Water fluoridation and dental caries in 5- and 12-year-old children from Canterbury and Wellington

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ABSTRACT

Objectives

Claims have been made that the effectiveness of water fluoridation has reduced due to the widespread availability of other sources of fluoride. This study examines the differences in the oral health of children living in fluoridated and non-fluoridated areas of Canterbury and Wellington, New Zealand.

Design

The data used in this cross-sectional study had been routinely collected into a computerized data-collection system by the School Dental Services in the two study areas.

Subjects and methods

Records of dental status (dmfs/DMFS), fluoridation status, ethnicity, and socio-economic status for 8030 5-year-olds, and 6916 12-year-olds in 1996 were analysed.

Results

Caries prevalence and severity was consistently lower for children in the fluoridated area for both age groups, and within all subgroups. Five-year-olds in the fluoridated area had 2.63 dmfs (sd, 5.88), and those in the non-fluoridated area 3.80 dmfs (sd, 6.79). For 12-year-olds the respective figures were 1.39 DMFS (sd, 2.30) and 2.37 DMFS (sd, 3.46). Multivariable analysis confirmed the independent association between water fluoridation and better dental health.

Conclusions

This results of this study show children living in a fluoridated area to have significantly better oral health compared to those not in a fluoridated area. These differences are greater for Maori and Pacific children and children of low socio-economic status.

INTRODUCTION

In 1999, the United States' Centers for Disease Control and Prevention (CDC) recognized water fluoridation as one of the ten great public health achievements in the United States during the 20th century (CDC, 1999). The CDC noted that "water fluoridation remains the most equitable and cost-effective method of delivering fluoride to all members of most communities, regardless of age, educational attainment, or income level". Despite these acknowledged benefits, little progress has been made since the 1970s in expanding the proportion of New Zealand's population receiving fluoridated water, and the Ministry of Health's target of increasing the proportion of the population on reticulated water supplies who receive fluoridated water to 70 percent by the end of 2000 was not achieved, as the level is currently 62 percent (ESR Water Group, 2002). One of the reasons for the lack of progress in extending water fluoridation in New Zealand may have been the perception that because of the widespread availability of other sources of fluoride, and declining dental caries rates, water fluoridation was seen as providing little additional benefit (Colquhoun, 1984; de Liefde, 1998). However, almost all the studies carried out in New Zealand that have examined the effect of water fluoridation on oral health have shown water fluoridation to be associated with significantly lower dental caries rates. The most recent of these was by Treasure and Dever (1994); this study showed that 14-year-olds in fluoridated Ashburton had DMFS scores that were 49 percent lower than their counterparts in non-fluoridated Oamaru. The same authors had previously shown 5-year-olds from fluoridated Dunedin and Ashburton to have dmfs scores 63 percent lower than children from non-fluoridated Oamaru and Timaru (Treasure and Dever, 1992). Of the 15 studies on water fluoridation in New Zealand published since 1980, and reviewed in the Public Health Commission's report *Water Fluoridation in New Zealand* (Public Health Commission, 1994), only two failed to report significant benefits from fluoridation.

One of the major themes to emerge from recent work on water fluoridation has been that of the relationship between water fluoridation and socio-economic status. It has been consistently observed that individuals and groups of low socio-economic status benefit to a much greater extent from water fluoridation than those of high socio-economic status (Fergusson and Horwood, 1986; Stockwell et al, 1990; Treasure and Dever, 1994; Slade et al, 1996; Jones and Worthington, 1999; Riley et al, 1999). This suggests that water fluoridation may be a powerful means of reducing inequalities in oral health status across the population.

This study examines the differences in dental caries rates between children living in fluoridated and non-fluoridated areas of Canterbury and Wellington, and examines the relationships between dental caries and water fluoridation, gender, ethnicity and socio-economic status.

METHODS

Data on the dental status of children from 5 to 12 years of age who had dental care provided for them in 1996 were obtained from the Hospital and Health Services providing school dental services in the Canterbury and Wellington regions. These two Hospital and Health Services (now the Canterbury and the Hutt Valley District Health Boards respectively) used the same computer system, (Molaris, E Pi Ltd, Lower Hutt, NZ) developed by one of the authors (PJD), to capture data on the dental care and oral health status of individual children. This information was entered into PSION Series 3 hand-held computers (PSION Plc, UK) at school dental clinics by dental therapists and assistants, and included the status of each tooth surface following completion of a course of routine dental treatment. Details included whether each surface was present or absent, or decayed, missing (extracted), filled, or sealed. Data were extracted from each database, and merged to form a single dataset for analysis. For each child, at the completion of their last course of dental care in 1996, the number of decayed, missing and filled deciduous and permanent tooth surfaces (dmfs and DMFS respectively), and age (rounded down to a whole number), were calculated.

