An assessment of compliance with optimal fluoride levels for oral health benefit by New Zealand drinking water suppliers.

CHAMBERS, Tim <http://orcid.org/0000-0001-5856-5600>, HOBBS, Matthew <http://orcid.org/0000-0001-8398-7485>, BROADBENT, Jonathan M <http://orcid.org/0000-0002-8905-398X> and - <http://orcid.org/0000-0002-0216-8224>

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BRIEF COMMUNICATION

An assessment of compliance with optimal fluoride levels for oral health benefit by New Zealand drinking water suppliers

Tim Chambers PhD[1] | **Matt Hobbs PhD**[2,3] | **Jonathan M. Broadbent BDS, PhD, PGDipComDent**[4]

[1]Department of Public Health, Environment & Infection Research Unit, Department of Public Health, University of Otago, Wellington, New Zealand

[2]GeoHealth Laboratory, Geospatial Research Institute, University of Canterbury, Christchurch, New Zealand

[3]Faculty of Health, University of Canterbury, Christchurch, New Zealand

[4]Department of Oral Sciences, Sir John Walsh Research, Faculty of Dentistry, University of Otago, Dunedin, New Zealand

Correspondence
Tim Chambers, University of Otago, 23a Mein Street, Newtown, Wellington 6023, New Zealand.
Email: tim.chambers@otago.ac.nz

Abstract

Objectives: Community water fluoridation (CWF) has proven oral health benefits. We investigated whether drinking water suppliers are meeting New Zealand CWF targets (0.7–1.0 ppm) to ensure these benefits.

Methods: We retrieved fluoride testing data from 25 supplies serving 2,059,000 people (82% of people on a fluoridated supply), for the years 1992–2022 (22,220 weekly observations). We descriptively assessed compliance with fluoride targets in this convenience sample.

Results: The mean fluoride level was 0.66 ppm (SD 0.28). Water suppliers achieved fluoride targets 54.1% of the time (range 4.2%–77.9%). Fluoride concentration fell short of the target in 42.2% of observations, exceeded but under the maximum acceptable value (MAV) in 3.6%, and in excess of the MAV in 0.1%. The percentage of compliant observations was greater in larger than smaller supplies.

Conclusions: Noncompliance with CWF targets was common. Epidemiological studies that rely on fluoridation status as their exposure may underestimate the oral health benefits of CWF. Our results highlight future challenges with the feasibility of expanding CWF under new legislation as well as the weaknesses in drinking water surveillance.

KEYWORDS
community water fluoridation, drinking water, fluoride, oral health, public health

INTRODUCTION

Community water fluoridation (CWF) has proven benefits for oral health and promotes health equity [1]. New Zealand (NZ) city and district councils are local government authorities that supply 98% of all drinking water to people on a reticulated water supply (85% of the population) [2]. NZ water supplies almost universally have naturally low-fluoride levels. Twenty-seven of 67 councils currently fluoridate at least one water supply in their jurisdiction, supplying water to ~2.5million people (50% of the population) [3].

A 2015 costing of extending fluoridation to nonfluoridated areas in NZ was estimated at $144 million over a 20-year period, with a net savings of $600 million [4]. Subsequently, NZ introduced the Health (Fluoridation of Drinking Water) Amendment Act 2021, which moved fluoridation decisions from councils to the Director General of Health, with the intention of expanding CWF to nonfluoridated regions of the country [5]. However, no legislative analysis or available NZ evidence has examined water suppliers' ability to consistently achieve fluoride levels required to improve oral health, with the exception of one study from Dunedin which found observed fluoride concentration from one council at a mean of 0.74 parts per million (ppm), with values ranging from 0.63 to 0.85 ppm [6]. Internationally, one systematic review of 14 Brazilian studies found that mean fluoride levels in city supplies ranged from 0.17 to 0.89 ppm, and levels were outside the target range for 56.6% (95% CI 45.5; 67.3) of measurements [7]. In the United States (US), some fluoride data from the US Fluoridation reporting System (WFRS) is publicly available via the Centers for Disease Control and Prevention web interface [8]. A quick analysis of Californian state fluoridation supplies from 2018 show that supplies met CDC optimal fluoride targets (0.6–1.0 ppm) 95% of the time, however, 23% of all observations were missing [9].

