

# **Fluoridation of water supplies – an evaluation of the recent epidemiological evidence.**

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## Executive summary

### ***Introduction and background***

A comprehensive report on water fluoridation published by the New Zealand Public Health Commission (PHC) in 1994 dealt, in part, with the evidence for possible health risks associated with fluoridation. The key issues considered were dental fluorosis, bone fractures, and cancer. The report concluded, on the basis of the evidence then available, that the possibility of small increased risks of hip fracture and/or osteosarcoma associated with water fluoridation could not be ruled out, and more research was needed. It also concluded that there was probably little, if any, significant effect from dental fluorosis. Any cosmetic effects associated with moderate fluorosis were more likely to be due to other fluoride sources, such as fluoride supplements and toothpaste swallowing.

The purpose of this report was to update the section of the earlier report that dealt with potential adverse effects of fluoridation, with particular focus on epidemiological studies.

### ***Objectives***

Specific objectives of this review were to determine whether there is persuasive evidence:

1. that fluoridation of water supplies at optimal levels is associated with increased rates of bone fractures
2. that fluoride in water supplies is associated with increased rates of cancer, particularly osteosarcoma
3. that, in New Zealand, optimal fluoridation is associated with unacceptable levels of dental fluorosis
4. that, since the publication of information assessed in the previous report, other adverse health effects have been associated with optimal fluoridation.

## **Methods**

A literature search was carried out using Medline and other sources of information for peer-reviewed reports of relevant studies published in the New Zealand and international literature since the PHC report. Original publications were obtained and evaluated.

## **Results**

Eight epidemiological studies of bone fracture risk and fluoridation published since the previous PHC report were identified and evaluated. Studies that looked solely at the relationship between bone mineral density and fluoridation were not considered.

Five of the eight studies examined used data on individuals; the remaining three studies were ecological studies. Ecological studies use data at the population level, and are susceptible to a number of biases. Therefore, they are not as useful for purposes of causal inference as studies that use data on individual persons. None of the ecological studies provided evidence of a positive (potentially causal) association between fluoridation and hip fracture. However, one of the studies suggested an association between fractures of the arm in men (but not women) and exposure to fluoridated water.

The three studies that were most appropriate for causal inference all used data at the individual person level. These generally showed either no risk or reduced risk of bone fracture associated with fluoridation. However, all three had some limitations in terms of statistical power, potential for generalisability or potential for bias.

Since the 1994 PHC report there have been four published studies that investigated possible cancer risks associated with fluoride in water. Two of these were case-control studies that examined the risk of osteosarcoma (bone cancer) associated with fluoridation of water. Neither of these showed evidence of an increased risk associated with water fluoridation. However, both studies had limitations in their designs that restricted their value. The other two studies involving cancer were ecological studies, one from Okinawa and one from Taiwan. One of these studies suggested an increased risk of bladder cancer in women and the other an increase in uterine cancer risk. These were both unique results, not found in any other studies.

For both of these studies the strong possibility existed that the findings were false positives arising from the carrying out of multiple statistical tests. For weight to be given to these findings, similar results would need to be obtained in other studies carried out in other settings.

Dental policy advice, issued by the New Zealand Ministry of Health in 1995, was aimed at preventing over-exposure to fluoride of young children, and minimising the prevalence of dental fluorosis. However, since the 1994 PHC report, no studies of the prevalence of dental fluorosis have been carried out in New Zealand. Therefore, it was not possible to assess whether this policy had any impact on the prevalence of dental fluorosis, or whether fluoridation in New Zealand was associated with unacceptable levels of dental fluorosis.

Two other relevant epidemiological studies were identified. One dealt with childhood behaviour problems and the other with goitre prevalence. Neither study provided evidence of an association between these problems and consumption of optimally fluoridated water.

## ***Discussion***

Overall, this update was reassuring. No persuasive evidence of harmful effects of optimal water fluoridation was revealed, and, generally, the evidence has strengthened that there are no serious health risks associated with the practice. That was particularly the case for bone fracture risk.

Both the case-controls studies that examined osteosarcoma risk had their limitations, leaving still the need for at least one well-designed and conducted study to examine this issue. Such a study might be considered in New Zealand, although osteosarcoma is a rare cancer and the number of cases of that cancer occurring annually in this country is small. The possibility of a further New Zealand study of hip fracture risk is also worth considering.

Another area potentially worthy of further investigation in New Zealand is dental fluorosis. A periodic New Zealand survey of dental fluorosis, using a standardised design for data collection would be useful for optimising the delivery of fluoride to

New Zealand children for minimisation of dental fluorosis and, at the same time, reassuring the public.

### **Conclusions**

This investigation produced no clear evidence of harmful effects associated with fluoridation and generally strengthened conclusions that there are no harmful effects associated with fluoridation. However, there is room for further strengthening of the evidence, particularly for bone fractures and osteosarcoma.

### **Recommendations**

It is recommended that the Ministry of Health:

1. promote the development of an optimal survey methodology for investigating the prevalence and degree of severity of dental fluorosis in fluoridated and non-fluoridated areas in New Zealand
2. promote the carrying out of this dental fluorosis survey in the near future and at regular intervals (say, every 5-10 years) thereafter to obtain longitudinally comparable data for the purposes of optimising the delivery of fluoride to New Zealand children, to promote good dental health while minimising the prevalence of dental fluorosis
3. promote the carrying out of a case-control study of bone fractures for the purposes of resolving the issue of whether there is an association between such fractures and optimal fluoridation of water supplies.

## Introduction and background

In July 1994 the New Zealand Public Health Commission (PHC) published a comprehensive report on water fluoridation in New Zealand (PHC, 1994). Parts of the report dealt specifically with the possible costs and risks of water fluoridation, and were based on an assessment of the published scientific evidence to that time. The key issues considered were dental fluorosis, bone fractures, and cancer. The report's executive summary (page 1) stated:

"It is possible that there is a small increased risk of hip fracture associated with water fluoridation, though the evidence for this is very inconclusive. More research is needed to clarify this issue. A large amount of research has failed to provide evidence that exposure to fluoride causes cancer. However, the possibility of a small increased risk of osteosarcoma (a rare type of bone cancer) in young men cannot be ruled out at this stage. Here, again, more research is needed.

There is probably very little or no significant cosmetic impact from dental fluorosis related to water fluoridation in New Zealand. Moderate fluorosis, which can cause cosmetic concerns, is more likely to be due to other fluoride sources such as fluoride supplements and toothpaste swallowing.

There is no scientific basis for concern about other health effects from exposure to fluoridated water at the level of one part per million (ppm)."

