th July 1981 Remarks

Suggested Classification D.2. (See Over)

Signed Date

Pilsley Junior and Infant School

December 1972 SMOKE - 102 SO_2 - 115

	1973		1974		1975	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	146	134	54	50	33	30
February	155	121	43	58	64	86
March	140	137	46	100	35	69
April	113	130	35	105	27	61
May	72	96	25	67	19	47
June	47	94	17	58	17	57
July	60	92	11	44	14	53
August	35	76	18	47	18	66
September	57	77	20	52	19	58
October	82	96	44	90	40	65
November	91	109	56	74	56	60
December	54	43	22	29	28	52

	1976		1977		1978	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	23	36	45	89	43	76
February	42	60	45	68	48	98
March	39	61	21	48	22	54
April	20	50	15	51	20	67
May	14	38	14	65	17	76
June	15	30	13	60	10	57
July	11	26	10	63	12	59
August	20	69	14	56	14	54
September	22	71	14	54	11	48
October	33	47	29	41	22	65
November	60	96	17	39	21	61
December	66	99	36	66	54	89

Pilsley Junior and Infant School (Continued)

	1979		1980		1981	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	52	116	59	114	20	43
February	35	100	33	87	36	70
March	16	55	27	87	16	44
April	24	73	22	74	29	67
May	12	51	15	61	51	132
June	11	57	9	47	53	104
July	9	52	13	50	35	61
August	11	43	14	41	13	52
September	18	54	-	-	16	54
October	31	63	26	61	16	47
November	30	64	9	53	29	67
December	26	62	15	44	51	132

	1982		1983		1984	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	53	104	9.5	17.75	14	46
February	35	61	20.5	40.5	34	83
March	33	68	18.6	42.6	22	61
April	-	-	15	42	10	40
May	-	-	9	43	22	66
June	11	53	7	52	13	60
July	8	48	11.25	81.25	8	43
August	9	40	10	58	11	25
September	-	-	8	39	14	35
October	-	-	11	36	9	33
November	-	-	27	71	33	55
December	40	39	16	45	33	61

W.S.L. 214 A.P.

DEPARTMENT OF TRADE + INDUSTRY ~~SCIENTIFIC AND INDUSTRIAL RESEARCH~~

WARREN SPRING LABORATORY

INVESTIGATION OF ATMOSPHERIC POLLUTION
PARTICULARS OF SITE FOR VOLUMETRIC INSTRUMENT

Authority CHESTERFIELD RURAL DISTRICT COUNCIL

Type of apparatus used (delete as necessary)

~~SMOKE only~~ : ~~SO$_2$ (Vol.) only~~ : Combined SMOKE/SO$_2$ (Vol.)

Address of site BRITISH STEEL CORPORATION MAIN RD. RENISHAW.

Short name of site RENISHAW 1.

Site is in civil administrative area of CHESTERFIELD RURAL (~~C.B. B. U.D.~~/R.D./ etc.)

National grid reference 446 779

Site is 7 miles N [✓ NE] E SE S SW W NW of town or city centre (CHESTERFIELD)

Height of ground above Mean Sea Level 150 feet

Air inlet funnel is 35 feet above ground

Situation of apparatus ATTIC IN OFFICE BUILDING IN WORKS YARD

Description of surrounding district (open country, park, residential, commercial, manufacturing)

RESIDENTIAL + COMMERCIAL + MANUFACTURING + OPEN COUNTRY.

Particulars of chimneys, housing estates, and other possible sources of pollution

Distance in feet from air inlet funnel		Description of source(s)*
N.	— ft	— —
	ft	
NE.	250 ft	CUPOLA 35ft (A)
	ft	
E.	300 ft	CUPOLA 65ft (A)
	ft	
SE.	400 – 2,500 ft	HOUSING ESTATE 0 – 50ft (A)
	ft	
S.	150 – 1150 ft	HOUSING ESTATE 0 – 50ft (A)
	ft	
SW.	400 – 1200 ft	HOUSING ESTATE 0 – 50ft (A)
	ft	
W.	300 – 800 ft	HOUSING ESTATE 0 – 50ft (A)
	ft	
NW.	650 ft	CUPOLA 10ft (B)
	ft	

*State distance above air inlet funnel (A), or below air inlet funnel (B) e.g.

N.	300 ft	Factory chimney 180 ft (A)
	350-6,000 ft	Domestic chimneys 5ft (B) to 15 ft (A)

Name of person responsible for care of apparatus D. WILKINS

Observations began on 15th JANUARY 1974

Remarks

Signed Date 28. 1. 74

(3573) Wt 45552-31 15m 9/59 M.P.Ltd. Gp. 722

Renishaw Foundry Offices: Chesterfield 25

	1974		1975		1976	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	–	–	60	50	39	38
February	73	66	91	104	73	8
March	57	84	51	63	64	56
April	37	69	41	43	35	38
May	36	49	28	31	27	25
June	24	35	29	35	25	19
July	22	21	23	26	17	10
August	30	28	25	33	22	41
September	39	43	35	41	38	59
October	55	71	70	58	59	67
November	–	–	95	70	102	12
December	35	37	101	78	93	12

	1977		1978		1979	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	85	108	89	95	–	–
February	74	91	75	92	–	–
March	44	67	44	62	31	60
April	25	53	30	54	32	67
May	–	–	23	61	25	53
June	17	44	16	41	19	52
July	15	43	18	42	–	–
August	18	33	27	42	–	–
September	25	46	21	35	32	51
October	65	62	44	68	62	62
November	19	39	45	70	67	70
December	78	91	80	98	57	73

Renishaw Foundry Offices : Chesterfield 25 (Continued)

	1980		1981		1982	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	91	108	38	55	84	125
February	70	105	35	41	54	79
March	–	–	–	–	51	68
April	–	–	24	31	27	54
May	18	58	25	44	26	45
June	17	48	13	36	15	34
July	22	46	11	31	13	34
August	21	36	–	–	15	27
September	28	53	–	–	30	41
October	48	57	36	46	45	65
November	24	51	52	69	36	49
December	30	51	85	138	–	–

	1983		1984	
	Smoke	SO_2	Smoke	SO_2
January	23	41	21	60
February	34	61	–	–
March	26	51	–	–
April	19	46	15	29
May	17	46	–	–
June	11	50	–	–
July	12	59	13	32
August	13	38	14	19
September	14	42	–	–
October	18	38		7
November	36	75	11	17
December	50	73	25	47

DEPARTMENT OF INDUSTRY–WARREN SPRING LABORATORY
NATIONAL SURVEY OF AIR POLLUTION
PARTICULARS OF SITE FOR VOLUMETRIC INSTRUMENT

ENVIRONMENTAL HEALTH
& HOUSING DEPT.
-7 MAR 1980
Passed to ....
Copy to ....
Action T..........
File ....