Classification of ethnicity, water fluoridation status, and socio-economic status was also made using the computerized information. Ethnic origin was assigned as either Maori, Pacific, or Other — based on a parent/caregiver selection when children were enrolled for school dental services (the "Other" category contained children identified as "European", "South East Asian", and "Other"; Europeans made up 97 percent of this category). Socio-economic status was classified according to the 1996 TFEA decile ranking of the school each child attended. The TFEA (Targeted Funding for Educational Attainment) index is the Ministry of Education's socio-economic indicator for schools, and is a multidimensional index of socio-economic disadvantage based partly on school enrolment data and partly on census data from each school's catchment area. The six dimensions are: (1) equivalent household income; (2) parents' occupation; (3) household crowding; (4) parents' educational qualifications; (5) income support payments received by parents; and (6) Maori and Pacific Islands ethnicity. On the basis of their scores, schools are ranked into deciles. Decile one represents those schools drawing from the lowest socio-economic groups, and decile ten the highest (Data Management and Analysis Section, 1997). For this study, three groups were formed by aggregating those in Deciles 1-3, 4-7, and 8-10 as low, medium, and high socio-economic status groups respectively.

The Significant Caries Index (SiC) was developed to re-focus the efforts of countries which had already achieved the WHO/FDI goal of three or less DMFT in 12-year-olds by the year 2000, and apply it to the third of the population with highest caries scores (Bratthall, 2000). Individuals are sorted according to their DMFT values and the one-third of the population with the highest caries score is selected. The mean DMFT for this subgroup is calculated and this value constitutes the SiC Index. In 1996, New Zealand was one of the countries which had already achieved the original WHO/FDI goal, and so it was of interest to apply this index to the 12-year-olds living in areas with and without water fluoridation, and analyse the data by gender, ethnicity and socio-economic status.

Whether or not children currently lived in an area with water fluoridation had been recorded when oral health status records were made at school dental clinics. No lifetime estimate of the length of each child's residence in a fluoridated area was made. In the areas studied, two local bodies had ceased fluoridating water supplies in the 12 years prior to 1996 and no new fluoridation schemes had been introduced. The areas concerned were Timaru city, in which fluoridation stopped in 1985, and Waimairi County (now part of Christchurch City), which ceased fluoridation in 1986.

The fact that the data used in this study had been collected by a large number of dental therapists, at a large number of sites, as a part of providing routine oral health care, meant that the examiners were not standardised, nor could the examiner reliability be assessed. Ethical approval was not sought because this study utilised data routinely collected for mandatory reporting to the Ministry of Health, monitoring and evaluating oral health, and service planning. No individuals were identified.

While data were available for each age-year group, from 5 to 12 years old, this study presents only analyses of oral health for 5- and 12-year-olds. This decision was made in order to reduce the amount of information presented, while maintaining consistency with previous studies. Standard methods of tabular analysis, including the Chi square test, and calculation of odds ratios were used to describe differences between groups for the categorical caries prevalence variables; the non-parametric Kruskal-Wallis test was used to test for differences between groups with continuous variables (dmfs/DMFS and SiC); and linear and logistic regression were used to examine the associations between multiple variables simultaneously. For the regression analyses dummy variable coding of categorical independent variables (fluoridation, gender, ethnicity, and socio-economic status) was used. This entails the creation of n-1 dummy variables in each category, where n equals the number of groups in the category, with each dummy variable representing membership of a group (eg "male"). One group is not coded; this is designated the reference group, and is not represented in the regression model. Levels of statistical significance were set at $p<0.05$. Data analysis was carried out using SPSS for Windows, Version 10 (SPSS Inc., Chicago, Ill).