In NZ, monitoring and reporting requirements for fluoride in drinking-water are based on compliance with the maximum acceptable value (MAV) of 1.5 ppm outlined in the Drinking-Water Standards for New Zealand (DWSNZ) [10], not the optimal levels for oral health (0.7–1.0 ppm). Water suppliers are required to test for fluoride weekly under the DWSNZ [10] but are not required to report test results below the MAV to the Ministry of Health (MoH), and a national longitudinal database for drinking water quality is not available in NZ [11]. NZ has a voluntary Code of Practice for CWF (COP); however, it is unclear how many water supplies adhere to the COP. [12]. Consequently, water suppliers effectively self-regulate the fluoridation of their supplies for oral health purposes.

Water supplier compliance has implications for assessing epidemiological evidence, the current state of CWF infrastructure and the feasibility of policy changes. The aim of this short report is to assess water supplier compliance with recommended fluoride levels (0.7–1.0 ppm) in a convenience sample of fluoridated areas of NZ.

METHODS

In March 2022, we sent official information requests to all 67 councils for water quality data as far back as records permit. At the time of publication, of 67 councils

TABLE 1 Characteristics of included community water fluoridation sites

Supply ID	Population	Supply type		Observations			Fluoride target achieved		Fluoride ppm	
	N[a]	MoH[b]	Council[c]	Total	First year	Last year	*n*	%	Mean	SD
Supply 1	1,348,200	Large	City	3722	2010	2022	2529	68.0	0.77	0.14
Supply 2	75,900	Large	City	3372	2012	2021	2573	76.3	0.75	0.10
Supply 3	64,800	Large	District	2956	2004	2016	1534	51.9	0.74	0.23
Supply 4	50,500	Large	City	1527	1992	2022	769	50.4	0.64	0.26
Supply 5	23,800	Large	District	1278	2000	2022	698	54.6	0.65	0.26
Supply 6	112,500	Large	City	1217	2001	2022	948	77.9	0.76	0.15
Supply 7	3,900	Small	District	994	2001	2022	374	37.6	0.52	0.34
Supply 8	176,600	Large	City	934	2004	2022	421	45.1	0.58	0.25
Supply 9	1,700	Small	District	931	2004	2022	503	54.0	0.68	0.19
Supply 10	59,100	Large	District	626	2000	2011	379	60.5	0.70	0.21
Supply 11	7,300	Medium	District	537	2012	2022	85	15.8	0.35	0.29
Supply12	6,900	Medium	District	530	2012	2022	148	27.9	0.41	0.33
Supply13	15,400	Large	District	513	2012	2022	283	55.2	0.65	0.27
Supply14	2,100	Small	District	427	2014	2022	57	13.4	0.31	0.26
Supply15	9,700	Medium	District	415	2015	2022	168	40.5	0.56	0.32
Supply16	38,000	Large	District	358	2015	2022	15	4.2	0.54	0.11
Supply17	19,000	Large	District	334	1995	2002	96	28.7	0.50	0.38
Supply18	6,800	Medium	District	258	2003	2022	194	75.2	0.77	0.14
Supply19	7,700	Medium	District	218	2011	2022	26	11.9	0.53	0.15
Supply20	21,000	Large	District	204	2009	2021	105	51.5	0.76	1.26
Supply21	3,900	Small	District	193	2016	2020	47	24.4	0.53	0.42
Supply22	2,500	Small	District	192	2016	2020	16	8.3	0.26	0.27
Supply23	800	Small	District	190	2016	2020	19	10.0	0.41	0.28
Supply24	700	Small	District	190	2016	2020	27	14.2	0.42	0.47
Supply25	1,000	Small	District	104	2020	2022	5	4.8	0.49	0.14
Total	2,059,900	12 L:5 M:8S	5C:20D	22,220	1992	2022	12,019	54.1	0.66	0.28

