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Review finds community water fluoridation safe and effective

A review of the scientific evidence for and against the efficacy and safety of fluoridation of public water supplies has found that the levels of fluoridation used in New Zealand create no health risks and provide protection against tooth decay. Councils currently implementing this measure can be confident about its public health benefits, while those not currently fluoridating water can consider it a safe and effective option.

The review, entitled *Health Effects of Water Fluoridation: a Review of the Scientific Evidence*, was commissioned by Sir Peter Gluckman, the New Zealand Prime Minister's Chief Science Advisor and Sir David Skegg, President of the Royal Society of New Zealand at the request of Auckland City on behalf of several local Councils.

"The process for the review was rigorous," said Sir David Skegg. "It included an extensive evaluation of the scientific literature by a panel of five experts, as well as one lay observer with local body experience. The resulting report was reviewed by three international experts and by the Director of the National Poisons Centre," he said.

According to Skegg, the panel paid particularly close attention to the claims that fluoride contributes to the risks of cancer, musculoskeletal and hormonal disorders, as well as to claims that it has adverse effects on brain development – these being the major contentions about potential harms that have been made.

"The panel concluded that the concerns raised by those opposed to fluoridation are not supported by the scientific evidence," said Skegg.

According to the report, the only side effect of fluoridation at the levels used in New Zealand is mild dental fluorosis, which can cause opaque white areas in the tooth enamel that is usually of no cosmetic significance. This is found to be as common in non-fluoridated areas as it is in fluoridated areas, which is probably a reflection of behaviour such as swallowing of fluoridated toothpaste by young children.

"The review finds compelling evidence that fluoridation of the water at the established and recommended levels produces broad and continuing benefits for the dental health of New Zealanders," said Sir Peter Gluckman. "The public can be reassured on the basis of robust scientific data, that the implementation of this public health measure poses no risk of adverse health effects," he said.

"It is worth noting that dental health remains a major issue for much of the New Zealand population, particularly in communities of low socioeconomic status."

From a scientific perspective, the report finds that community water fluoridation provides a cost-effective and equitable way of improving public health. However, it should be noted that the review does not address the broader philosophical issues that have surrounded fluoridation.

The executive summary is included below and the full review is available to download at www.royalsociety.org.nz and www.pmcsa.org.nz

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Health Effects of Water Fluoridation: A Review of Scientific Evidence

Executive Summary

Oral health and tooth decay in New Zealand

Despite notable overall improvements in oral health over the last half century, tooth decay (dental caries) remains the single most common chronic disease among New Zealanders of all ages, with consequences including pain, infection, impaired chewing ability, tooth loss, compromised appearance, and absence from work or school. Tooth decay is an irreversible disease; if untreated it is cumulative through the lifespan, such that individuals who are adversely affected early in life tend to have pervasive decay by adulthood, and are likely to suffer extensive tooth loss later in life. Prevention of tooth decay is essential from very early childhood through to old age.

The role of fluoride

Fluoride is known to have a protective effect against tooth decay by preventing demineralization of tooth enamel during attack by acid-producing plaque bacteria. In infants and young children with pre-erupted teeth, ingested fluoride is incorporated into the developing enamel, making the teeth more resistant to decay. Drinking fluoridated water or brushing teeth with fluoride toothpaste raises the concentration of fluoride in saliva and plaque fluid, which reduces the rate of enamel demineralisation during the caries process and promotes the remineralisation of early caries lesions. When ingested in water, fluoride is absorbed and secreted back into saliva, where it can again act to inhibit enamel demineralisation. A constant, low-level of fluoride in the mouth has been shown to combat the effects of plaque bacteria, which are fuelled by dietary sugars. Drinking fluoridated water accomplishes this through both topical and systemic actions.