The purpose of the present review is to update the sections in the previous report that dealt with potential adverse health effects of fluoridation, with particular focus on bone fractures, cancer, and dental fluorosis. The report also addresses other health-related issues that have arisen since the 1994 PHC report. The focus of this update is epidemiological studies. In a situation such as this, when there is substantial human exposure experience, it is appropriate that studies involving human data (epidemiological studies) take precedence over studies with laboratory animals. In this review, non-epidemiological studies are considered only in passing, insofar as they have a bearing on the epidemiology.

## ***Objectives of this review***

Specific objectives of the present review were to determine whether there is persuasive evidence:

1. that fluoridation of water supplies at optimal levels is associated with increased rates of bone fractures
2. that fluoride in water supplies is associated with increased rates of cancer, particularly osteosarcoma
3. that, in New Zealand, optimal fluoridation is associated with unacceptable levels of dental fluorosis
4. that, since the publication of information assessed in the 1994 PHC report, other adverse health effects have been associated with optimal fluoridation.

## **Methods**

A literature search was carried out using Medline and other sources, such as review articles, to identify all original peer-reviewed reports of studies published in the New Zealand and international literature, that investigated whether fluoridation was associated with increased risks of bone fracture, cancer, or other adverse health effects. The original publications were obtained.

Research publications obtained and assessed were limited to those not reviewed in the 1994 report published by the New Zealand Public Health Commission. The effect of this limitation was to restrict coverage to publications from 1994 onward.

In this review, dental fluorosis was treated differently to other health effects allegedly linked with fluoridation, such as bone fractures and cancer. This was because there is general acceptance that some dental fluorosis, involving minimal cosmetic effects, is associated with fluoridation of water supplies. The extent to which such fluorosis occurs is very much a function of local circumstances, including climate (which

influences the amount of water consumed), and exposure to other sources of fluoride, including toothpastes and fluoride supplements. This becomes an issue of acceptability, or how to minimise the likelihood of such effects occurring. For the other adverse health effects alleged to be associated with fluoridation, the key issue is whether fluoridation causes these effects at all. These are issues of "causal inference". Resolving an issue of causal inference generally requires reference to the original research publications, wherever they originate. Strengths and weaknesses of the design and conduct of the individual studies need to be critically evaluated, and the overall weight of the evidence and limitations of the conclusions that can be drawn need to be carefully defined. Consideration of acceptability of risks and ways to minimise effects can make greater use of reviews and expert commentary.

## Results

### ***Bone fractures***

The issues concerning fluoride and bone strength were well summarised in the earlier report (PHC, 1994) and it is not intended to reiterate them in any detail here. However, in brief, fluoride tends to accumulate in bone with age and this may affect the strength of bone. Osteoporosis (the loss of bone mass while maintaining a normal composition) occurs naturally with increasing age and is influenced by a variety of genetic, environmental and lifestyle factors, including nutrition, use of medicines, alcohol and tobacco use, and amount of physical activity. Fractures associated with osteoporosis are a significant cause of morbidity and mortality in the elderly, and the incidence rate of these may be increasing in some countries for reasons that are not altogether apparent (Kannus, 1999). If fluoridation were contributing to the incidence of bone fracture by increasing the prevalence or degree of osteoporosis, it would be important that this be taken into account in national policy-making.

The PHC (1994) report considered epidemiological studies published up to 1993. It noted that most of the studies that had investigated the relationship between fluoridation and bone fractures had been ecological in nature. That is to say, the units of analysis were populations, rather than individuals. There are two particular

difficulties in interpreting ecological studies. Firstly, the individuals who experience the health event (in this case a bone fracture) are not necessarily the people who were most exposed to fluoridated water. This is the basis of the so-called “ecological fallacy” (Rothman & Greenland, 1998, page 469). Secondly, in ecological studies it is seldom, if ever, possible to adjust adequately for confounding factors, as the data are not available. Nonetheless, ecological studies can be useful for identifying issues worthy of further investigation in studies in which data on individual persons are collected. Data on individuals usually permits adjustment for the possible effects of confounding factors.

The earlier review (PHC, 1994) reported that some ecological studies had found an association between fluoridation and bone fracture; others had not.

Two studies reviewed previously (PHC, 1994) looked at fracture risk in individuals. A prospective cohort study (Sowers et al., 1991) found an increased relative risk for fractures of the wrist, spine, and hip in women exposed to 4.0 ppm of fluoride in their water, compared with women in another community with 1.0 ppm of fluoride in their water (relative risk [RR] = 2.2; 95% CI: 1.1-4.7). A difficulty in interpreting this study in relation to fluoridated water supplies is that the “exposed” group had naturally high levels of fluoride, in excess of the level in deliberately fluoridated water supplies. Studies of the usefulness of fluoride therapy for treatment of osteoporosis suggest that high levels of fluoride ingestion may increase skeletal fragility. Fluoride administration is, therefore, not an effective osteoporosis treatment (Riggs et al., 1990).

Another prospective cohort study of about 2000 white menopausal women found no evidence of an association between exposure to fluoridated drinking water and bone density or risk of fractures (Cauley et al., 1991). However, this study had low statistical power to detect relative risks of less than 2.

In regard to the relationship between fluoridation and bone fractures the PHC (1994) report concluded (page 49):

Considering the data overall, it would appear that the issue of exposure to fluoridated water at the 1 ppm level and increased risk of fractures remains unresolved. The experimental work on

bone strength tends to favour there being no effect at low levels of exposure. The epidemiological data offer only limited support for an association. If a risk is actually present, the data to date would suggest it is likely to be at a fairly low level of increased risk. Most commentators consider that policy decisions based on the work in this area would be premature and that more studies are required to clarify the issues.

This conclusion has been taken as a starting point for this update.

### ***Review of recently published studies***

Since the PHC (1994) report there have been eight additional published epidemiological studies in peer-reviewed journals that have investigated the relationship between fluoridation and bone fracture. Each of these publications is briefly summarised below. Each summary is followed by critical comment on the design and conduct of the study and the weight that could be accorded the results. The focus in the present update is epidemiological studies that have directly investigated bone fracture risk. Studies that looked solely at bone mineral density in relation to fluoridation are not reviewed, as these are more difficult to interpret and have only indirect bearing on the key issue of this review.

Cauley et al. (1995).