[a]Population is rounded to the nearest hundred.
[b]Ministry of Health (MoH) water supply definitions small = <5000; medium 5000–9999; and large ≥10,000. Beta regression showed large supplies (conditional mean 0.50, 95%CI 0.38, 0.61) outperformed small supplies (conditional mean 0.23, 95%CI 0.12, 0.34, $p = 0.002$) but not medium sized supplies (conditional mean 0.35, 95%CI 0.18, 0.51, $p = 0.159$).
[c]Council definition. City council are generally larger metropolitan areas, district councils are generally smaller, rural and/or cover large areas. Beta regression showed city council supplies (conditional mean 0.62, 95%CI 0.44, 0.79) outperformed district council supplies (conditional mean 0.31, 95%CI 0.23, 0.40, $p < 0.001$).

have yet to complete the request (response rate 88% among all councils; 70% response rate among fluoridating councils). All weekly fluoride test data were provided in Excel files which were collated into a single database. The data were provided at the treatment plant level (some supplies have multiple treatment plants). Data were analyzed at the water supply level so treatment plant data were aggregated within each water supply. Compliance with oral health targets was defined as any fluoride measurement from 0.7 to 1.0 ppm. Population size was based on the number of people served by a water supply according to the MoH database of registered supplies. To determine the impact of population size on fluoride compliance we used beta regression. Population size was treated as a categorical variable based on MoH water supply definitions small = <5000; medium 5000–9999; and large ≥10,000 and binary variable using council definitions: either a city council which are generally large metropolitan areas or a district council which are generally smaller populations, rural and/or cover large areas. Descriptive statistics and regression results were generated in Stata V17.0 (StataCorp LLC, College Station, TX).

RESULTS

In total, we received data from 25 water supplies serving 2,059,000 people (82% of people on a fluoridated supply), including 22,220 weekly observations from 1992 to 2022 (Table 1). The mean fluoride level was 0.66 ppm (SD 0.28) across 25 fluoridated water supplies (Table 1). Water suppliers achieved fluoride targets 54.1% of the time overall, while individual water supply compliance percentages ranged from 4.2% to 77.9%, with an interquartile range of 14.2%–54.6%. Nearly half of observations (42.2%) were under targets (<0.7 ppm), 3.6% were over targets but under the MAV (>1.0 & <1.5 ppm), while 0.1% exceeded the MAV (≥1.5 ppm). Large supplies had higher fluoride compliance percentage than smaller supplies but not medium sized supplies, while city councils outperformed district councils.

DISCUSSION

Our findings demonstrate major inconsistencies in councils' achievement of oral health targets. These compliance rates are consistent with one previous review of Brazilian cities [7], but much worse than those observed in one previous NZ study [6]. Even the best performing water supply only achieved fluoride targets 77.9% of the time, while 75% of water supplies had compliance percentages lower than 55%. The results show that non-compliance was mainly from under dosing, while in rare cases, targets were exceeded.

Previous studies have suggested environmental conditions, chemical instability and fluoridation equipment aging or malfunction as potential causes for inconsistent fluoride dosing [7]. In NZ, the causes are typically aged equipment, an over-reliance on manual make-up systems and monitoring, problems with clumping of sodium fluorosilicate powder, and a general lack of good process control. In 2022, Wellington Water revealed it had not been fluoridating Wellington's water supplies for almost a year, while dosing had been inconsistent for almost 4 years due to faulty equipment [13]. Wellington Water is one of NZ's largest water suppliers controlling water assets worth $6.1 billion, with an annual operating budget of $225 m [14], suggesting smaller water supplies may struggle with the challenges posed by ongoing maintenance and securing the required technical expertise. This is consistent with findings from the US, where operators of smaller water treatment plants were less knowledgeable with respect to fluoridation and were less able to maintain a fluoride concentration to within 0.1 ppm of the target concentration [15].