Authority NORTH EAST DERBYSHIRE DISTRICT COUNCIL

Type of apparatus used (delete as necessary)

~~SMOKE only~~ : ~~SO2 (Vol) only~~ : Combined SMOKE / SO_2 (Vol)

Address of site STONEBROOM COUNTY JUNIOR SCHOOL, HIGH ST. STONEBROOM.

Short name of site STONEBROOM

Site is in civil administrative area of CHESTERFIELD ~~M D / D / etc~~

National grid reference SK. 410 - 595

Site is 13 km ~~N NE E SE~~ S ~~SW W NW~~ of town or city centre (CHESTERFIELD.)

Height of ground above Mean Sea Level 150 metres

Air inlet funnel is 4 metres above ground

Situation of apparatus STORE ROOM AT SCHOOL.

Description of surrounding district (open country, park, residential, commercial, manufacturing)

RESIDENTIAL / COMMERCIAL / MANUFACTURING.

Particulars of chimneys, housing estates, and other possible sources of pollution

Distance in metres from air inlet funnel		Description of source(s)*
N	804 m	Small Village (Domestic Chimneys / Light INDUSTRY)
NE	4827 m	Village ( )
E	4900 m	( )
SE	m	
S	4022 m	Town (Domestic Chimneys (MED. INDUSTRY.)
SW	1025 m	Village Domestic Chimneys
W	1609 m	
NW	5620 m	Small Town Domestic Chimneys Med/Heavy Industry

*State distance above air inlet funnel (A), or below air inlet funnel (B) e.g.

N 90 m Factory chimney 52 m (A)
105 - 1800 m Domestic chimneys 1 m (B) to 5 m (A)

Name of person responsible for care of apparatus N. R. TRANMER / D. R. LEATY

Observations began on MON. 29th JAN. 1980 Remarks STONEBROOM POSSIBLE SMOKE CONTROL AREA.

Suggested Classification B3 (See Over)

Signed NRT Date 3/4/80

Stonebroom Junior School

	1980		1981		1982	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	-	-	41	73	78	131
February	60	122	53	86	57	80
March	39	92	34	60	57	74
April	25	81	32	90	25	56
May	16	71	-	-	22	57
June	14	53	-	-	14	52
July	17	56	13	45	12	45
August	22	46	15	32	16	34
September	-	-	25	54	28	58
October	-	-	36	52	-	-
November	37	67	53	72	41	52
December	41	60	69	141	78	90

	1983		1984	
	Smoke	SO_2	Smoke	SO_2
January	35	47	35	62
February	34	71	60	78
March	21	50	31	74
April	22	57	37	71
May	21	64	23	65
June	17	71	32	74
July	14	64	23	50
August	-	-	28	63
September	21	47	2	10
October	23	53	31	57
November	60	109	47	79
December	47	78	50	90

W.S.L. 214 A.P.

DEPARTMENT OF TRADE & INDUSTRY,

~~[illegible]OGY~~

WARREN SPRING LABORATORY

NATIONAL SURVEY OF AIR POLLUTION
PARTICULARS OF SITE FOR VOLUMETRIC INSTRUMENT

Authority: NORTH EAST DERBYSHIRE DISTRICT COUNCIL

Type of apparatus used (delete as necessary)
SMOKE ~~only~~ : SO$_2$ ~~(Vol.) only~~ : Combined SMOKE/SO$_2$ (Vol.)

Address of site: NORTH WINGFIELD CHURCH, NORTH WINGFIELD

Short name of site: NORTH WINGFIELD (2)

Site is in civil administrative area of: CHESTERFIELD (~~C.B.~~/B./U.D./R.D./ etc.)

National grid reference: 404 645

Site is 5 miles ~~N~~ ~~NE~~ E SE ~~S~~ ~~SW~~ ~~W~~ NW of town or city centre (CHESTERFIELD)

Height of ground above Mean Sea Level: 400 feet

Air inlet funnel is 25 feet above ground

Situation of apparatus: OUTHOUSE IN GROUNDS OF NORTH WINGFIELD CHURCH

Description of surrounding district (open country, park, residential, commercial, manufacturing):
LOW DENSITY HOUSING / MANUFACTURING / AREAS OF OPEN COUNTRY.

Particulars of chimneys, housing estates, and other possible sources of pollution

Distance in feet from air inlet funnel		Description of source(s)*
N.	100 – 2,500 ft	DOMESTIC CHIMNEY'S up to 40 ft. (B)
	ft	
NE.	2,500+ ft	DOMESTIC CHIMNEYS 13 ft (A)
	ft	
E.	NIL ft	NIL
	ft	
SE.	50–5000 ft	DOMESTIC CHIMNEY'S 90 ft (B)
	ft	
S.	NIL ft	NIL
	ft	
SW.	200 ft	FACTORY CHIMNEYS (IRON WORKS) 40 ft (B)
	ft	
W.	NIL ft	NIL
	ft	
NW.	NIL ft	NIL.
	ft	

*State distance above air inlet funnel (A), or below air inlet funnel (B) e.g.

N.	300 ft	Factory chimney 180 ft (A)
	350-6,000 ft	Domestic chimneys 5ft (B) to 15 ft (A)

Name of person responsible for care of apparatus: D. R. PEATY

Observations begun on: 5th NOVEMBER 1976.

Remarks: SEE ATTACHED LETTER

Signed .... Date 5/11/76

D/N17/1/557 2? 10/66 CL

North Wingfield

	1976		1977		1978	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January			42	91	42	79
February			43	80	40	100
March			22	57	21	59
April			13	47	17	66
May			12	63	15	76
June			11	61	10	49
July			9	47	10	48
August			11	45	13	45
September			13	49	10	42
October			33	54	22	64
November	68	56	19	41	22	55
December	56	101	35	84	48	105

	1979		1980	
	Smoke	SO_2	Smoke	SO_2
January	51	126	56	113
February	33	102	32	81
March	11	46	25	77
April	–	–	21	68
May	–	–	12	53
June	10	51	8	35
July	10	41	10	45
August	12	38	–	–
September	19	47	–	–
October	–	–	–	–
November	31	55	–	–
December	24	52	12	27

North Wingfield Church

	1981		1982		1983	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	17	36	49	54	11	20
February	14	36	30	48	-	-
March	17	59	30	39	9	27.4
April	17	59	17.75	43	12	36.3
May	12	51	13.9	41.9	9	31
June	8	40	12.5	37.5	7	40.14
July	6	28	10	40.1	8	52
August	11	29	10.1	27.5	10	40.1
September	-	-	18.2	24.2	9	26.1
October	16	25	-	-	18	28.2
November	21	37	-	-	22	48
December	-	-	-	-	13	30