#### **Effects of fluoridated drinking water on bone mass and fractures: the study of osteoporotic fractures.**

##### Outline of the study

This study was a continuation of the prospective cohort study (Cauley et al., 1991) considered in the earlier review (PHC, 1994). This study considered 2076 non-black women, aged 65 or older. In the data analysis, the measure of fluoride exposure was the years of exposure to fluoridated water in community water supplies. This measure was based on residential history and knowledge of which water supplies were fluoridated, and when. Bone mineral density was also measured.

There was no association between fluoridation exposure and bone mass. Women exposed to fluoride for more than 20 years had similar bone mass to women exposed to fluoridation for a lesser period.

Women exposed to fluoridation for more than 20 years (n = 192) had a lower risk of non-spine fractures (RR = 0.73; 95% CI: 0.48-1.12), osteoporotic fractures (RR = 0.74, 95% CI: 0.46-1.19), and hip fractures (RR = 0.44; 95% CI: 0.10-1.86) than women not exposed (n = 1248). There was no association between fluoridation and wrist or spinal fractures.

#### Comments on the study

This is a useful study that obtained data for individual women. It has some limitations in that it was restricted to white women and a relatively low proportion of women were exposed to fluoridation for a long period. Other exposures to fluoride, such as in the diet or in dental products, were not assessed. Despite these limitations, the study is useful and supports the view that there is no effect of fluoridation on the risk of bone fractures.

Karagas et al. (1996).

#### **Patterns of fracture among the United States elderly: geographic and fluoride effects.**

#### Outline of the study

This was an ecological study that examined patterns of occurrence of fractures of the hip, proximal humerus, distal forearm and ankle. Subjects were a 5% sample of the white U.S. Medicare population, aged 65 to 89 years, during 1986-90. Each subject was classified as exposed or unexposed to fluoridated drinking water, depending on the proportion of the population of their county of residence that received fluoridated drinking water. Data were analysed using Poisson regression analysis.

No association with exposure was found for fractures of the hip or the ankle. For men only, when comparing exposed with unexposed subjects, there were statistically significant increased relative risks for fractures of the proximal humerus (RR = 1.23, 95% CI: 1.06-1.43) and fractures of the distal forearm (RR = 1.16, 95% CI: 1.02-1.33). The authors concluded that, on the basis of their results, "water fluoridation

may affect the occurrence of the fractures of the proximal humerus and distal forearm in men and that these fractures have similar geographic determinants that are distinct from both those of hip and ankle."

#### Comments on this study

This study shares the limitations of other ecological studies in that individual level data were lacking and there was no adjustment for potential confounding factors, including other sources of fluoride. At most, this study provides only weak evidence that there might be some risk to men associated with fluoridation.

Jacqmin-Gadda et al. (1998)

#### **Risk factors for fractures in the elderly.**

#### Outline of the study

This was a prospective cohort study of 3,216 French men and women, aged 65 and older, followed for 5 years. Exposure to fluoride in water supplies was based upon water measurements carried out by regional health departments. Seventy-eight drinking water areas were defined and, for each of these areas, a weighted mean fluoride concentration was calculated, based on the available measures of fluoride concentration for each of the water supplies used in the area over the previous 10 years. Each subject was allocated a fluoride exposure that was equivalent to the time- and flow-weighted mean concentration for the water supplies of the area in which he or she was resident at the time of the study. For purposes of analysis, fluoride concentrations were categorised using two cutoff values – the median (0.11 mg/litre) and the third quartile (0.25 mg/litre) of the distribution of weighted means among parishes. The analysis was carried out using logistic regression with repeated measures, so that recurrence of fractures could be taken into account.

Results showed no association between fluoride exposure and non-hip fractures. However, an association was present with hip fractures for the fluoride concentration range 0.11-0.25 mg/litre (RR = 3.25, 95% CI: 1.66-6.38) and for fluoride levels above 0.25 mg/litre (RR = 2.43, 95% CI: 1.11-5.33). These associations were very susceptible to choice of cut-points. With a fluoride concentration cut-point of 0.7 mg/liter of fluoride the association disappeared (RR = 0.77, 95% CI: 0.37-1.62), as it

did with a cut-point of 1 mg/litre (RR = 0.89, 95% CI: 0.21-3.72). The authors concluded that the study "indicates a deleterious effect of moderate but not high water fluorine concentrations on the risk for hip fractures."

#### Comment on the study

This study is potentially useful in that it is based on data for individuals. However, a particular weakness is how exposure to fluoride in water was assessed. Fluoride exposure was based on the weighted average level (over the last 10 years) of fluoride in all the water supplies serving the area (approximately equivalent to a parish) in which the study subject lived at the time that the study was carried out. This means that the water supply to a study subject's actual residence may be only one of several water supplies in the area, and used in the calculation of the mean fluoride concentration for that parish. The method of assessing exposure also takes no account of residential movement over the subjects' lifetimes. This could lead to further exposure misclassification. However, it is stated that the average time that individuals had resided in the same parish was 41 years at the beginning of the study. This suggests that misclassification as a result of residential changes may not be severe.

Although the study appears to show statistically significant relationships between hip fractures and fluoride level in the water supply, interpretation of this is not straightforward. First, there is no exposure-response relationship. That is, the risk does not increase with increasing exposure. The relative risk for the higher fluoride level (> 0.25 mg/litre) is less than that for the lower level (0.11-0.25 mg/litre). Second, the relative risks for fairly low levels of fluoride are much higher than have been found in other comparable studies. Third, there appears to be no association between hip fracture risk and fluoridation when using fluoride concentration cut-points of 0.7 or 1.0 mg/liter. These puzzling features suggest that there is some bias, such as confounding, in the data. This renders the results suspect. Overall, in the opinion of this reviewer, the results do not provide useful evidence either for or against an association between fluoridation and hip fracture.

Feskanich et al. (1998).

**Use of toenail fluoride levels as an indicator for the risk of hip and forearm fractures in women.**

Outline of the study

This was a case-control study nested in the Nurses' Health Study, a prospective cohort study begun in 1976. At entry into the cohort study, all subjects were female nurses aged 30 to 55 years. Cases for the case-control study were cohort members who had had a hip fracture (n = 53) and a sample of those who had had a forearm fracture (n = 188), between 1982 and 1988. Each case was matched to a control randomly selected from those in the cohort with the same year of birth. Fluoride concentration was measured in toenail clippings collected from subjects in 1982. Odds ratios obtained from conditional logistic regression analysis were adjusted for age, menopausal status, postmenopausal hormone use, caffeine consumption, and alcohol consumption. Toenail fluoride concentrations were categorised into quartiles, with the reference level being the lowest quartile.