In part, the poor performance could be attributable to the self-regulatory system of fluoridation implementation. Our results would suggest very few councils are upholding the code of practice (COP). There is no obligation to implement the COP nor is there any central oversight of water supplier performance against oral health targets. Water agencies reportedly prioritize resources toward managing microbiological and chemical risks, while health agencies did not include fluoridation in their policy agenda [16] and there is a lack of clarity as to who should "own" the monitoring and enforcement of fluoridation to ensure oral health benefits.

Implications for dental public health

Some reports have relied on fluoridation status as a proxy for exposure to fluoride at the levels required for oral health benefits [1], but our preliminary analysis casts doubt on the reliability of this as an exposure assessment. Consequently, such reports may be underestimating the oral health benefits of fluoridation. This exacerbates existing limitations of exposure assessments that may be masking the true effectiveness of CWF. For example, in NZ, much research relies on administrative units as a proxy for water supply boundaries such as the area supplied by a particular water supply. Consequently, people who live outside a fluoridated water supply boundary but in the same administrative unit will be misclassified, and vice versa.

In NZ, the MoH routinely reports key oral health outcomes for children at age 5 years by fluoridation status of the child's school location. Figure 1a,b demonstrate the fluoridation levels in one district council and changes in the proportion of children aged 5 who are caries free, stratified by fluoridated and nonfluoridated areas

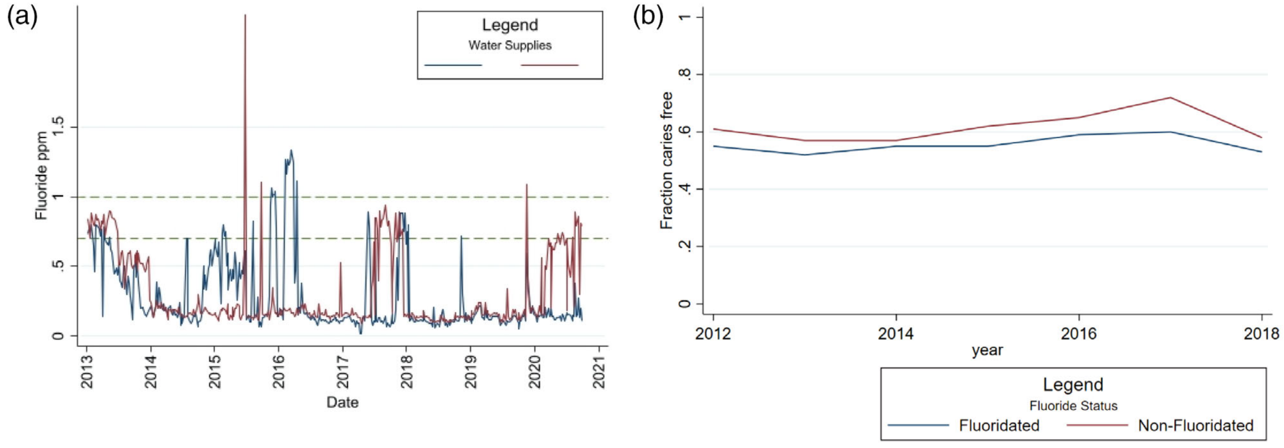

FIGURE 1 Fluoride levels from two supplies in one district council (panel 1A); and the proportion of caries free children at age five in the same district council, unadjusted for area-level deprivation (panel 1B) [Color figure can be viewed at wileyonlinelibrary.com]

in the same region, unadjusted for area-level deprivation. These comparisons are used by opponents of fluoridation to claim no effect of CWF. This type of ecological comparison is severely limited. First, school is an imperfect proxy for a child's residential address and likely leads to exposure misclassification. Second, the fluoridated areas in this region are lower SES than the nonfluoridated areas, which is a key confounder. Third, we can now add significant uncertainty around drinking water supplier compliance to the list of limitations. These limitations reinforce calls for national geospatial datasets of water supply boundaries and longitudinal quantitative water quality testing results [11].