	1984	
	Smoke	SO_2
January	15	32
February	Gauge Switched off	
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		

Killamarsh - Norwood

	1982		1983		1984	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January			9.9	30.2	13	10
February			29.5	52.6	-	-
March			10.6	36.2	<u>Gauge Switched</u>	
April			17.5	56.2	<u>Off</u>	
May			10.5	44.1		
June			8	50.7		
July			9.9	50.8		
August			10.6	40.6		
September			8.2	14.5		
October			20	55		
November			22	21		
December			10	10		

D. PAST SMOKE AND SULPHUR DIOXIDE MONITORING SITES.

- site description forms
- monthly determined means

Pilsley 5

	1974		1975	
	Smoke	SO_2	Smoke	SO_2
January	40	63	24	24
February	25	44	52	75
March	33	81	24	46
April	27	75	19	37
May	17	41	18	31
June	13	35	-	-
July	9	26		
August	13	27		
September	15	31		
October	35	65		
November	45	67		
December	9	22		

Pilsley 6

	1974		1975	
	Smoke	SO_2	Smoke	SO_2
January	40	63	15	19
February	23	42	80	106
March	22	64	26	60
April	31	80	17	50
May	11	38	16	49
June	12	28	18	42
July	8	16		
August	-	-		
September	-	-		
October	25	57		
November	41	61		
December	7	13		

Form W.S.L. 213 A.P.

Dept of Trade & Industry
~~MINISTRY OF TECHNOLOGY~~

WARREN SPRING LABORATORY

INVESTIGATION OF ATMOSPHERIC POLLUTION
PARTICULARS OF SITE FOR DEPOSIT GAUGE/LEAD PEROXIDE INSTRUMENT

Authority NORTH EAST DERBYSHIRE DISTRICT COUNCIL Short name of site BARLOW
Address of site SMEEKLEY BORE HOLE, FOX LANE, BARLOW.
Site is in civil administrative area of CHESTERFIELD. (C.B./B./U.D./R.D./etc.)
National grid reference SK 298 765.
Site is 10.5 KM. ~~miles~~ ~~N NE E SE S SW W~~ NW of town or city centre (CHESTERFIELD.)
Description of surrounding district (open country, park, residential, commercial, manufacturing)
OPEN COUNTRY.

Height of ground above Mean Sea Level 198 ~~feet~~ METRES.

DEPOSIT GAUGE	LEAD PEROXIDE INSTRUMENT
Situation SMEEKLEY BORE HOLE.	Situation
Gauge bowl is 4 ft above ground	Louvered cover is ft above ground

Particulars of objects 30° or more above the horizon, viewed from the level of the bowl of the deposit gauge, or louvered box:

		Description	Above gauge bowl			Description	Above louvered box
ft.	N	NONE	ft.	ft.	N		ft.
ft.	NE		ft.	ft.	NE		ft.
ft.	E		ft.	ft.	E		ft.
ft.	SE		ft.	ft.	SE		ft.
ft.	S		ft.	ft.	S		ft.
ft.	SW		ft.	ft.	SW		ft.
ft.	W		ft.	ft.	W		ft.
ft.	NW		ft.	ft.	NW		ft.

Chimneys, housing estates, and other possible sources of pollution:
* Insert A if above, B if below

M		Description	Above/below gauge bowl*				Description	Above/below louvered box*	
ft.	N		ft.	( )	ft.	N		ft.	( )
3203 M	NE	SMALL VILLAGE.	45 M	(A)	ft.	NE		ft.	( )
ft.	E		ft.	( )	ft.	E		ft.	( )
4805 M	SE	SMALL VILLAGE	6[illegible] M	(B)	ft.	SE		ft.	( )
ft.	S		ft.	( )	ft.	S		ft.	( )
ft.	SW		ft.	( )	ft.	SW		ft.	( )
ft.	W		ft.	( )	ft.	W		ft.	( )
ft.	NW		ft.	( )	ft.	NW		ft.	( )

Deposit Gauge Bowl: Number P1933 Factors: Metric 1316 British 33.56

Deposits ~~and/or lead peroxide cylinders analysed by~~ COUNTY ANALYST - MATLOCK.
Name of person responsible for care of apparatus MR. R. M. CHAPMAN.
Observations began on 1st AUGUST 1978
Remarks AREA OF EXPECTED LOW POLLUTION AND TO BE USED AS A CONTROL.

Signed [illegible] Date 2 8 78

Barlow 1 : Fox Lane

	1978		1979		1980	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	–	–	18	71	22	62
February	–	–	–	–	15	51
March	–	–	7	36	11	45
April	–	–	9	40	11	41
May	–	–	5	34	8	39
June	–	–	5	37	5	27
July	–	–	–	–	5	29
August	6	27	–	–	8	19
September	5	17	6	24	5	25
October	9	36	13	31	9	31
November	7	23	8	23	8	29
December	20	47	8	27	5	18

	1981	
	Smoke	SO_2
January	6	28
February	–	–
March	7	31
April	12	58
May	7	41
June	–	–
July		
August		
September		
October		
November		
December		

DEPARTMENT OF ~~SCIENTIFIC AND INDUSTRIAL RESEARCH~~ TRADE + INDUSTRY

WARREN SPRING LABORATORY

INVESTIGATION OF ATMOSPHERIC POLLUTION

PARTICULARS OF SITE FOR VOLUMETRIC INSTRUMENT

Authority NORTH EAST DERBYSHIRE DISTRICT COUNCIL

Type of apparatus used (delete as necessary)

~~SMOKE only~~ : ~~SO₂ (Vol.) only~~ : Combined SMOKE/SO_2 (Vol.)

Address of site CHESTERFIELD & DISTRICT COOPERATIVE SOCIETY BRANCH No 35, STATION RD HOLMEWOOD

Short name of site STATION RD HOLMEWOOD.

Site is in civil administrative area of N/E DERBYSHIRE D.C. (~~C.B./B./U.D./R.D./~~ etc.)

National grid reference SK 435 661.

Site is 6 miles N NE E [✓ SE] S SW W NW of town or city centre (CHESTERFIELD)

Height of ground above Mean Sea Level 490 feet

Air inlet funnel is 14 feet above ground

Situation of apparatus TOP FLOOR STOREROOM.

Description of surrounding district (open country, park, residential, commercial, manufacturing)

Commercial / Industrial area. Small town.

Particulars of chimneys, housing estates, and other possible sources of pollution

Distance in feet from air inlet funnel		Description of source(s)*
N.	4 miles ft	Coal Carbonisation & Chemical Plant ~~[illegible]~~ 154 ft (B)
NE.	1320 - 3960 ft	Small housing Estate 21 ft (A)
E.	660 ft	Small industrial Estate 50 ft (A)
SE.	ft	NONE (RURAL)
S.	ft	NONE (RURAL)
SW.	0 - 3960 ft	Small housing Estate 22 ft (A)
W.	0 - 5280 ft	Large housing Estate / Commercial properties 2 ft (A)
NW.	5280 - 6500 ft	Small Boiler Plants / Industrial premises 32 ft (A)

*State distance above air inlet funnel (A), or below air inlet funnel (B) e.g.