Community water fluoridation as a public health measure

New Zealand water supplies generally have naturally low concentrations of fluoride. Fluoridation of public drinking-water supplies involves the deliberate adjustment of fluoride concentrations in drinking water from their naturally low levels ($\sim 0.1\text{-}0.2\text{ mg/L}^1$ in most parts of New Zealand), upwards to between 0.7 and 1.0 mg/L. Public health authorities worldwide agree that community water fluoridation (CWF) is the most effective public health measure to reduce the burden of dental caries, reducing both its prevalence within a population and its severity in individuals who are affected. With a history dating back to the 1940s in the US, CWF is now practised in over 30 countries around the world, providing over 370 million people with optimally fluoridated water. Epidemiological evidence of its efficacy and safety has been accumulating for over six decades. The fluoride concentrations recommended for CWF have been set based on data from both animal toxicology studies and human epidemiological studies to provide a daily oral exposure that confers maximum benefit without appreciable risk of adverse effects.

Naturally occurring concentrations of fluoride in water in some parts of the world (e.g. parts of China, Africa, and India) are much higher than those found in fluoridated water, and in some of these regions high fluoride intakes are known to cause problems in teeth and bones (dental and skeletal fluorosis). It is important to distinguish between effects of apparent fluoride toxicity at very high intakes, and effects that may occur at the much lower intakes from CWF. Some studies have failed to do so, giving rise to potentially misleading statements and confusion.

There remains ongoing debate about the long-term safety of adding fluoride to drinking water. It is important to separate concerns that are evaluable by science and those concerns that arise from philosophical/ideological considerations. With respect to the former it is important to note that the inherent nature of science is such that it is never possible to prove there is absolutely no risk of a very rare negative effect – science can only draw conclusions that are highly probable, but not absolute.

¹ Fluoride concentrations in water are expressed as either mg/L or parts per million [ppm]; these units are effectively interchangeable. Fluoride concentrations in toothpaste are typically expressed as ppm.

Most recently, the concerns for potential side effects have revolved around (a) whether consuming fluoridated water increases the risk of cancer (in particular osteosarcoma), and (b) the effects of fluoride on the cognitive development of children. The potential for increased bone fracture risk has also been extensively examined. While the scientific consensus confirmed in this review is that these are not significant or realistic risks, as a matter of public health surveillance, such claims continue to be studied and monitored in populations receiving fluoridated water.

'Artificial' vs 'natural' fluoride

The fluoride-containing compounds used for adjusting fluoride levels in drinking water have been shown to dissolve fully in water to release fluoride ions. These ions are identical to those found naturally in the water. The reagents used for water fluoridation in New Zealand are regularly tested for purity and to ensure that any trace metals (or other impurities) that they may contain, when added to drinking water, are well below the maximum safe limits described in the Drinking Water Standards for New Zealand. The water supply itself is then regularly monitored to ensure fluoride levels and any impurities (including from the source water) are within the maximum safe limits set in the Drinking Water Standards.

Evidence for benefits of water fluoridation

Analysis of evidence from a large number of epidemiological studies and thorough systematic reviews has confirmed a beneficial effect of CWF on oral health throughout the lifespan. This includes relatively recent studies in the context of the overall reduced burden of caries that has resulted from the widespread use of topical fluoride products (e.g. toothpastes, mouth rinses, and fluoride varnishes). In New Zealand, significant differences in decay rates between fluoridated and non-fluoridated communities continue to exist, despite the fact that the majority of people use fluoride toothpastes. These data come from multiple studies across different regions of the country conducted over the last 15 years, as well as from a national survey of the oral health status of New Zealanders conducted in 2009. Various studies indicate that CWF has an additive effect over and above that of fluoride toothpaste and other sources of fluoride that are now in common use.

The burden of tooth decay is highest among the most deprived socioeconomic groups, and this is the segment of the population for which the benefits of CWF appear to be greatest.

Known effects of fluoride exposure – dental fluorosis

Dental fluorosis is a tooth enamel defect characterised by opaque white areas in the enamel, caused by excess exposure to fluoride while the teeth are forming in the jaw and before they erupt into the mouth. Tooth development occurs during the first 8 years of life; beyond this age children are no longer susceptible to fluorosis. In the common, mild forms it is of minor or no cosmetic significance, but severe forms result in pitted and discoloured teeth that are prone to fracture and wear. Dental fluorosis reflects overall fluoride absorption from all sources at a young age, and is a known effect of drinking water containing naturally very high concentrations of fluoride. The amount of fluoride added to water in CWF programmes is set to minimise the risk of this condition while still providing maximum protective benefit against tooth decay. No severe form of fluorosis has ever been reported in New Zealand.

