Rolling Revision of the WHO Guidelines for Drinking-Water Quality

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Fluoride

By ***M A Lennon, H Whelton, D O'Mullane, J Ekstrand***

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Introduction

Fluoride has both beneficial and detrimental effects on human health. In terms of dental health, the prevalence of dental caries is inversely related to the concentration of fluoride in drinking water; while there is a dose-response relationship between the concentration of fluoride in drinking water and the prevalence of dental fluorosis. In terms of general health, in communities where drinking water and foodstuffs are excessively high in fluoride, skeletal fluorosis and bone fracture are the most relevant adverse effects. However, there are also other sources of fluoride.

Processes such as desalination will remove virtually all fluoride from water. In terms of using such sources for drinking water, the implications for public health will strongly depend on local circumstances. However, the public health requirement is to maximise the beneficial effects of fluoride in drinking water supplies for caries prevention, whilst minimising the unwanted dental and potential general health effects.

The aetiology of dental caries involves the interplay on the tooth surface between certain oral bacteria and simple sugars (e.g. sucrose) derived from the diet. In the absence of those sugars in foods and drinks dental caries will not be a public health problem. However where sugar consumption is high or is increasing, dental caries will be *or will become* a major public health problem unless there is appropriate intervention.

Removing fluoride from a local drinking water supply by desalination could potentially exacerbate an existing or developing dental public health problem.

Fluoride intake in man

Fluoride is widely distributed in the lithosphere mainly as fluorspar, fluorapatite and cryolite, and is recognised as the thirteenth most common element in the earth's crust. It is found in seawater at a concentration of around 1.2 – 1.4 mg/litre, in ground waters at concentrations up to 67 mg/litre, and in most surface waters at concentrations less than 0.1 mg/litre. Fluoride is also found in foods particularly fish and tea (IPCS 2002).

Whilst almost all foodstuffs contain at least traces of fluoride, water and non-dairy beverages are the main sources of ingested fluoride, accounting for 66 to 80% of fluoride intake in US adults according to the concentration of fluoride in the public drinking water. Other significant sources of ingested fluoride are toothpaste in very young children (who tend to swallow most of their toothpaste), tea in tea-drinking communities, and inhaled fluoride in some communities in China where coal containing very high levels fluoride is burned indoors. Absorption of ingested fluoride is via the stomach and small intestine (IPCS 2002).

Most of the fluoride in water, either naturally occurring or added, will be in the form of the free fluoride ion (IPCS 2002). The effect of water hardness in the range 0 to 500 mg $Ca\ Co_3$ /litre has little effect on ionic dissociation, and therefore little effect on the bio-availability of fluoride. Absorption of a standard dose of fluoride will vary from 100% on a fasting stomach, to 60% when taken with a calcium-rich breakfast.

Dental effects of ingested fluoride

The dental effects of fluoride naturally present in public drinking water were established during the 1930s and 40s by Trendley Dean and his colleagues at the US Public Health Service. In a series of epidemiological studies across the United States they demonstrated that as the concentration of fluoride naturally present in drinking water increased, the prevalence and severity of dental fluorosis increased and, the prevalence and severity of dental caries (decay) decreased.

Furthermore Dean's data suggested that at a natural fluoride concentration of around 1 mg/litre, the prevalence, severity and cosmetic impact of dental fluorosis was not of public health significance, and that the increased resistance to dental caries was of substantial public health importance.

Inevitably this led to the question as to whether artificially raising the fluoride level of public drinking water would have the same effects. The first intervention study was undertaken under the direction of USPHS in Grand Rapids in 1945. The results after 6 years of fluoridation were published in 1953. Additional studies were started in 1945/6 in New York State, in Illinois, and in Ontario Canada. Further intervention studies were established in the Netherlands (1953), New Zealand (1954), the UK (1955-6), and East Germany (1959). All of these intervention studies demonstrated clinically important reductions in the incidence of dental caries.

Following the publication of the results of these intervention studies the application of water fluoridation as a public health measure became widespread. Some of the countries involved and the populations receiving artificially fluoridated water are listed in Table 1.