Implications for policy

NZ's Health (Fluoridation of Drinking Water) Amendment Act 2021 is intended to result in wider adoption of CWF across NZ. Our results shed some light on council capacity to implement and maintain effective CWF schemes, which were not visibly considered in the original policy and regulatory impact assessments [3, 17]. These preliminary results suggest that the costs of CWF may be higher than anticipated if existing costings assumed 100% compliance, [4] particularly for smaller supplies. This is a serious concern as one of the three criteria for fluoridation decision-making under the new Act is:

"the likely financial cost and savings of adding fluoride to the drinking water, including any additional financial costs of ongoing management and monitoring." [5], p. 4.

Some of NZ's largest, most resourced councils have been unable to consistently maintain fluoridation schemes across the country – primarily due to the implications of aging infrastructure [13]. It appears unlikely central Government will cover the expected cost of additional fluoridation. The 2015 report prepared for the MoH estimated expanding fluoridation schemes would cost \$144 m over 20 years (assuming current schemes were 100% effective) [4], while central Government has proposed initial financial support of \$8.3 m, plus another \$3 m per year (\$68.3 m over 20 years). However, price inflation over the past 7 years will exacerbate this resourcing deficit, for example, the cost of fluoridating Christchurch City's water supply is estimated at \$60 m, plus \$2.5 m annual operating costs. The resourcing deficit will likely widen oral health inequities as more affluent areas will likely have greater capacity to effectively implement schemes.

Our results support the regulatory implementation of the NZ COP. Specifically, the requirement to implement a standardized quality assurance system that ensures adequate monitoring, verification of the fluoride testing results and corrective actions in the event of over- or under-dosing [12]. Clearly, in NZ, either the quality assurance systems implemented under the voluntary COP are inadequate or suppliers are not upholding the code. Mandatory implementation of the COP will also bring important improvements in health and safety procedures and system design and performance.

The scarcity of data to inform policy decisions on fluoridation is attributable to the MoH's failure to collect, store and maintain a national database of drinking water quality for public health surveillance. Responsibility for drinking-water regulation has recently been transferred to a new independent water regulator, Taumata Arowai, who is currently consulting on new drinking water standards and compliance rules. However, Taumata Arowai have yet to publicly commit to developing or maintaining a national database of drinking-water quality. Without such a commitment, NZ's fragmented and data-poor approach to public health surveillance and drinking water is likely to continue [11]. Further, without central oversight, the existing approach of council self-regulation that has obscured robust assessment of their performance and the provision of a key public health intervention will continue.

CONCLUSION

Most NZ water suppliers have not consistently achieved fluoride levels necessary for oral health benefits. Consequently, epidemiological studies using exposure assessments reliant on fluoridation status may be underestimating the true oral health benefits of CWF. The failings of water suppliers also highlight some concerns for the new Health (Fluoridation of Drinking Water) Amendment Act 2021 to consider and the need for Taumata Arowai to create and maintain a national dataset of drinking water quality. Our results demonstrate the need to update and incorporate the Code of Practice into legislation or regulation, with central oversight from the new water regulator, Taumata Arowai.

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CONFLICT OF INTEREST

The authors have no conflicts of interest.