For the highest quartile, the odds ratio for hip fracture was 0.8 (95% CI: 0.2-4.0) and for forearm fracture it was 1.6 (95% CI: 0.8-3.1). These results were not altered by further adjustment for body mass index, smoking status or calcium and vitamin D intake.

Comments on the study

This study is useful in that it uses actual measures of fluoride exposure in individuals, lacks any obvious selection bias, and there was adjustment of the data for potential confounding factors. It is well-established that water supply fluoride level alone is a very inaccurate measure of actual fluoride exposure as it does not take account of the use of home water purifiers, use of other sources of water, such as bottled water, consumption of bottled beverages produced with fluoridated water, and use of fluoridated toothpaste and other fluoridated dental products. Therefore, the availability of a biomarker of fluoride exposure was a distinct advantage. Despite this, a limitation of the study was that toenail fluoride concentration at only one point in time (1982) was used. A further set of toenail clippings, collected in 1988, was analysed to examine reproducibility. This produced a correlation coefficient of 0.60

with the fluoride concentrations in samples from 1982, which implies that the variation in toenail concentrations in 1982 accounts for 36% of the corresponding variation in 1988. This confirms that there will be some exposure misclassification based on the use of toenail clippings from one time point. This misclassification would tend to obscure any true risks. The other major limitation of the study is that the sample size was fairly small. It was insufficient to distinguish whether the small elevated relative risk estimate for forearm fracture was a result of random variation in the data or indicative of a truly elevated risk.

Lehmann et al. (1998).

**Drinking water fluoridation: bone mineral density and hip fracture incidence.**

Outline of the study

This was an ecological study comparing the rates of osteoporotic hip fractures in two similar cities in the former East Germany: Chemnitz, which was fluoridated (1 mg/litre) and Halle, which was unfluoridated. Patients, 35 years or older, treated for hip fracture (not associated with major trauma) in the two cities during 1987-89 were identified from hospital records. Population-based rates for hip fracture were calculated for the two studies.

After age-standardisation, the rates (per  $10^5$ ) for men were 72.5 in Chemnitz and 89.2 in Halle; for women the corresponding rates were 142.2 in Chemnitz and 178.5 in Halle. The lower hip fracture rates in the fluoridated Chemnitz, compared with the unfluoridated Halle, were statistically significant ( $p < 0.0001$ ) for both men and women. In an associated study, no difference in bone mineral density was found in populations of the two cities.

Comments on this study

This ecological study suggests that fluoridation does not increase the risk of hip fracture (and may even reduce it). However, it is subject to the usual limitations associated with ecological studies, including a lack of adjustment for possible confounding factors (other than age and sex).

Fabiani et al. (1999)

**Bone fracture incidence in two Italian regions with different fluoride concentration levels in drinking water.**

Outline of the study

This was an ecological study comparing bone fracture rates in two Italian counties: Bracciano with a natural fluoride level of 1.45 mg/litre in the water supply, and Avezzano, with a low fluoride concentration of 0.05 mg/litre in the water supply. Cases of bone fracture treated at one public hospital in each of the study counties during the years 1990 and 1991 were used. Age-adjusted population-based rates and rate ratios were calculated. For hip fracture, the relative risks (rate ratios) for Avezzano compared with Bracciano were 2.64 (95% CI: 2.54-2.75) in females and 4.28 (95% CI: 4.16-4.40) in males, indicating lower rates of fracture in the high fluoride area. Rates of other types of fractures were almost all lower in the high fluoride area compared to the low fluoride area.

Comments on this study

This study is subject to the same reservations as for other ecological studies considered in this report. A particular issue is the completeness of attendance of bone fracture cases in the counties at the two hospitals used in the study. For example, if residents of Bracciano were less likely to be treated for bone fractures at their county public hospital than residents of Avezzano were likely to be treated for bone fracture at their county public hospital, then this could result in a greater underestimate of the rates of fracture in Bracciano, compared with Avezzano. Whether this could have occurred cannot be judged from the published information.

Kurttio et al. (1999).

**Exposure to natural fluoride in well water and hip fracture: a cohort analysis in Finland.**

Outline of the study

This was a retrospective cohort study of 145,000 Finnish persons who were born in the years 1900-1930 and who had lived in the same rural area between 1967 and 1980. Hip fractures occurring between 1981 and 1994 were studied. Fluoride

concentrations in wells serving each cohort member were estimated using a weighted median smoothing method applied to a nation-wide database on fluoride concentrations in 9,000 wells. Results were adjusted for age and occupational classification.

There was no association with fluoride concentration when all age groups were analysed together. However, when age groups were analysed separately there was an increased relative risk associated with fluoride concentration among younger women (50-65 years in 1981). The age-adjusted relative risk was 2.09 (95% CI: 1.16-3.76) in the group with the highest estimated exposure to fluoride ( $> 1.5$  mg/litre), compared with the group estimated to be least exposed ( $\leq 0.1$  mg/litre). There was a suggestion of a weak protective effect for the corresponding group of men (RR = 0.87, 95% CI: 0.35-2.16). No associations were found for older men or women.

#### Comments on this study

Although individual level data were available, this study suffers from some of the problems associated with ecological studies. In particular, there were insufficient data for other than minimal adjustment for confounding, it was necessary to estimate fluoride exposures using a geographic mapping process for groundwater fluoride concentrations, and no information on long-term exposure to fluoride in water was available for study subjects. Although the association between high fluoride concentration and hip fracture in younger women was of interest and potential concern, the possibility that it may be a chance false positive finding associated with having carried out multiple statistical tests must be considered.

Hillier et al. (2000).

#### **Fluoride in drinking water and risk of hip fracture in the UK: a case-control study.**

##### Outline of the study

This was a case-control study of hip fracture in people aged 50 and older in the English county of Cleveland. There were 914 cases and 1196 controls. The latter group was randomly selected from a list of all residents of Cleveland, aged  $\geq 50$  years, registered with the National Health Service. Cases and controls were

interviewed to obtain information that included residential history and potential confounding factors. Lifetime fluoride exposure was estimated using residential histories and information on water supply fluoride concentrations. A parallel investigation measured fluoride concentration in femoral heads from a subset of cases who had had hip replacement. For the analysis of data, average lifetime exposures to fluoride in water were dichotomised as  $\geq 0.9$  ppm and  $< 0.9$  ppm.