N. 300 ft Factory chimney 180 ft (A)

350-6,000 ft Domestic chimneys 5ft (B) to 15 ft (A)

Name of person responsible for care of apparatus MR. J. WILSON CEHO + HQ

Observations began on 1-8-76

Remarks

Signed Date

(3523) Wt.45552/31 15m 9/59 M.P.Ltd Gp. 722.

Holmewood   Station Road, Holmewood

	1976		1977		1978	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January			81	131	46	89
February			65	98	54	101
March			32	65	27	64
April			34	68	26	59
May			29	68	22	73
June	Monitoring		23	67	15	54
July	started		20	56	15	50
August	34	69	18	43	18	50
September	45	84	21	51	14	40
October	46	73	31	55	27	68
November	94	141	30	56	25	62
December	111	156	45	86	52	101

	1979		1980		1981	
	Smoke	SO_2	Smoke	SO_2	Smoke	SO_2
January	50	129	64	127	24	63
February	40	106	39	110	38	71
March	23	62	31	84	19	47
April	25	85	24	70	31	79
May					17	67
June					**	
July	12	45	12	45		
August	13	44	13	44		
September	20	55	18	42		
October	32	67	26	60		
November	31	82	23	62		
December	27	72	19	51		

* No results available

** Volumetric gauge removed, sampling tube retained

NEDDC

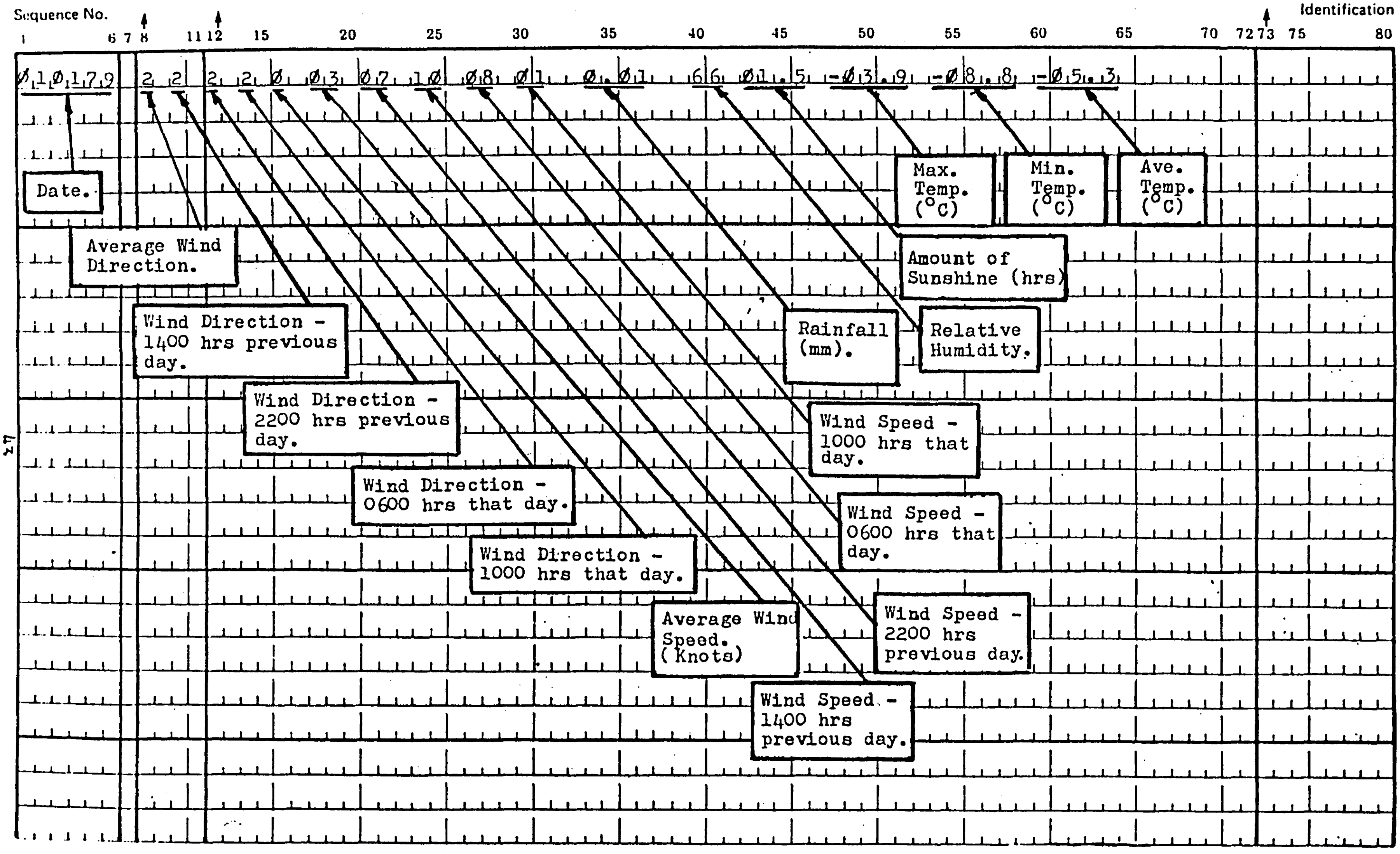
COBOL program sheet

title

programmer

sheet number

date



27

```
TOF:
      DIMENSION D(5476,20)
      DO 1 I=1,1825
      READ(1,*)(D(I,J),J=1,3)
    1 CONTINUE
      WRITE(6,900)
900   FORMAT(2HAA)
      DO 2 I=1826,5475
      READ(2,*)(D(I,J),J=1,3)
    2 CONTINUE
      WRITE(6,900)
      IA=0
      DO 6 L=1,3
      WRITE(6,900)
      DO 3 I=1,365
      IA=IA+1
      READ(3,*)(D(IA,J),J=4,20)
      DO 5 K=1,4
      DO 4 J=4,20
      D(IA+365*K,J)=D(IA,J)
    4 CONTINUE
    5 CONTINUE
    3 CONTINUE
      WRITE(6,900)
      IA=IA+1460
    6 CONTINUE
      WRITE(6,950)
950    FORMAT(5HHELLO)
      DO 7 I=1,5475
      WRITE(4,100)(D(I,J),J=1,20)
  100 FORMAT(F2.0,2F5.0,F7.0,5F2.0,5F3.0,F5.2,F4.0,2F4.1,2F5.1)
    7 CONTINUE
      STOP
      END
EOF:
```