ORCID

Tim Chambers https://orcid.org/0000-0002-0216-8224
Matt Hobbs https://orcid.org/0000-0001-8398-7485
Jonathan M. Broadbent https://orcid.org/0000-0002-8905-398X

REFERENCES

1. Office of the Prime Minister's Chief Science Advisor, Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia. Fluoridation: an update on evidence. Wellington: PMCSA; 2021. https://www.pmcsa.ac.nz/topics/fluoridation-an-update-on-evidence/.
2. Richards J, Chambers T, Hales S, Joy MK, Radu T, Woodward A, et al. Nitrate contamination in drinking water and colorectal cancer: exposure assessment and estimated health burden in New Zealand. Environ Res. 2022;204(112322):112322. https://doi.org/10.1016/j.envres.2021.112322
3. Cabinet Social Policy Committee. Decision-making on the fluoridation of drinking-water supplies. Wellington: Cabinet Social Policy Committee;2016. https://www.health.govt.nz/system/files/documents/pages/cabinet-paper-decision-making-fluoridation-drinking-water-supplies.pdf.
4. Moore D, Poynton M. Review of the benefits and costs of water fluoridation in New Zealand Wellington: Sapere research group;2015. https://www.health.govt.nz/system/files/documents/publications/review-benefits-costs-water-fluoridation-new-zealand-apr16.pdf.
5. Health (Fluoridation of Drinking Water) Amendment Act 2021. 2021. https://www.legislation.govt.nz/act/public/2021/0044/latest/whole.html.
6. Tirtawijaya J, Thomson W, Broadbent J, Peake B, Brownie P. Fluoride concentration in Dunedin (New Zealand) drinking water. New Zealand Dent J. 2017;113(1):11–16 .
7. Rosário BSM, Rosário HD, de Andrade VW, Cericato GO, Nóbrega DF, Blumenberg C, et al. External control of fluoridation in the public water supplies of Brazilian cities as a strategy against caries: a systematic review and meta-analysis. BMC Oral Health. 2021;21(1):1–13. https://doi.org/10.1186/s12903-021-01754-2
8. Centers for Disease Control and Prevention. Water fluoridation reporting system; 2022. https://www.cdc.gov/fluoridation/data-tools/reporting-system.html.
9. Centers for Disease Control and Prevention. Average fluoride levels by month report - California. US Fluoridation reporting System;2018. https://nccd.cdc.gov/DOH_MWF/Reports/AvgFlLevel_Month_Rpt.aspx.
10. Ministry of Health. Drinking-water standards for New Zealand 2005 (revised 2018). Wellington (NZL) 2018. https://www.health.govt.nz/system/files/documents/publications/dwsnz-2005-revised-mar2019.pdf.
11. Chambers T, Hales S, Wilson N, Baker M. Improvements to drinking water monitoring, reporting and record-keeping needed to protect health. Policy Quarterly. 2022;18(2):23–27.
12. Water New Zealand. Water New Zealand code of practice: fluoridation of drinking-water supplies in New Zealand. Water New Zealand; 2014. https://www.waternz.org.nz/Folder?Action=View%20File&Folder_id=89&File=Code%20of%20Practice%20-%20Fluoridation%20of%20drinking-water%20supplies.pdf.
13. Hunt T. Wellington fluoride shutdown followed overdosing at one plant. Dominion Post;2022. https://www.stuff.co.nz/dominion-post/news/wellington/128117421/wellington-fluoride-shutdown-followed-overdosing-at-one-plant.
14. Wellington Water. Annual report 2020/21. Wellington (NZL); 2021. https://www.wellingtonwater.co.nz/publication-library/publications-3/document/672/.
15. Lalumandier JA, Hernandez LC, Locci AB, Reeves TG. US drinking water: fluoridation knowledge level of water plant operators. J Public Health Dent. 2007;61(2):92–8. https://doi.org/10.1111/j.1752-7325.2001.tb03372.x
16. Bomfim RA, Watt RG, Frazão P. Intersectoral collaboration and coordination mechanisms for implementing water fluoridation: challenges from a case study in Brazil. J Public Health Dent. 2021: 1– 10.
17. Ministry of Health. Regulatory impact assessment: transferring decision-making on the fluoridation of drinking-water from local authorities to district health boards. Wellington (NZL); 2016. https://www.health.govt.nz/system/files/documents/information-release/ris-decision-making-on-fluoridation.pdf.

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