Strong risks were found in association with low body mass index and low levels of physical activity. After adjustment for potential confounding factors, the odds ratio for the higher fluoride exposure group compared to the lower exposure group was 1.0 (95% CI: 0.7-1.5). The main dietary source of fluoride in the UK is tea. No statistically significant association was found in this study between hip fracture and tea consumption (OR = 1.3, 95% CI: 0.9-2.1). In the associated study of fluoride levels in bone some association was found between exposure to fluoride levels in water and fluoride levels in cortical bone, although the association was less clear for trabecular bone. This helps to confirm the validity of the fluoride exposure assessment based on residential histories. The authors concluded "that fluoridation of water to 1 ppm is not likely to have any important effect on the risk of hip fracture, and that concerns about this potential hazard should not be a reason for withholding the measure".

#### Comments on this study

This is one of the most important studies that have examined the association between fluoride in water supplies and bone fracture, as it uses individual data, involved adjustment for potential confounding factors (BMI, physical activity, age at menopause, current alcohol consumption, smoking, treatment with corticosteroids, dietary intake of calcium, age and sex), and sought to assess fluoride exposure from water supplies over a lifetime. However, the study also has some weaknesses. Firstly, the participation rate in interviews was low (56% of cases and 44% of controls). This leaves open the possibility of some sort of selection bias. Secondly, almost all exposures to fluoride in the county took place in the city of Hartlepool, which has a fluoridated water supply. If, for example, there were some risk factor for hip fracture that was lower in Hartlepool than elsewhere in the county then this could have counterbalanced any increased risk associated with fluoride in the water supply.

There is no reason to believe that this was the case, although it would have been preferable if exposure of study subjects to fluoride in water could have been based on exposures from a variety of water supplies. Thirdly, the fluoride exposure assessment was based on time and place of residence. This does not take into account the amount of tap water that a person consumes, nor whether they used some sort of water purifier or other source of water. Fourthly, adjustment for confounders did not include other sources of fluoride, particularly fluoridated toothpaste use.

Despite these limitations, the study is one of the most important that has been carried out and gives considerable weight to the view that there is no association between fluoridation and hip fracture.

### ***Overall assessment of the evidence for fractures***

Since the previous report (PHC, 1994) there have been eight studies, summarised above, that addressed the question of whether there could be some association between fluoridation and bone fracture risk. Five of these studies used data on individuals; three were ecological. Two of the ecological studies suggested a protective effect for hip fracture of fluoride in the water, one study suggested an increased risk for fractures of the arm for males, but no increase in hip fracture risk, and no increased risks for women. For reasons discussed earlier, ecological studies are of limited value for causal inference.

Of the five studies that used data on individuals, two were of limited value for causal inference. One was the study of Jacqmin-Gadda et al. (1998), in which the exposure-response relationship was difficult or impossible to interpret. The other was the study of Kurttio et al. (1999), in which the measure of exposure was ecological and there was no information on other than current exposure, or adjustment for potential confounding factors. The other three studies were more useful for purposes of causal inference. They all had individual measures of exposure, involved adjustment for possible confounding factors, and the results were interpretable. These were the studies of Cauley et al. (1995), Feskanich et al. (1998), and Hillier et al. (2000). Generally, all three of these studies showed either no risk or reduced risk of bone

fracture associated with fluoridation. Despite this, for reasons outlined above, none of these studies can be considered completely definitive. They all had some limitations in terms of statistical power, potential for generalisability, or potential for bias. Nonetheless, the results were reassuring and strengthened the evidence that there is no increased risk of bone fracture associated with optimal levels of fluoridation of water supplies.

### ***Fluoridation and cancer***

The question of whether exposure to fluoride may cause cancer, in animals or people, has been controversial. The previous report (PHC, 1994) extensively reviewed the history of this debate and outlined the evidence from both animal toxicology and epidemiological studies. It concluded (pages 59-60):

“There is some weak and inconclusive evidence from one animal study that sodium fluoride at high levels causes osteosarcoma in male rats. The value of this and other animal studies in assessing risk in humans is, however, limited by a range of important factors. Two ecological epidemiological studies suggest an association with water fluoridation and osteosarcoma in young men, while six others show no association. The one small study at an individual level suggests no increased risk. Overall there is little evidence for the hypothesis that fluoride causes osteosarcoma in humans at levels associated with water fluoridation. Nevertheless, there is inadequate epidemiological data at the individual level to be confident that fluoride exposure is very unlikely to cause a small increase in osteosarcoma. For this reason it is highly desirable for case control or cohort studies to further examine risk factors for osteosarcoma, including exposure to fluoridation...”

“There is some very weak evidence that workers exposed to heavy fluoride levels are at risk from bladder cancer but this may not be relevant to exposure to water fluoridation at 1 ppm. All the other epidemiological studies conducted in a range of countries and totalling around 50 in number, suggest that there is no association between water fluoridation and with any type of cancer.”

### ***Review of recently published studies***

Since the 1994 PHC report there have been four further published studies of fluoride in water supplies and cancer. Two of these have been focused on osteosarcoma. These studies are reviewed below:

Gelberg et al. (1995).

**Fluoride exposure and childhood osteosarcoma: a case-control study.**

Outline of the study

This study, set in New York State, involved 171 osteosarcoma cases 24 years or younger, diagnosed between 1978 and 1988. Controls were pair-matched with cases on the basis of year of birth and sex, and selected from live birth records of the state. Case and control subjects and their parents were interviewed. Information obtained on exposure to fluoride included fluoride tablets, mouth rinses, toothpastes, and a complete residential history, with the fluoridation status of the water supply at each residence. Cumulative exposure to fluoride from each source, separately and combined, was estimated. Conditional logistic regression analysis was used to calculate odds ratios, with separate analyses using data obtained from cases and controls themselves, and from their parents.

Interview data were obtained for 130 cases and corresponding controls. From the data analysis there was no significant association between total fluoride exposure and osteosarcoma either in all subjects or in females. There was a statistically significant protective trend associated with fluoride exposure in males.

Comments on the study

This case-control study was carried out in response to the need for analytical epidemiological studies to investigate the association between osteosarcoma and fluoride exposure that had been found in a toxicological study with rats. This case-control study had the particular strength that it attempted to assess fluoride exposure from a number of sources. Despite this, it had weaknesses that limit the value of the results. First, the study identified cases retrospectively diagnosed in the period 1978-88. Potentially, there could have been recall problems because of the delays between diagnosis and interviews taking place. Secondly, there is an issue of comparability between cases and controls. Controls were people born in New York State, whereas cases were persons residing in the state at the time of diagnosis. The key criterion for choice of controls in case-control studies is that the controls should be representative of the population from which the cases were drawn

(Hennekens & Buring, 1987, page 137). Although the cases could have included out-of-state immigrants to New York, these people could not have been included in the control group. The bias introduced by this difference between the cases and controls would be to make any exposure that was more or less common in the immigrants than in those born in the state appear, respectively, as a risk or protective factor in the analysis. Strictly, cases not born in New York State should have been excluded from the study, to ensure case and control comparability. However, since this restriction was apparently not imposed on cases, it throws some doubt on the validity of the results. Overall, because of these issues, this study provides only limited evidence that there is no association between osteosarcoma and fluoride exposure.