F. SMOKE AND SULPHUR DIOXIDE COMPUTER PROGRAMME AND SAMPLE PRINT OUT.

```
   5 REM "run"
  11 POKE 23561,255
  13 POKE 23609,255
  14 LPRINT
  15 LPRINT "####Ram availabilit
y = ";PEEK 23733/4-15.75;"K####"
  16 LPRINT
  17 LPRINT "-------------------
------------"
  18 LPRINT
  20 BORDER 0
  21 PAPER 0
  22 INK 5
  23 CLS
  25 FOR y=0 TO 20 STEP 0.5
  26 PRINT AT y,0;"         .   .   .   .
 .   .   .   .   ."
  27 PRINT AT y+1,0;"     P   O   L
 L   U   T   I   O   N"
  28 NEXT y
  30 PAUSE 50
  31 CLS
  32 FOR y=0 TO 20 STEP 0.5
  33 PRINT AT y,0;"             .   .   .
 .   .   .   ."
  34 PRINT AT y+1,0;"         C   O
 N   T   R   O   L"
  35 NEXT y
  36 PAUSE 50
  37 CLS
  44 PRINT
  45 PRINT
  46 PRINT
  47 PRINT
  48 PRINT
  49 PRINT "     North East Derb
yshire      "
  50 PRINT "     District Counc
il          "
  55 BEEP 1,24
  60 PRINT
  61 LPRINT "     North East Der
byshire     "
  62 LPRINT "      District Coun
cil         "
~~63 LPRINT~~
  70 PRINT
  80 PRINT "    Data Processing
and Air     "
  90 PRINT "   Pollution Analysi
s Service   "
  91 LPRINT "    Data Processing
 and Air    "
  92 LPRINT "   Pollution Analys
is Service  "
  95 BEEP 1,14
 100 PAUSE 50
 110 CLS
 111 LPRINT
 112 PRINT
 113 PRINT
 114 PRINT
 115 PRINT
 116 PRINT
 120 PRINT
 121 PRINT
 122 PRINT "          #############
#"
 130 PRINT "          NEDIC SOFTWAR
E
 132 PRINT "          #############
```

```
-
 133 LPRINT "      *************
*"
 134 LPRINT "      NEDDC SOFTWAR
E         "
 135 LPRINT "      *************
*"
 139 BEEP 1,24
 140 PAUSE 50
 142 LPRINT
 143 LPRINT
 150 CLS
 190 PRINT
 191 PRINT
 192 PRINT
 193 PRINT
 194 PRINT
 195 PRINT
 200 PRINT
 210 PRINT
 220 PRINT "This program will ca
lculate"
 222 PRINT "and graphically disp
lay"
 225 PRINT "daily smoke and sulp
hur"
 230 PRINT "dioxide levels"
 240 BEEP 2,24
 250 PAUSE 50
 260 CLS
 280 PRINT "ENTER THE OPERATORS
NUMBER"
 290 PRINT
 300 PRINT
 310 PRINT
 320 PRINT "1. N.R.Tranmer"
 330 PRINT "2. D.R.Peaty"
 340 PRINT "3. T. Bingham"
 342 PRINT "4. S.Baddeley"
 345 PRINT
 346 PRINT
 347 PRINT
 348 PRINT "?"
 349 BEEP 2,24
 350 INPUT rr
 360 IF rr=1 THEN LET X$="N.R.Tr
anmer"
 370 IF rr=2 THEN LET X$="D.R.Pe
aty"
 380 IF rr=4 THEN LET X$="T. Bin
gham  "

 385 IF rr=4 THEN LET X$="S.Badd
eley"
 390 PRINT
 403 PRINT
 410 PRINT "Data processed by"
 420 PRINT X$
 424 PRINT
```

```
 425 PRINT
 432 BEEP 1,14
 433 PRINT AT 20,0;"Press any ke
y to continue"
 434 IF INKEY$="" THEN GO TO 434
 435 CLS
 436 PRINT "N.B. All meter readi
ngs must"
 437 PRINT "be in Cubic Feet."
 438 PRINT
 439 PRINT
 445 PRINT "ENTER THIS WEEKS MET
ER READING"
 447 PRINT
 448 PRINT
 449 PRINT
 450 PRINT "?"
 451 INPUT XX
 452 PRINT
 453 PRINT
 455 PRINT "= ";XX;" cubic feet"
 457 BEEP 1,24
 460 PRINT AT 20,0;"Press any ke
y to continue"
 461 IF INKEY$="" THEN GO TO 461
 465 CLS
 466 PRINT
 468 PRINT
 469 PRINT
 471 PRINT
 520 PRINT "ENTER LAST WEEKS MET
ER READING"
 522 PRINT
 523 PRINT
 524 PRINT
 526 PRINT "?"
 530 INPUT YY
 531 PRINT
 532 PRINT
 536 PRINT "= ";YY;" cubic feet"
 538 BEEP 1,20
 540 PRINT AT 20,0;"Press any ke
y to continue"
 541 IF INKEY$="" THEN GO TO 541
 542 CLS
~~ 560 PRINT "ENTER NUMBER OF GAUG~~
E SITE"
 562 PRINT
 563 BEEP 1,24
 570 PRINT "1 Stonelow, Dronfiel
d."
 571 PRINT "2 North Wingfield Ch
urch."
 572 PRINT "3 Stonebroom School.
"
 573 PRINT "4 Norwood, Killamars
h."
 574 PRINT "5 Renishaw Foundry."
 575 PRINT "6 Pilsley School."
 576 PRINT "7 Tupton School."
 577 PRINT "8 New Gauge Site"
 610 INPUT oo
 612 IF oo=1 THEN LET G$="Stonel
ow, Dronfield."
 613 IF oo=2 THEN LET G$="North
wingfield Ch."
 614 IF oo=3 THEN LET G$="Stoneb
room School"
 615 IF oo=4 THEN LET G$="Norwoo
d, Killamarsh"
 616 IF oo=5 THEN LET G$="Renish
aw Foundry"
 617 IF oo=6 THEN LET G$="Pilsle
y, School"
```

```
 618 IF oo=7 THEN LET G$="Tupton
 School"
 619 IF oo=8 THEN LET G$="New Ga
uge Site"
 623 PRINT
 624 PRINT
 625 PRINT
 629 PRINT
 640 PRINT "Gauge located at "
 645 PRINT G$
 646 BEEP 1,24
 648 PRINT AT 20,0;"Press any ke
y to continue"
 649 IF INKEY$="" THEN GO TO 649