RESULTS

The sample. The two databases yielded records for 9486 5-year-old and 8150 12-year-old children. Data for some individuals were incomplete, and their records were excluded from the analysis to leave complete records for 8375 5-year-olds and 7158 12-year-olds. Table I shows that the principal reason for exclusion in both age groups was missing TFEA decile information. The relatively high rate of exclusion for this category is because the 1996 version of the TFEA index did not include private and independent schools. For both age groups, the excluded group had a higher proportion caries-free, and lower mean dmfs/DMFS scores. Of the children included in the study, there were significant differences in the composition of the fluoridated and non-fluoridated groups at both ages, with higher proportions of Maori and Pacific children, and children from decile 1-3 schools in the fluoridated group.

TABLE I – Summary of the numbers of records available, and records excluded from analysis for both 5- and 12-year-old children.

	5-year-olds	12-year-olds
Available records	9486	8150
Records with missing data elements		
dmfs/DMFS	53	73
Gender	7	3
Fluoridation	8	3
Ethnicity	3	0
TFEA decile	1052	925
Excluded records (percentage of available records)*	1111 (11.7)	992 (12.2)
Complete records included in this study	8375	7158

*Sum of records with missing data is greater than the number of excluded records because some records have more than one element missing

This study compares those children in the Canterbury region who were not receiving fluoridated water, and those from Wellington who were receiving fluoridated water. Accordingly, the small group of Canterbury children that had received fluoridated water was not included, and nor was the still smaller group of Wellington children who had not received fluoridated water. These numbers of children in each group are shown in Table II.

Results for five-year-olds. Table III shows water fluoridation to be associated with 31 percent lower dental caries severity scores in deciduous teeth (dmfs) among 5-year-old children. Fluoridated water supplies were consistently associated with lower dmfs scores for males and females separately, and among all ethnic and socio-economic groups. Linear regression analysis (Table IV) showed that the presence of water fluoridation was associated with significantly lower dmfs scores after controlling for gender, ethnicity, and socio-economic status. In addition to lower dental caries severity, water fluoridation was associated with lower proportions of children having caries (Table III). As with the dmfs scores, this difference was seen consistently across all gender, ethnic, and socio-economic status groups. Logistic regression was used to calculate odds ratios, and these showed children receiving fluoridated water to have 0.6 times the odds of having caries than those with non-fluoridated water (Table IV).

TABLE II – Numbers of 5- and 12-year-old children, by water fluoridation status for Canterbury and Wellington regions (percentage of children within regions).

		Fluoridated water No	Fluoridated water Yes	Total
Age 5				
	Canterbury	4970 (95.2 percent)	252 (4.8 percent)	5222
	Wellington	93 (2.9 percent)	3060 (97.1 percent)	3153
		5063	3312	8375
Age 12				
	Canterbury	4285 (95.8 percent)	186 (4.2 percent)	4471
	Wellington	56 (2.1 percent)	2631 (97.9 percent)	2687
		4341	2817	7158

Results for 12-year-olds. The results for 12-year-old children paralleled those for 5-year-olds. Water fluoridation was associated with 41 percent lower dental caries severity scores in permanent teeth (DMFS) for the group as a whole, and similar differences were observed within all sub-groups considered in this study (Table V). Multivariable analysis (Table VI) showed water fluoridation to be independently associated with significantly lower DMFS scores, and only 0.6 times the odds of having caries.

Differences between ethnic and socio-economic groups. Although it was not the intention of this study to examine differences in oral health between ethnic or socio-economic groups, it is clear that Maori and Pacific children, and those from low socio-economic groups have much worse oral health than children from the very largely European "Other" group, and the more socio-economically advantaged groups. For example, in the non-fluoridated group, the mean dmfs score of Maori five-year-olds was double that for the "Other" group, and that for Pacific children, three times greater than the "Others". The data in Tables III and V show markedly lower dental caries severity scores at both ages for Maori and Pacific children living in fluoridated areas – and this fluoridation-associated benefit is also seen in the higher percentages of children caries-free.

Significant Caries Index (SiC) The results of the SiC index calculations (Table VII) show that across all sub-groups there are significant ($p<0.01$) differences associated with water fluoridation in the dental caries severity (DMFT) of the one-third of 12-year-olds in the tail of the distribution curve. It was evident that in the fluoridated areas, the SiC index was

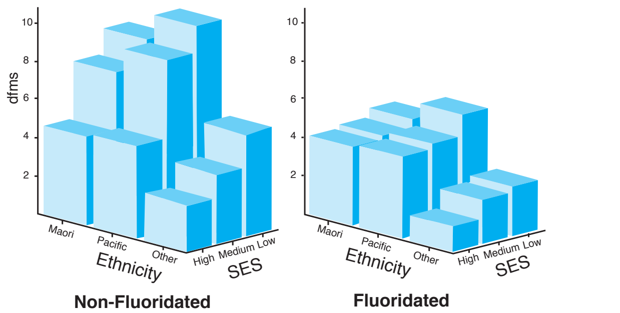

FIG 1 - Mean dmfs scores by ethicity and socioeconomic status for 5-year-olds from non-fluoridated and fluoridated areas.