Moss et al. (1995).

**Osteosarcoma, seasonality, and environmental factors in Wisconsin, 1979-1989.**

Outline of the study

This was a case-control study of 167 osteosarcoma cases and 989 controls who had either brain cancer or digestive system cancer. All cases and controls were drawn from the Wisconsin Cancer Reporting System. Exposure data were obtained entirely from existing records (i.e., there were no interviews). Estimation of exposure to fluoride was based on information about fluoride levels in water supplies and the place of residence at time of diagnosis. A cut-point of 0.7 ppm in the water supply was used to distinguish "fluoridated" from "unfluoridated" water supplies. The overall odds ratio, adjusted for age, sex, population size of residential area, and level of local radiation, was 1.0 (95% CI: 0.6-1.5).

Comment on the study

This study was of limited value, mainly because of the lack of detailed information on cases and controls. In particular, there was no information on residential history or other potential exposures to fluoride. Exposure to fluoridated water was based solely on the fluoridation status of the place of residence at the time of diagnosis. Since any actual association between osteosarcoma and fluoridation would almost certainly be related to exposure to fluoridation over a much longer time, use of current residential fluoridation status would lead to exposure misclassification. This would

have tended to reduce elevated relative risks towards 1.0. In principle at least, this could have obscured a true causal association.

Tohyama E. (1996).

**Relationship between fluoride concentration in drinking water and mortality rate from uterine cancer in Okinawa prefecture, Japan.**

Outline of the study

During the period of U.S. administration of the Okinawa Islands (1945-72) some water supplies were fluoridated. However, fluoridation ceased when the islands reverted to Japanese administration. This ecological study examined mortality rates for uterine cancer in 20 Okinawan municipalities during the period 1973-85, in relation to the mean drinking water levels of fluoride for the period 1968-80. Adjustment for some socio-economic and demographic factors was carried out. Time trends for uterine cancer mortality were also examined.

A significant positive correlation between fluoride concentration and uterine cancer mortality was found ( $r = 0.626$ ,  $p < 0.005$ ). The association remained significant after adjusting for the potential confounding factors for which data were available. In both fluoridated and non-fluoridated municipalities there was a reduction in uterine cancer mortality rates over the period 1973-92, although the decline was steeper in the municipalities that had previously been fluoridated.

Comment on the study

This is the only area in which a statistical association between uterine cancer mortality and fluoridation has been noted. The association was originally discovered in an investigation by the same author of the relationship between 15 components of water supplies and mortality rates for 38 different diseases in Okinawan men and women. This raises the strong possibility that the association is a false positive result due to chance, because of the large number of statistical tests that were originally carried out. Before it could be accorded much weight, such an association would need to be corroborated in studies carried out in other settings. The reduction in mortality rates from 1973 is hard to interpret, as the decline happened in both

fluoridated and unfluoridated municipalities. It would have been helpful to know what were the trends in mortality rates before 1973, when fluoridation was still in place.

The study suffers from the usual limitations of ecological studies, including limitations in the adjustment for potential confounding factors. Although some adjustment was carried out, this was at an ecological level and used data collected for other purposes. These variables were selected on the basis that the data already existed. They were not necessarily the most appropriate adjustment factors. Overall, no conclusions can be drawn from this single study.

Yang et al. (2000).

### **Fluoride in drinking water and cancer mortality in Taiwan.**

#### Outline of the study

This was an ecological study in which the age-standardised cancer mortality rates in 10 Taiwanese municipalities with the highest level of naturally occurring fluoride in the water (there is no deliberate fluoridation in Taiwan) were compared with 10 municipalities matched on the basis of the degree of urbanisation (regarded as a proxy for a large number of potentially confounding variables, such as socio-economic status). The period of study was 1982 to 1991.

For males, the overall cancer mortality rate ratio in naturally fluoridated vs non-fluoridated municipalities was 1.08 (95% CI: 0.96-1.22) and for osteosarcoma, 1.58 (95% CI: 0.92-2.17); for females the overall cancer mortality rate ratio was 1.15 (95% CI: 0.99-1.33), and for osteosarcoma 0.87 (95% CI: 0.52-1.44). Only the female bladder cancer rate ratio achieved statistical significance at the  $p < 0.05$  level (RR = 2.79, 95% CI: 1.41-5.55). The corresponding rate ratio for males was 1.27 (95% CI: 0.75-2.15). The authors of the study suggested the high rate ratio for females may have been a consequence of carrying out multiple statistical comparisons. They concluded that the results of the study "do not support the suggestion that fluoridation of water supplies is associated with an increase in cancer mortality. However, even if fluoride increases cancer risk, such increases may not be observed in this study because the level of fluoride in the naturally fluoridated municipalities was quite low."

### Comments on this study

This study was an ecological study, with all the limitations associated with such studies. As pointed out by the authors, the association with bladder cancer in females is likely to be a result of the large number of statistical comparisons that were carried out. Also, the value of the study was limited by the low concentration of fluoride in the water of the naturally fluoridated municipalities (mean fluoride level: 0.24 mg/litre).

### ***Overall assessment of the evidence for an association between fluoridation and cancer***

Of the four studies examining cancer in relation to fluoridation published since the previous report, two were ecological. They examined the risks for a wide range of cancers and identified different cancers that appeared to be associated with higher levels of fluoride in the water. The cancers identified (uterine and female bladder) have not been found to be associated with fluoridation exposure in other studies, and are very likely chance findings, because of the large numbers of statistical tests that were carried out.

The evidence for an association between fluoride exposure and osteosarcoma is from one toxicological study using rats (Bucher et al., 1991). Four osteosarcomas developed in the male rats consuming drinking water at the highest level used in the experiment. No osteosarcomas developed in the female rats at this dose level, nor in the male or female mice in a parallel study. Another experiment, in which rats were administered dose levels of fluoride more than twice as high as in the Bucher study, found no evidence of increased risk for any cancers, including osteosarcoma (Maurer et al., 1990). Neither of the two case-control studies of osteosarcoma, considered in this review, found any association with exposure to fluoridated water. However, as described above, both studies had methodological limitations that restricted their value.