 659 CLS
 660 LET Z=INT (((XX-YY)/7)+0.5)
 670 PRINT "ENTER THE STARTING D
ATE OF"
 675 PRINT "THE MONITORING PERIO
D"
 676 PRINT
 677 PRINT "?"
 690 INPUT P$
 691 PRINT
 692 PRINT
 693 PRINT "ENTER NUMBER OF MONT
H DURING"
 694 PRINT "WHICH MONITORING STA
RTED"
 695 PRINT
 696 PRINT "?"
 697 INPUT kk
 698 IF kk=2 THEN LET H$="Februa
ry"
 699 IF kk=3 THEN LET H$="March"
 700 IF kk=4 THEN LET H$="April"
 701 IF kk=5 THEN LET H$="May"
 702 IF kk=6 THEN LET H$="June"
 703 IF kk=7 THEN LET H$="July"
 704 IF kk=8 THEN LET H$="August
"
 705 IF kk=9 THEN LET H$="Septem
ber"
 706 IF kk=10 THEN LET H$="Octob
er"
 707 IF kk=11 THEN LET H$="Novem
ber"
 708 IF kk=12 THEN LET H$="Decem
ber"
 709 IF kk=1 THEN LET H$="Januar
y"
 710 PRINT
 715 PRINT
 720 PRINT "Monitoring started"
 721 PRINT "on ";P$;" of ";H$;"
1984"
 723 BEEP 1,24
 740 PRINT AT 20,0;"Press any ke
y to continue"
 741 IF INKEY$="" THEN GO TO 741
 742 CLS
 743 FOR y=0 TO 20 STEP 0.5
 744 PRINT AT y,0;"    .   .   .   .
  .   .   .   .   ."
 745 PRINT AT y+1,0;"    T   I   T
 R   A   T   I   O   N"
 746 NEXT y
 747 PAUSE 50
 748 CLS
 750 PRINT "ENTER AMOUNTS OF ALK
ALI"
 751 PRINT "TIMES 10"
 770 INPUT aa
```

```
 771 INPUT bb
 772 INPUT cc
 773 INPUT dd
 774 INPUT ee
 775 INPUT ff
 776 INPUT gg
 777 LET A=aa/10
 778 LET B=bb/10
 779 LET C=cc/10
 780 LET D=dd/10
 781 LET E=ee/10
 782 LET F=ff/10
 783 LET G=gg/10
 784 PRINT
 785 PRINT
 786 PRINT
 787 PRINT "Check data entered c
orrectly"
 788 PRINT
 790 PRINT A;"          mi."
 791 PRINT B
 792 PRINT C
 793 PRINT D
 794 PRINT E
 795 PRINT F
 796 PRINT G
 860 PRINT AT 20,0;"Press any ke
y to continue"
 861 IF INKEY$="" THEN GO TO 861
 862 CLS
 863 FOR y=0 TO 20 STEP 0.5
 864 PRINT AT y,0;"  . . . . . .
. . . . . . ."
 865 PRINT AT y+1,0;"  R E F L E
C T O M E T E R"
 866 NEXT y
 867 PAUSE 50
 868 CLS
 870 PRINT "ENTER REFLECTOMETER
"

 871 PRINT "READINGS"
 900 INPUT H
 905 INPUT I
 910 INPUT J
 915 INPUT K
 920 INPUT L
 925 INPUT M
 926 INPUT nN
 928 PRINT
 929 PRINT
 930 PRINT
 931 PRINT "Check data entered c
orrectly"
 932 PRINT
 933 PRINT
 939 PRINT H
 940 PRINT I
 941 PRINT J
 942 PRINT K
 943 PRINT L
 944 PRINT M
 945 PRINT nN
 950 PRINT AT 20,0;"Press any ke
y to continue"
 951 IF INKEY$="" THEN GO TO 951
1000 LET O=INT (((4520*A)/Z)+0.5
)
1005 LET P=INT (((4520*B)/Z)+0.5
)
1006 LET Q=INT (((4520*C)/Z)+0.5
)
1010 LET R=INT (((4520*D)/Z)-0.5
)
```

```
1012 LET S=INT (((4520*E)/Z)+0.5
)
1014 LET T=INT (((4520*F)/Z)+0.5
)
1016 LET U=INT (((4520*G)/Z)+0.5
)
1100 LET V=INT (1/Z*(91679.22-33
32.046*H+49.618884*(H*H)-0.35329
778*(H*H*H)+0.0009863435*(H*H*H*
H))+0.5)
1105 LET W=INT (1/Z*(91679.22-33
32.046*I+49.618884*(I*I)-0.35329
778*(I*I*I)+0.0009863435*(I*I*I*
I))+0.5)
1110 LET X=INT (1/Z*(91679.22-33
32.046*J+49.618884*(J*J)-0.35329
778*(J*J*J)+0.0009863435*(J*J*J*
J))+0.5)
1115 LET Y=INT (1/Z*(91679.22-33
32.046*K+49.618884*(K*K)-0.35329
778*(K*K*K)+0.0009863435*(K*K*K*
K))+0.5)
1120 LET AA=INT (1/Z*(91679.22-3
332.046*L+49.618884*(L*L)-0.3532
9778*(L*L*L)+0.0009863435*(L*L*L
*L))+0.5)
1125 LET BB=INT (1/Z*(91679.22-3
332.046*M+49.618884*(M*M)-0.3532
9778*(M*M*M)+0.0009863435*(M*M*M
*M))+0.5)
1130 LET CC=INT (1/Z*(91679.22-3
332.046*nN+49.618884*(nN*nN)-0.3
5329778*(nN*nN*nN)+0.0009863435*
(nN*nN*nN*nN))+0.5)
1140 CLS
1160 PRINT "Volumetric Gauge Res
ults"
1170 PRINT "for the 7 days start
ing"
1180 PRINT "* ";P$;" ",H$;" 1984
 *"
1200 PRINT "at the volumetric ga
uge sited"
1210 PRINT "at * ";G$;" *"
1220 PRINT
1230 PRINT "DAILY SO2 LEVELS:-
ml. added"
1240 PRINT "(mic.g./cu.m.)"
1250 PRINT "Tuesday      ";O;TAB 2
0;A
1255 PRINT "Wednesday  ";P;TAB 2
0;B
1260 PRINT "Thursday    ";Q;TAB 2
0;C
1265 PRINT "Friday       ";R;TAB 2
0;D
1270 PRINT "Saturday    ";S;TAB 2
0;E
1271 PRINT "Sunday       ";T;TAB 2
0;F
1272 PRINT "Monday       ";U;TAB 2
0;G
1273 LET jk=((O+P+Q+R+S+T+U)/7)*
100
1274 LET kl=(INT jk)/100
1275 LET lm=((A+B+C+D+E+F+G)/7)*
100
1276 LET mn=(INT lm)/100
1278 PRINT "--------------------
----------"
1279 PRINT "MEAN = ";TAB 11;kl;T
AB 20;mn
1280 PRINT "--------------------
```