The prevalence of mild dental fluorosis has increased somewhat since the initiation of CWF in communities around the world, but further increases have coincided with the widespread use of fluoridated dental products, particularly toothpaste and fluoride supplements. There is a substantial evidence base to indicate that inappropriate use of such dental products (e.g. young children swallowing large amounts of toothpaste; inappropriate prescribing of supplements) is the main factor in increasing fluorosis risk, as the prevalence of fluorosis has increased more in non-fluoridated areas than in fluoridated ones. Most of the dental fluorosis that occurs in this country is very mild, having effects that are only identified by professional dental examination. The levels of fluoride used for CWF in New Zealand are relatively low in the range that is known to cause minimal risk for cosmetically problematic fluorosis, as reflected in data from the 2009 New Zealand Oral Health Survey, which showed the overall prevalence of moderate fluorosis to be very low. The survey indicated that fluorosis prevalence is not increasing, and that levels of fluorosis are similar between fluoridated and non-fluoridated areas.

The risk for mild fluorosis that is associated with fluoride exposure is highest for formula-fed infants, and young children who are likely to swallow toothpaste. In some cases the fluoride intake by these groups can approach or exceed the currently recommended a conservative upper intake level, but the rarity of cosmetically concerning dental fluorosis in New Zealand indicates that such excess intake is not generally a safety concern.

Analysis of evidence for adverse effects

A number of potential adverse effects of the consumption of fluoride have been suggested, though many have only been reported in areas where the natural level of fluoride in water is very high.

Most recently, the main issues in question are whether fluoride in drinking water has an impact on cancer rates (particularly the bone cancer osteosarcoma) or on the intellectual development (IQ) of children. Because fluoride accumulates in bones, the risk of bone defects or fractures has also been extensively analysed. While there are published studies suggesting that such associations exist, they are mostly of very poor design (and thus of low scientific validity) or do not pertain to CWF because the fluoride levels in question are substantially higher than would be encountered by individuals drinking intentionally fluoridated water.

Cancer

The large majority of epidemiological studies have found no association between fluoride and cancer, even after decades of exposure in some populations. This includes populations with lifetime exposure to very high natural fluoride levels in water, as well as high-level industrial exposures. The few studies that have suggested a cancer link with CWF suffer from poor methodology and/or errors in analysis. Multiple thorough systematic reviews conducted between 2000 and 2011 all concluded that based on the best available evidence, fluoride (at any level) could *not* be classified as carcinogenic in humans. More recent studies, including a large and detailed study in the UK in 2014, have not changed this conclusion.

Bone cancers have received specific attention because of fluoride's deposition in bone. Although a small study published in 2006 claimed an increased risk for osteosarcoma in young males, extensive reviews of these and other data conclude that there is no association between exposure to fluoridated water and risk of osteosarcoma. Likewise, in the New Zealand context, data from the New Zealand Cancer Registry from 2000-2008 show no evidence of association between osteosarcoma incidence and residence in CWF areas.

We conclude that on the available evidence there is no appreciable risk of cancer arising from CWF.

Effects on IQ

Recently there have been a number of reports from China and other areas where fluoride levels in groundwater are naturally very high, that have claimed an association between high water fluoride levels and minimally reduced intelligence (measured as IQ) in children. In addition to the fact that the fluoride exposures in these studies were many (up to 20) times higher than any that are experienced in New Zealand or other CWF communities, the studies also mostly failed to consider other factors that might influence IQ, including exposures to arsenic, iodine deficiency, socioeconomic status, or the nutritional status of the children. Further, the claimed shift of less than one IQ point suggests that this is likely to be a measurement or statistical artefact of no functional significance. A recently published study in New Zealand followed a group of people born in the early 1970s and measured childhood IQ at the ages of 7, 9, 11 and 13 years, and adult IQ at the age of 38 years. Early-life exposure to fluoride from a variety of sources was recorded, and adjustments were made for factors potentially influencing IQ. This extensive study revealed no evidence that exposure to water fluoridation in New Zealand affects neurological development or IQ.

We conclude that on the available evidence there is no appreciable effect on cognition arising from CWF.