Overall, since the previous report (PHC, 1994) no meaningful evidence has been published that there is an association between fluoridation and cancer. However, there is still a need for well-designed and conducted, analytic epidemiological studies

of osteosarcoma and fluoridation, so that the possibility of this association can be definitively ruled out.

### ***Dental fluorosis***

Dental fluorosis is a defect of the tooth enamel caused by the ingestion of fluoride during the development of the tooth. It is only one of a wide range of developmental effects that can occur in tooth enamel (Holloway & Elwood, 1997). Clinically, dental fluorosis is characterised by opaque white areas in the enamel. In its mild forms these opacities have no more than cosmetic significance. Public health practitioners generally agree that the health benefits in terms of caries reduction outweigh the relatively slight cosmetic disadvantages of mild fluorosis. With increasing levels of fluoride ingestion the enamel can become pitted and mottled. In very severe cases the opaque areas may become stained yellow to dark brown (DenBesten, 1999).

Dental fluorosis can only occur during the formation of the enamel (Pendry, 1999). With the exception of the third molars, enamel formation for the permanent teeth takes place between birth and about eight years. However, a full assessment of the extent of dental fluorosis cannot be made until all permanent teeth have erupted - at around 12-13 years of age.

The previous report (PHC, 1994) summarised New Zealand studies of fluorosis that had been conducted since 1980. These showed a higher prevalence of very mild and mild fluorosis in fluoridated areas, compared with unfluoridated areas. In summary, the report stated (page 40):

"In New Zealand, very mild and mild dental fluorosis appears to be significantly more common in areas with water fluoridation though this has not been confirmed for "unaesthetic" defects. The New Zealand data also suggest some association between fluoride supplement use and unaesthetic defects (for exposures prior to the dose of fluoride supplement being reduced in 1983). It is possible that there is some level of cosmetic concern associated with dental fluorosis in New Zealand, but studies similar to those in Australia would need to be repeated here to clarify this (e.g., Riordan, 1993). Given the New Zealand and international data, however, fluorosis at a level that causes cosmetic concerns is more likely to be attributable to other forms of fluoride use (supplements and toothpaste ingestion) than to water fluoridation."

### ***More recent developments***

Since the publication of the earlier report (PHC, 1994) there have been no further surveys of dental fluorosis in New Zealand, the last being published in 1992. There have been many studies of dental fluorosis carried out in other countries, but these studies are only indirectly relevant to the New Zealand situation, because of differences in overall fluoride exposure between countries. However, the other studies generally confirm:

- That fluoridated areas often have a higher prevalence of dental fluorosis than is found in unfluoridated areas. However, the greatest relative increases in the prevalence of dental fluorosis have occurred in non-fluoridated areas, suggesting that sources of fluoride other than optimally fluoridated water must be responsible (Rozier, 1999; Pendrys, 1999).
- That in optimally fluoridated areas dental fluorosis is usually only mild or very mild.
- That the likelihood of dental fluorosis occurring is a function of exposure to fluoride from all sources, including diet and dental products, but more severe forms of dental fluorosis are likely to be associated with use of fluoride tablets or ingestion of fluoride toothpaste by young children (Levy et al., 1999; Warren & Levy, 1998, 1999; Kumar & Green, 1998). Some authors have gone so far as to advocate the discontinuation altogether of the use of fluoride tablets by young children (Burt, 1999; Riordan, 1999).
- That the prevalence of fluorosis is dependent on local circumstances and, therefore, it would be difficult to extrapolate to the New Zealand situation from the prevalences found in areas overseas.
- Different scales of measurement of fluorosis make comparison between studies difficult (Pendrys, 1999).

Current Ministry of Health policy (Ministry of Health, 1995) on fluoridation and fluoride in dental products advises, amongst other things, that:

- Children under the age of five should use no more than a smear of fluoride toothpaste on a small brush (this is a reduction from the previous amount of toothpaste advocated, which was the size of a small pea).
- Children should be discouraged from swallowing or eating toothpaste.
- Fluoride in drinking water should be adjusted to between 0.7 and 1.0 ppm (this is a reduction from the previous range recommended of between 0.9 and 1.0 ppm. It recognises the availability of other sources of fluoride, particularly toothpaste).
- Fluoride tablets are no longer recommended as a public health measure, except where the level of fluoride in the water supply is less than 0.3 ppm when there is a high risk of tooth decay (this recognises that fluoride tablets have been shown to be a risk factor for dental fluorosis when not given appropriately, or when children are already ingesting fluoride from other sources).

This policy seeks to optimise exposure to fluoride for good dental health while, at the same time, minimising the likelihood of dental fluorosis. Since there have been no recent surveys of dental fluorosis in New Zealand, it is not clear what impact this policy, including the recent changes, has had on the prevalence of dental fluorosis.

### ***Other adverse health outcomes***

Two other publications were identified that investigated associations between adverse health outcomes and fluoridation. The first dealt with childhood behaviour problems, the second with goitre. These are summarised and assessed below.

Morgan L, et al. (1998)

#### **Investigation of the possible associations between fluorosis, fluoride exposure, and childhood behaviour problems.**

##### Outline of the study

This cross-sectional study of 197 children, aged 7-11, drawn from a Boston paediatric dental practice, investigated the potential association between fluoride exposure and behaviour problems, as well as the prevalence of dental fluorosis. Parents of the children completed questionnaires on fluoride exposure history and social and

medical backgrounds, as well as on child behaviour (the Child Behaviour Checklist – CBCL). Presence of fluorosis was assessed in oral examinations.

There was no significant association between either fluoride exposure history or fluorosis and the childhood behaviour problems in the study children. Sixty-nine percent of the children in the study showed evidence of fluorosis, usually mild.

#### Comments on this study

This study is the first which has examined childhood behaviour problems in relation to fluoride or fluoridation exposure. It was prompted by a study showing sodium fluoride at sufficient dosage could be neurotoxic to rats (Mullenix et al., 1995). The negative results of the study by Morgan et al. are reassuring. However, as acknowledged by the authors, the study had its limitations. In particular, the study population was generally from the same geographic area, of similar socio-economic status, and had similar fluoride exposures. A more ideal study would have had wider variation among the study subjects, particularly in relation to fluoride exposure.

Jooste PL. (1999)

#### **Endemic goitre in the absence of iodine deficiency in schoolchildren of the Northern Cape Province of South Africa.**

#### Outline of the study

This was a cross-sectional study of goitre prevalence, in 671 children aged 6, 12 and 15, in six South African towns. Two of the towns had low levels of fluoride in their water supplies (0.3-0.5 ppm), two had near-optimal levels (0.9-1.1 ppm) and two had "supra-optimal" levels (1.7-2.6 ppm). All children were lifetime residents of their towns. Urinary samples were collected for iodine measurement, and goitre examination was carried out by one clinician.