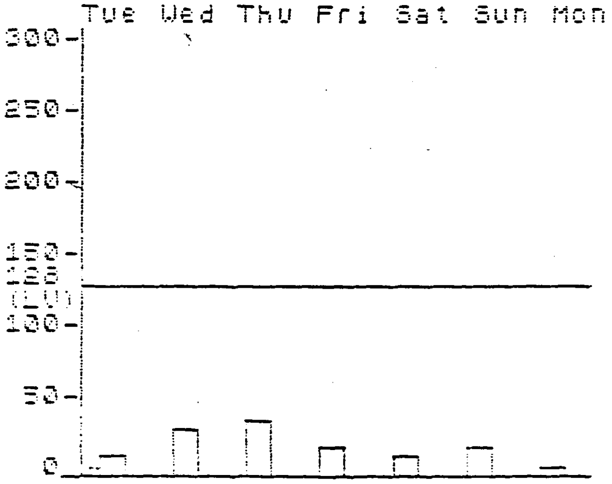
```
-----------"
1282 PRINT
1283 PRINT "Daily air flow = ";Z
;" cu.ft."
1284 PRINT "***SHOULD BE BETWEEN
 45-85***"
1303 COPY
1304 CLS
1320 LPRINT
1400 PRINT AT 0,4;"SO2 LEVELS(mi
c.g./cu.m.)"
1410 PRINT "********************
***********"
1420 PRINT AT 2,4;"Tue"
1440 PRINT AT 2,8;"Wed"
1450 PRINT AT 2,12;"Thu"
1460 PRINT AT 2,16;"Fri"
1470 PRINT AT 2,20;"Sat"
1480 PRINT AT 2,24;"Sun"
1498 PRINT AT 2,28;"Mon"
1500 PRINT AT 21,2;"0_"
1510 PRINT AT 18,1;"50-"
1520 PRINT AT 15,0;"100-"
1530 PRINT AT 12,0;"150-"
1540 PRINT AT 9,0;"200-"
1550 PRINT AT 6,0;"250-"
1560 PRINT AT 3,0;"300-"
1570 PRINT AT 14,0;"(LV)"
1572 PRINT AT 13,0;"128"
1580 FOR n=32 TO 240
1590 PLOT n,64
1600 NEXT n
1610 FOR n=0 TO 150
1620 PLOT 32,n
1630 NEXT n
1631 FOR n=32 TO 240
1632 PLOT n,0
1633 NEXT n
1635 FOR n=0 TO (O/2)
1637 PLOT 40,n
1639 NEXT n
1641 FOR n=40 TO 50
1643 PLOT n,(O/2)
1645 NEXT n
1647 FOR n=0 TO (O/2)
1649 PLOT 50,n
1651 NEXT n
1653 FOR n=0 TO (P/2)
1655 PLOT 70,n
1657 NEXT n
1658 FOR n=70 TO 80
1659 PLOT n,(P/2)
1660 NEXT n
1661 FOR n=0 TO (P/2)
1663 PLOT 80,n
1664 NEXT n
1665 FOR n=0 TO (Q/2)
1666 PLOT 100,n
1667 NEXT n
1669 FOR n=100 TO 110
1670 PLOT n,(Q/2)
1672 NEXT n
1673 FOR n=0 TO (Q/2)
1674 PLOT 110,n
1675 NEXT n
1677 FOR n=0 TO (R/2)
1678 PLOT 130,n
1680 NEXT n
1681 FOR n=130 TO 140
1682 PLOT n,(R/2)
1683 NEXT n
1684 FOR n=0 TO (S/2)
1685 PLOT 140,n
```

```
1686 NEXT n
1687 FOR n=0 TO (S/2)
1688 PLOT 150,n
1690 NEXT n
1691 FOR n=150 TO 170
1692 PLOT n,(S/2)
1693 NEXT n
1695 FOR n=0 TO (S/2)
1696 PLOT 170,n
1697 NEXT n
1698 FOR n=0 TO (T/2)
1700 PLOT 190,n
1703 NEXT n
1705 FOR n=190 TO 200
1709 PLOT n,(T/2)
1710 NEXT n
1713 FOR n=0 TO (T/2)
1715 PLOT 200,n
1717 NEXT n
1720 FOR n=0 TO (U/2)
1724 PLOT 220,n
1728 NEXT n
1743 FOR n=220 TO 230
1745 PLOT n,(U/2)
1748 NEXT n
1750 FOR n=0 TO (U/2)
1752 PLOT 230,n
1755 NEXT n
1760 COPY
1781 LPRINT
1782 LPRINT
1783 CLS
1785 LET a=(V/O)*100
1786 LET aaa=(INT a)/100
1787 LET b=(W/P)*100
1788 LET bbb=(INT b)/100
1789 LET c=(X/Q)*100
1790 LET ccc=(INT c)/100
1791 LET d=(Y/R)*100
1792 LET ddd=(INT d)/100
1793 LET e=(AA/S)*100
1794 LET eee=(INT e)/100
1795 LET f=(BB/T)*100
1796 LET fff=(INT f)/100
1797 LET g=(CC/U)*100
1798 LET ggg=(INT g)/100
1800 PRINT "DAILY SMOKE LEVELS.
Refl. Ratio"
1808 PRINT "(mic.g./cu.m.)";TAB
25;"(S/SO2)"
1820 PRINT "Tuesday      ";V;TAB 2
0;H;TAB 26;aaa
1830 PRINT "Wednesday    ";W;TAB 2
0;I;TAB 26;bbb
1840 PRINT "Thursday     ";X;TAB 2
0;J;TAB 26;ccc
1850 PRINT "Friday       ";Y;TAB 2
0;K;TAB 26;ddd
1860 PRINT "Saturday     ";AA;TAB
20;L;TAB 26;eee
1870 PRINT "Sunday       ";BB;TAB
20;M;TAB 26;fff
1871 PRINT "Monday       ";CC;TAB
20;nN;TAB 26;ggg
1872 LET qr=((V+W+X+Y+AA+BB+CC)/
7)*100
1873 LET rs=(INT qr)/100
1874 LET tu=((H+I+J+K+L+M+nN)/7)
*100
1877 LET uv=(INT tu)/100
1878 LET vw=((aaa+bbb+ccc+ddd+ee
e+fff+ggg)/7)*100
1879 LET wx=(INT vw)/100
```

```
1882 PRINT "--------------------
-----------"
1883 PRINT "MEAN = ";TAB 11;rs;T
AB 20;uv;TAB 26;wx
1885 PRINT "--------------------
-----------"
1886 PRINT
1887 PRINT "Data processed by ";
X$
1888 PRINT
1890 PRINT "The gauge meter read
ing on the"
1891 PRINT P$;" ";H$;" 1984"
1892 PRINT "was ";YY;" cu. ft."
1893 PRINT "and ";XX;" cu. ft.,
7 days later"
1899 COPY
1999 CLS
2000 PRINT AT 0,4;"SMOKE LEVELS(
mic.g./cu.m.)"
2010 PRINT "********************
***********"
2015 PRINT AT 2,4;"Tue"
2020 PRINT AT 2,8;"Wed"
2025 PRINT AT 2,12;"Thu"
2030 PRINT AT 2,16;"Fri"
2035 PRINT AT 2,20;"Sat"
2040 PRINT AT 2,24;"Sun"
2045 PRINT AT 2,28;"Mon"
2050 PRINT AT 21,2;"0_"
2055 PRINT AT 18,1;"50-"
2060 PRINT AT 15,0;"100-"
2065 PRINT AT 12,0;"150-"
2070 PRINT AT 9,0;"200-"
2075 PRINT AT 6,0;"250-"
2080 PRINT AT 3,0;"300-"
2082 PRINT AT 7,0;"213"
2083 PRINT AT 8,0;"(LV)"
3000 FOR n=32 TO 240
3010 PLOT n,0
3015 NEXT n
3020 FOR n=0 TO 150
3025 PLOT 32,n
3030 NEXT n
3031 FOR n=32 TO 240
3032 PLOT n,104
3033 NEXT n
3035 FOR n=0 TO (V/2)
3040 PLOT 40,n
3045 NEXT n
3050 FOR n=40 TO 50
3055 PLOT n,(V/2)
3060 NEXT n
3065 FOR n=0 TO (V/2)
3070 PLOT 50,n
3075 NEXT n
3080 FOR n=0 TO (W/2)
3085 PLOT 70,n
3090 NEXT n
3095 FOR n=70 TO 80
4000 PLOT n,(W/2)
4005 NEXT n
4010 FOR n=0 TO (W/2)
4015 PLOT 80,n
4020 NEXT n
4025 FOR n=0 TO (X/2)
4030 PLOT 100,n
4035 NEXT n
4040 FOR n=100 TO 110
4045 PLOT n,(X/2)
4050 NEXT n
4055 FOR n=0 TO (X/2)
4060 PLOT 110,n
4065 NEXT n
```

```
4070 FOR n=0 TO (Y/2)
4075 PLOT 130,n
4080 NEXT n
4085 FOR n=130 TO 140
4090 PLOT n,(Y/2)
4095 NEXT n
4100 FOR n=0 TO (Y/2)
4105 PLOT 140,n
4110 NEXT n
4115 FOR n=0 TO (AA/2)
4120 PLOT 160,n
4125 NEXT n
4130 FOR n=160 TO 170
4135 PLOT n,(AA/2)
4140 NEXT n
4145 FOR n=0 TO (AA/2)
4150 PLOT 170,n
4155 NEXT n
4160 FOR n=0 TO (BB/2)
4165 PLOT 190,n
4170 NEXT n
4175 FOR n=190 TO 200
4180 PLOT n,(BB/2)
4185 NEXT n
4190 FOR n=0 TO (BB/2)
4195 PLOT 200,n
4200 NEXT n
4205 FOR n=0 TO (CC/2)
4210 PLOT 220,n
4215 NEXT n
4220 FOR n=220 TO 230
4225 PLOT n,(CC/2)
4230 NEXT n
4235 FOR n=0 TO (CC/2)
4240 PLOT 230,n
4245 NEXT n
4255 COPY
4256 CLS
4258 LPRINT
4259 LPRINT
4260 LPRINT "N.B. (L.V.) on grap
hs are the"
4261 LPRINT "EEC peak limit valu
es,which "
4262 LPRINT "should not be excee
ded by 98th "
4263 LPRINT "percentile of daily
 values"
4264 LPRINT "over one years moni
toring"
4266 LPRINT "(Consult circ. 11/8
1 for other"
4267 LPRINT "limit values.)"
4268 LPRINT
4269 LPRINT
4370 GO TO 20
```

```
####Ram availability = 18K####

---------------------------------

     North East Derbyshire
      District Council

     Data Processing and Air
   Pollution Analysis Service

      ##############
      NEDDC SOFTWARE
      ##############

Volumetric Gauge Results
for the 7 days starting
* 23 April 1984 *
at the volumetric gauge sited
at * Pilsley, School *

DAILY SO2 LEVELS:-  ml. added
(mic.g./cu.m.)
Tuesday     13        0.2
Wednesday   32        0.5
Thursday    38        0.5
Friday      19        0.3
Saturday    13        0.2
Sunday      19        0.3
Monday      5         0.1
--------------------------------
MEAN =      20        0.31
---------------------------------

Daily air flow = 71 cu.ft.
###SHOULD BE BETWEEN 45-85###


    SO2 LEVELS(mic.g./cu.m.)
################################
```