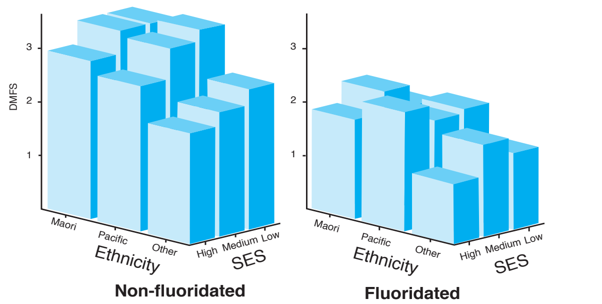

FIG 2 - Mean DMFS scores by ethicity and socioeconomic status for 12-year-olds from non-fluoridated and fluoridated areas.

Table III – Five-year-old children: mean numbers of decayed missing and filled deciduous tooth surfaces (dmfs), and percentage caries-free for children receiving and not receiving fluoridated water, and absolute and percentage differences between the two groups.

		Non-fluoridated n	Non-fluoridated dmfs mean	Non-fluoridated dmfs sd	Non-fluoridated Percent caries-free	Fluoridated n	Fluoridated dmfs mean	Fluoridated dmfs sd	Fluoridated Percent caries-free	dmfs difference (NF to F) Absolute	dmfs difference (NF to F) percent	caries-free difference percent
Gender												
	Female	2406	3.74	6.80	54.9	1470	2.32	5.24	61.8	1.42 [a]	-38	13 [b]
	Male	2564	3.86	6.78	53.4	1590	2.91	6.41	60.0	0.95 [a]	-25	12 [b]
Ethnic group												
Maori	346	8.07	9.48	28.3	490	4.43	6.50	40.4	3.64 [a]	-45	43 [b]	
	Pacific	93	9.42	9.45	22.6	414	5.35	7.69	38.6	4.07 [a]	-43	71 [c]
	Other	4531	3.36	6.30	56.7	2156	1.69	5.01	69.8	1.67 [a]	-50	23 [b]
Socioeconomic status												
Low	950	6.27	8.69	38.5	795	4.45	7.09	43.6	1.82 [a]	-29	13 [d]	
	Medium	1887	4.03	7.01	52.3	837	2.80	6.47	60.9	1.23 [a]	-31	16 [b]
	High	2133	2.50	5.11	62.7	1428	1.51	4.29	70.4	0.99 [a]	-40	12 [b]
All combined		4970	3.80	6.79	54.1	3060	2.63	5.88	60.9	1.17 [a]	-31	13 [b]

[a] dmfs: Kruskal-Wallis test: $p < 0.001$

[b] caries-free: chi square test: $p < 0.001$

[c] caries-free: chi square test: $p < 0.01$

[d] caries-free: chi square test: $p < 0.05$

TABLE IV – Results of linear and logistic regression analyses for 5-year-old children.

Independent variables		Linear regression dependent variable: dmfs B	Standard error of B	Logistic regression dependent variable: dmfs > 0 Odds ratio	95 percent CI
Water fluoridation					
	Fluoridated	-1.82 [a]	0.15	0.59 [a]	0.53–0.65
Gender					
	Male	0.30 [b]	0.14	1.07	0.98–1.18
Ethnicity					
	Maori	2.79 [a]	0.24	2.65 [a]	2.25–3.11
	Pacific	3.04 [a]	0.32	2.64 [a]	2.14–3.25
Socioeconomic status					
	Low	2.29 [a]	0.20	2.02 [a]	1.77–2.29
	Medium	1.11 [a]	0.16	1.38 [a]	1.25–1.54
Constant		2.54		0.58	

[a]$p < 0.001$ [b]$p < 0.05$

Model statistics - Linear regression: $R^2 = 0.07$, ANOVA: $p < 0.001$; Logistic regression: $R^2 = 0.65$, Chi square: $p < 0.001$

TABLE V – Twelve-year-old children: mean numbers of decayed missing and filled permanent tooth surfaces (DMFS), and percentage caries-free for children receiving and not receiving fluoridated water, and absolute and percentage differences between the two groups.