Endemic goitre prevalence ranging from 5 to 29% was found in the study towns. This appeared not to be related to inadequate iodine intake, as iodine status was satisfactory in all the towns. The highest prevalence of goitre was found in the two towns with the highest water fluoride levels. The prevalence of goitre in the low and near-optimal fluoride towns was not associated with the fluoride level. The authors

noted that the lowest prevalence of goitre was found in the town with the least amount of undernutrition. They concluded that no causal inference was possible, but "...either fluoride at high levels may behave as a goitrogen or that the high fluoride levels were associated with another factor with goitrogenic properties."

#### Comments on the study

This study was prompted by some early epidemiological studies that noted an apparent relationship between fluoride in water and goitre. Other studies have found no evidence that fluoride at low or near optimal concentrations adversely affects the thyroid. However, even with the towns in this study for which the water fluoride levels were high, there is still a strong possibility of confounding, particularly by some nutritional factor, possibly related to undernutrition. It was also noted in the report that the towns were situated in a hot, dry climate, such that water intake was likely to be relatively high. Fluoride intake in the high fluoride towns was stated to be sufficiently high to cause severe mottling of the teeth in most of the children studied.

Overall, this study provides limited evidence that high concentrations of fluoride in water may have a goitrogenic effect, particularly when water intake is high, but no evidence that optimally fluoridated water is associated with such an effect.

#### **General discussion**

This review has considered only recently published material and took, as a point of departure, the comprehensive review of fluoridation published by the Public Health Commission in 1994. Overall, the update has been reassuring. No persuasive evidence of harmful effects of optimal water fluoridation has been revealed, and, generally, the evidence has strengthened that there are no serious health risks associated with this practice. This is particularly the case for bone fracture risk, which is perhaps the health issue that is most widely cited by those opposed to the practice of water supply fluoridation. Several studies using data on individuals now support the view that there is no increased risk from water fluoridated at optimal levels for dental health. This view is supported by a recent review by the Australian National Health and Medical Research Council (NHMRC, 1999). The NHMRC concluded, *inter alia*, that there is a "variable effect on the incidence of hip fractures with different fluoridated water exposures with the stronger studies suggesting a

protective effect". Although its conclusions are consistent with this review, the NHMRC review placed more emphasis on the study by Jacqmin-Gadda et al. (1998), describing it as "pivotal". As discussed above, the results of this study have some puzzling features which (in the opinion of this reviewer) make it difficult, or impossible, to interpret.

A second area of public concern regarding fluoridation has been the possibility of cancer associated with fluoridation, particularly the bone cancer osteosarcoma. Two recent case-control studies have examined osteosarcoma in relation to fluoridation. Neither showed any evidence of an association between fluoridation and osteosarcoma. However, both studies had their limitations, leaving still the need for at least one well-designed and conducted study to put this issue to rest.

The question arises whether such a study might be carried out in New Zealand. There are less than 50 cases of osteosarcoma diagnosed in New Zealand each year. Therefore, although such a study would be possible here, given time to collect sufficient cases, it could more quickly be carried out in a population that generated a larger number of cases. The same question about possible New Zealand research may be asked in regard to bone fracture, for which the definitive study is also lacking. The number of bone fractures requiring hospitalisation occurring in New Zealand is comparatively large. For example, in the year ending 30 June 1998 there were 3,344 hip fractures (ICD-9 code 820) treated in publicly funded hospitals in New Zealand (NZHIS, 1999). Clearly, numbers of hospitalised fractures would be quite sufficient for a large case-control study. Ideally such a study would collect cases generated over a wide geographic area, to maximise variability of water fluoridation exposure. The Auckland Hip Fracture Study that has already been carried out in New Zealand collected cases and controls from the Auckland region (Norton et al., 1995). This geographic restriction would have tended to make cases and controls similar in regard to their exposure to fluoridated water supplies.

A further area of investigation could involve the prevalence and degree of severity of dental fluorosis in fluoridated and non-fluoridated areas of New Zealand. Since the most recent policy adjustments to optimise fluoride exposures in New Zealand, there has been no survey of dental fluorosis prevalence in fluoridated or non-fluoridated areas of this country. It is, therefore, not possible to be completely confident that

current New Zealand policy on fluoridation and fluoride availability is optimal. It would be useful if a dental fluorosis survey of fluoridated and non-fluoridated areas were to be carried out, using a methodology that could periodically be replicated, say every five to ten years, to provide longitudinally consistent data. Such a regular survey would permit evaluation of current policy concerning fluoride exposure, justify any modifications to the policy, and provide public reassurance that unacceptable levels of dental fluorosis were not occurring. The alternative is to rely on anecdotal reports from dental therapists and dentists. Such reports would possibly alert authorities if serious dental fluorosis were occurring, but would not provide a valid comparison between fluoridated and non-fluoridated areas. The proposed regular surveys, provided they obtained information on all sources of fluoride exposure, could be used to optimise New Zealand policy on fluoridation and use of other fluoride-containing products.

The timing of the first such survey might take into account the most recent change to New Zealand policy on fluoride, which was in 1995. Since fluorosis affects teeth during development, before eruption, the benefits of the new policy might not be evident for at least another year (when permanent upper incisors of 6-year olds will be beginning to erupt). Nonetheless, an earlier survey might establish a baseline against which the benefits of the most recent policy change could be measured.

## **Conclusions**

The results of studies that have become available since the earlier (1994) Public Health Commission report have produced no clear evidence of harmful effects associated with optimal fluoridation of water supplies, and have generally strengthened conclusions that there are no adverse health effects associated with fluoridation. However, there is room for further strengthening of the evidence, particularly for bone fractures and osteosarcoma.

## Recommendations

It is recommended that the Ministry of Health:

1. promote the development of an optimal survey methodology for investigating the prevalence and degree of severity of dental fluorosis in fluoridated and non-fluoridated areas in New Zealand
2. promote the carrying out of this dental fluorosis survey in the near future and at regular intervals (say, every 5-10 years) thereafter to obtain longitudinally comparable data for the purposes of optimising the delivery of fluoride to New Zealand children, to promote good dental health while minimising the prevalence of dental fluorosis
3. promote the carrying out of a case-control study of bone fractures for the purposes of resolving the issue of whether there is an association between such fractures and optimal fluoridation of water supplies.

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