Bone fractures

Fluoride is incorporated into bone during bone development and remodeling. Evidence from both animal and human studies suggests that water fluoride levels of 1 mg/L – a level considered optimal for prevention of tooth decay – may lead to increased bone strength, while levels of 4 mg/L may cause a decrease in bone strength.

Prolonged exposure to fluoride at five times the levels used in CWF (~5 mg/L) can result in denser bones that may be more brittle than normal bone, and may increase the risk of fracture in older individuals. However, despite a large number of studies over many years, no evidence has been found that fluoride at optimal concentrations in water is associated with any elevated risk of bone fracture. In children, intake of fluoridated water does not appear to affect bone density through adolescence.

We conclude that on the available evidence there is no appreciable risk of bone fractures arising from CWF.

Other effects

A number of other alleged effects of CWF on health outcomes have been reviewed, including effects on reproduction, endocrine function, cardiovascular and renal effects, and effects on the immune system. The most reliable and valid evidence to date for all of these effects indicates that fluoride in levels used for CWF does not pose appreciable risks of harm to human health.

Fluoride exposure in specific population groups

A number of public health agencies around the world, including the US Institute of Medicine, Health Canada, the European Food Safety Authority, the Australian National Health and Medical Research Council, and the New Zealand Ministry of Health provide recommendations on adequate intakes (AIs) for nutrients considered necessary for optimal health, as well as safe upper levels of intake (ULs). Fluoride is included among the nutrients assigned AI and UL recommendations.

Infants

Infants who are exclusively breastfed to 6 months of age have very low fluoride intake, and the low recommended intake level for this age group (0.01 mg/day) reflects this. Infants 0-6 months of age who are exclusively fed formula reconstituted with fluoridated water will have intakes at or exceeding the upper end of the recommended range (UL; 0.7 mg/day). The higher intakes may help strengthen the developing teeth against future decay, but are also associated with a slightly increased risk of very mild or mild dental fluorosis. This risk is considered to be very low, and recommendations from several authoritative groups support the safety of reconstituting infant formula with fluoridated water.

Young children (1-4 years)

Typical intakes of fluoride from water, food, and beverages in young children in New Zealand are within or below the recommended levels (0.7-2.0 mg/day depending on age and weight). However, intake of fluoride from toothpaste contributes a significant proportion of total ingested fluoride in this group. In combination with dietary intake this can raise the total daily intake above the recommended adequate intake level. Consumption of fluoridated water is highly recommended for young children, as is the use of fluoride toothpaste (adult strength – at least 1000ppm), but only a smear of toothpaste should be used, and children should be supervised during toothbrushing to ensure that toothpaste is not swallowed/eaten.

Children (5+years) and adolescents

Fluoride exposure estimates for children and adolescents in New Zealand indicate that the average total dietary intake for this age group (including fluoride ingested from toothpaste) is below the recommended adequate intake level even in fluoridated areas. This group is not considered at high risk of exposure to excess fluoride, and consumption of fluoridated water and use of fluoride toothpaste (≥ 1000 ppm) are both recommended.

Pregnant or breastfeeding women

Pregnant women are not themselves any more vulnerable to the effects of fluoride than their non-pregnant counterparts, but they may have concerns about fluoride ingestion and its possible effects on their unborn fetus. However, no studies to date have found any evidence of reproductive toxicity attributable to fluoride at or around levels used for CWF. The recommendations for fluoride intake for pregnant women therefore do not differ from those for non-pregnant women – i.e. they are encouraged to drink fluoridated water and to use full-strength fluoride toothpaste throughout their pregnancy. This is considered beneficial to their own oral health (which is often compromised by physiological changes in pregnancy) and safe for their offspring.

The same recommendations apply during breastfeeding. Fluoride does not transfer readily into breast milk, so the fluoride intake of the mother does not affect the amount received by her breastfeeding infant.

Adults and the elderly

Although most studies of the effects of CWF have focused on benefits in children, caries experience continues to accumulate with age, and CWF has also been found to help reduce the extent and severity of dental decay in adults, particularly with prolonged exposure. Elderly individuals may have decreased ability to undertake personal oral healthcare, and therefore are vulnerable to tooth decay, particularly in exposed root surfaces. As with other groups who are at high risk of tooth decay, consumption of fluoridated water can have important preventive impact against this disease in the elderly. Epidemiological studies have shown that elderly individuals indeed benefit from drinking fluoridated water, experiencing lower levels of root decay and better tooth retention. It should be noted that the increasing retention of natural teeth in the elderly brings with it an increased need for long-term maintenance of tooth function, and a continuing benefit of CWF exposure in this group.