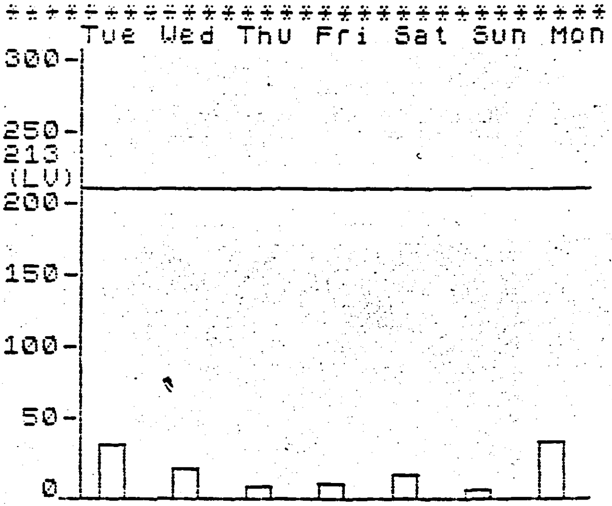


```
DAILY SMOKE LEVELS.  Refl.  Ratio
(mic.g./cu.m.)              (S/SO2)
Tuesday       35        78     2.69
Wednesday     19        86     0.59
Thursday      7         94     0.18
Friday        9         92     0.47
Saturday      15        88     1.15
Sunday        5         95     0.26
Monday .      38        77     6.33
-----------------------------------
MEAN =        18.28     87.14  1.66
-----------------------------------
```

Data processed by N.R.Tranmer

The gauge meter reading on the
23 April 1984
was 4002 cu. ft.
and 4500 cu. ft., 7 days later

SMOKE LEVELS(mic.g./cu.m.)



N.B. (L.V.) on graphs are the EEC peak limit values,which should not be exceeded by 98th percentile of daily values over one years monitoring (Consult circ. 11/81 for other limit values.)

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The author wishes to make it clear that the North East Derbyshire District Council are not in any way responsible for any conclusions or opinions expressed in this thesis.

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