	Non-fluoridated n	Non-fluoridated DMFS mean	Non-fluoridated Sd	Non-fluoridated Percent caries-free	Fluoridated n	Fluoridated DMFS mean	Fluoridated sd	Fluoridated Percent caries-free	DMFS difference (NF to F) Absolute	DMFS difference (NF to F) percent	Caries-free difference percent
Gender											
Female	2150	2.46	3.48	40.9	1259	1.60	2.62	48.8	0.86 [a]	-35	19 [b]
Male	2135	2.28	3.44	42.2	1372	1.20	1.93	54.5	1.08 [a]	-47	29 [b]
Ethnic group											
Maori	292	3.40	3.83	29.5	449	1.86	3.07	44.8	1.54 [a]	-45	52 [b]
Pacific	87	3.40	3.63	25.3	290	2.04	3.13	41.7	1.36 [a]	-40	65 [c]
Other	3906	2.27	3.41	42.9	1892	1.18	1.85	54.8	1.09 [a]	-48	28 [b]
Socioeconomic status											
Low	542	2.78	3.63	37.5	768	1.74	2.59	43.5	1.04 [a]	-37	16 [d]
Medium	2223	2.46	3.48	40.1	546	1.36	2.00	51.8	1.10 [a]	-45	29 [b]
High	1520	2.11	3.36	45.3	1317	1.21	2.20	56.3	0.9 [a]	-43	24 [b]
All combined	4285	2.37	3.46	41.6	2631	1.39	2.30	51.7	0.98 [a]	-41	24 [b]

[a] DMFS: Kruskal-Wallis test: $p < 0.001$ [b] caries-free: chi square test: $p < 0.001$

[c] caries-free: chi square test: $p < 0.01$ [d] caries-free: chi square test: $p < 0.05$

25 percent less than in the non-fluoridated areas, and already met the new WHO goal of a SiC index score of 3.0 or less before 2015.

DISCUSSION

With the exception of two studies by Colquhoun (1977, 1985), previous research into the effectiveness of water fluoridation in New Zealand has been carried out using traditional oral health survey methods, however the results of this study are based on routine dental records made following courses of dental care. The use of routinely-collected information in New Zealand dental epidemiology is increasing – since 1990, three of the six published studies on dental caries in New Zealand children and adolescents have relied on a routinely-collected data source (Kanagaratnam, 1997, Thomson, 1993, and Thomson et al, 2002, but not Anderson and Treasure, 1994 nor Treasure and Dever, 1992, 1994). This study is the third to be based on information gathered using the Molaris data collection system (Thomson et al, 2002; Wright et al, 2001). There are potential weaknesses with this approach, especially when ecological measures are used, such as the use of the school-based TFEA index as a measure of socio-economic status. These ecological measures increase the likelihood of misclassification. For example, children from disadvantaged families can attend high-decile (more advantaged) schools and be misclassified as having high socio-economic status. Misclassification tends to make inter-group differences less distinct, leading in turn to difficulties demonstrating differences (Type II error) rather than finding differences that do not exist (Type I error). However, this lack of precision is mitigated by the large numbers of participants included when routinely-collected data sources are used.

Oral health surveys are normally carried out purposively, using trained dentist-examiners, and often include repeat

TABLE VI – Results of linear and logistic regression analyses for 12-year-old children.

Independent variables		Linear regression dependent variable: DMFS		Logistic regression dependent variable: DMFS > 0	
		B	Standard error of B	Odds ratio	95% CI
Water fluoridation					
	Fluoridated	-1.12 [a]	0.08	0.62 [a]	0.56–0.69
Gender					
	Male	-0.26 [a]	0.07	0.89 [c]	0.80–0.97
Ethnicity					
	Maori	0.77 [a]	0.13	1.47 [a]	1.24–1.73
	Pacific	0.79 [a]	0.17	1.58 [a]	1.25–1.99
Socioeconomic status					
	Low	0.32 [b]	0.11	1.33 [b]	1.15–1.54
	Medium	0.21 [c]	0.09	1.19 [a]	1.06–1.33
Constant		2.29			