Individuals with kidney disease

Chronic kidney disease is relatively common in New Zealand, with a higher prevalence amongst Māori, and numbers are increasing due to the increasing prevalence of hypertension and diabetes. Because the kidney is the major route of fluoride excretion, blood fluoride concentrations are typically elevated in patients with end-stage kidney disease, and this group may be considered to be at increased risk of excess fluoride exposure. However, to date no adverse effects of CWF exposure in people with impaired kidney function have been documented.

Cost-effectiveness of water fluoridation

Tooth decay is responsible for significant health loss (lost years of healthy life) in New Zealand. The 'burden' of the disease – its 'cost' in terms of lost years of healthy life – is equivalent to 3/4 that of prostate cancer, and 2/5 that of breast cancer in New Zealand. Tooth decay thus has substantial direct and indirect costs to society.

There is strong evidence that CWF is a cost-effective use of ratepayer funds – with it being likely to save more in dental costs than it costs to run fluoridation programmes (at least in communities of 1000+ people). There is New Zealand evidence for this, along with evidence from Australia, the US, Canada, Chile and South Africa. CWF appears to be most cost-effective in those communities that are most in need of improved oral health. In New Zealand these include communities of low socioeconomic status, and those with a high proportion of children or Maori.

Conclusions

The World Health Organization (WHO), along with many other international health authorities, recommends fluoridation of water supplies, where possible, as the most effective public health measure for the prevention of dental decay.

A large number of studies and systematic reviews have concluded that water fluoridation is an effective preventive measure against tooth decay that reaches all segments of the population, and is particularly beneficial to those most in need of improved oral health. Extensive analyses of potential adverse effects have not found evidence that the levels of fluoride used for community water fluoridation schemes

contribute *any* increased risk to public health, though there is a narrow range between optimal dental health effectiveness and a risk of mild dental fluorosis. The prevalence of fluorosis of aesthetic concern is minimal in New Zealand, and is not different between fluoridated and non-fluoridated communities, confirming that a substantial proportion of the risk is attributable to the intake of fluoride from sources other than water (most notably, the swallowing of high-fluoride toothpaste by young children). The current fluoridation levels therefore appear to be appropriate.

This analysis concludes that from a medical and public health perspective, water fluoridation at the levels used in New Zealand poses no significant health risks and is effective at reducing the prevalence and severity of tooth decay in communities where it is used. Communities currently without CWF can be confident that this is a safe option that is cost saving and of significant public health benefit – particularly in those communities with high prevalence of dental caries.

Review Methodology

This report aimed to evaluate the current state of scientific knowledge on the health effects of water fluoridation, in order to inform decision-making on continuing or implementing community water fluoridation, particularly within the New Zealand context. Several previous rigorous systematic reviews were used as the basis for this analysis, and literature searches in Medline, EMBASE, the Cochrane library database, Scopus, and Web of Science were undertaken to identify subsequent studies in the peer-reviewed scientific literature. Alleged health effects from both the scientific and non-scientific literature were considered, and many original studies relating to these claims were re-analysed. The main review sources are presented in the Appendix.

Aside from animal toxicity studies, articles considered for this review were those that had a primary focus on community water fluoridation or human exposure to fluoride at levels around those used for CWF. Studies were assessed for robust design, including adequate sample size, appropriate data collection and analysis, adjustment for possible confounding factors, and conclusions appropriate to the data analysis.

The report does not consider in depth the broader philosophical issues that lead some people to have objections to CWF.

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Background information

About the Royal Society of New Zealand

The Royal Society of New Zealand promotes science, technology and humanities in schools, in industry and in society. We administer funds for research, publish peer-reviewed journals, offer advice to government, and foster international scientific contact and co-operation.

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About the Office of the Prime Minister's Chief Science Advisor

The Role of the Chief Science Advisor is to give the Prime Minister strategic and operational advice on science and science policy issues.

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