[a] $p < 0.001$ [b] $p < 0.01$ [c] $p < 0.05$

Model statistics – Linear regression: $R^2 = 0.04$, ANOVA: $p < 0.001$; Logistic regression: $R^2 = 0.02$, Chi square: $p < 0.001$

TABLE VII – Significant Caries Index scores (SiC) for 12-year-olds[§]

		Non-fluoridated			Fluoridated		
		n	SiC	sd	n	SiC	sd
Gender							
	Female	710	4.25 [a]	1.95	416	3.23	1.69
	Male	705	3.97 [a]	2.00	453	2.52	1.36
Ethnic group							
	Maori	97	5.33 [a]	2.13	149	3.54	2.15
	Pacific	29	4.72 [b]	1.85	96	3.69	1.76
	Other	1289	3.98 [a]	1.96	616	2.55	1.28
Socioeconomic status							
	Low	179	4.59 [a]	1.81	2.54	3.30	1.58
	Medium	734	4.21 [a]	1.98	181	2.86	1.31
	High	502	3.80 [a]	2.01	435	2.57	1.63
All combined		1415	4.11 [a]	1.98	869	2.86	1.57

Kruskal-Wallis test: [a] $p < 0.001$ [b] $p < 0.01$

[§] These scores are the mean DMFT of the one-third of individuals having the highest DMFT scores in the group described; "n" refers to the number of individuals for whom the index was calculated.

examinations of a proportion of participants to ensure that both diagnosis and recording are reliable (World Health Organization, 1987). Despite the fact that the dental therapists who recorded the data used in this study had not been trained as epidemiological examiners, and there having been no checks made on the reliability of the records, we do not believe any significant bias has affected the results. Other studies have shown that in standardised conditions, dental auxiliaries are as capable as dentists at detecting dental caries (Kwan et al, 1996; Öhrn et al, 1996), and Hausen and colleagues (2001) have shown that data collected from patient records is of comparable quality to that obtained directly by trained examiners.

We consider that one of the strengths of this study is the very large numbers of children involved – 8375 5-year-olds, and 7158 12-year-olds – which resulted in relatively large numbers of Maori and Pacific children. Large, routinely-collected datasets may have significant advantages in illustrating the oral health status of the New Zealand population, compared to conventional survey methods that utilise smaller samples, as smaller samples may lack sufficient statistical power to demonstrate associations involving small but important subgroups. These routinely-collected datasets also allow for longitudinal research, so that changes over time can be examined, such as the study carried out by Thomson et al (2002).

Early studies on the effectiveness of water fluoridation found reductions in dental caries severity scores in excess of 50 percent. However, the differences between fluoridated and non-fluoridated areas appear to have decreased over time (Lewis and Banting, 1994), and the UK National Health Service review of water fluoridation (which involved a meta-analysis of longitudinal studies) reported that fluoridation was more recently associated with a 15 percent improvement in DMFT (McDonagh et al, 2000). The results of this study show that the benefits of fluoridation in New Zealand continue to be significant. Lower caries prevalence and severity in fluoridated areas in excess of 30 percent for both 5- and 12-year-old children are important both from a public health perspective, and for individual children. Many of the children who had received fluoridated water would have benefited from clinically meaningful reductions in their dental caries experience, and the consequent reductions in the amount of dental treatment they had received. This study also shows water fluoridation to be associated with marked differences in oral health inequalities between fluoridated and non-fluoridated areas, and much larger absolute differences in caries prevalence and severity for Maori and Pacific children, and for socio-economically disadvantaged children.

An unexpected finding of the linear regression analysis was that gender had an independent effect on dmfs scores at age five, with males having worse oral health than females. We had expected that females would have worse oral health at age 12, because the permanent teeth of females tend to erupt earlier (Mugonzibwa et al, 2002), and are therefore more likely to have experienced dental caries, but we would not like to speculate on the reasons for the differences at age five.

CONCLUSIONS

This study provides evidence of real differences in dental health for both 5- and 12-year-old children associated with water fluoridation, and demonstrates how fluoridated water reduces oral health inequalities among children of different ethnic and socio-economic backgrounds. It is our hope that an increasing number of New Zealand communities will become aware of the benefits of water fluoridation, and take the necessary steps to implement the community water fluoridation schemes that will help protect the oral health of their local population.

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