The optimal concentration of fluoride varies according to climatic conditions with the range 0.5mg-1.0mg/litre being generally recommended (WHO, 1994). Worldwide around 355 million people are receiving artificially fluoridated water. In addition, around 50 million people receive water naturally fluoridated at a concentration of around 1 mg/litre. Table 2 lists countries where community drinking water supplies with a natural fluoride concentration of around 1 mg/litre serve populations of 1 million or more. In some countries, particularly parts of India, Africa and China, drinking water can contain very high concentrations of naturally occurring fluoride - well in excess of the WHO's recommended Guideline Value of 1.5 mg/litre.

Many countries that have introduced water fluoridation continue to monitor the effects on both dental caries and dental fluorosis using cross-sectional random samples of children aged 5 through 15 years. An excellent example of such monitoring is a recently published report of child dental health in the Republic of Ireland (mainly fluoridated) and the North of Ireland (not fluoridated) (Whelton et al 2003)**. (TABLE 3)**

Ingested fluoride and health

The health effects of ingested fluoride were reviewed by Moulton (1942) prior to the Grand Rapids intervention and regularly ever since by numerous organisations and individuals. More recently IPCS (2002) have carried out a detailed review of fluoride and the potential for impacts on health. Studies and reviews have concentrated on bone fractures, skeletal fluorosis, cancers and birth defects but also cover many other disorders claimed to be caused, or aggravated, by fluoridation. There is no good evidence of any adverse medical effects associated with the consumption of water with fluoride naturally or artificially added at a concentration of 0.5 – 1.0 mg/litre other than the increase in dental fluorosis described above. Furthermore, US studies in areas with natural fluoride levels of up to 8 mg/litre found no clinical evidence of harm. However there is clear evidence from India and China that skeletal fluorosis and an increased risk of bone fractures occur as a result of long-term excessive exposure to fluoride (total intakes of

14 mg fluoride per day), and evidence suggestive of an increased risk of bone effects at total intakes above about 6 mg fluoride per day (IPCS 2002).

The U.S. National Academy of Sciences Institute of Medicine has recommended an Adequate Intake of fluoride from all sources as 0.05 mg F/kg body weight/day, defined as the estimated intake that has been shown to reduce the occurrence of dental caries maximally in a population without causing unwanted side effects including moderate dental fluorosis. The U.S. Environmental Protection Agency sets a maximum contaminant level of 4.0 mg/litre to protect against skeletal fluorosis, and a secondary (guidance0 value of 2 mg/litre to protect against moderate to severe dental fluorosis.

The WHO's drinking water quality Guideline Value for fluoride is 1.5 mg/litre (WHO, 1993). However, WHO emphasises that in setting *national* standards for fluoride it is particularly important to consider climatic conditions, volumes of water intake, and intake of fluoride from other sources (e.g. food and air). WHO (1993) also noted that in areas with high natural fluoride levels the Guideline Value might be difficult to achieve in some circumstances with the limited technology available.

Fluoride is not irreversibly bound to bone. During the growth phase of the skeleton, a relatively high portion of an ingested fluoride dose will be deposited in the skeleton. The "balance" of fluoride in the body i.e. the difference between the amount of fluoride ingested and the amount of fluoride excreted in the urine and the faeces can be positive and negative**.** When the fluoride is derived from human milk or cow's milk, biological fluids with a low fluoride content (0.005 mg/L) urinary excretion generally exceeds intake i.e. there is a negative fluoride balance. In infants when fluoride intakes are extremely low sufficient fluoride is released from bone to extracellular fluid to result in urinary excretion higher than intake. This is in great contrast to the situation in an adult approximately one half of the daily fluoride intake by adults will be deposited in the skeleton and the rest excreted in the urine. . Thus, fluoride will be mobilized slowly but continuously from the skeleton depending on present and past fluoride exposure. This relationship is largely due to the fact that bone is not static but, instead, continuously undergoes a remodelling, whereby old bone is resorbed and new bone is formed (Ekstrand 1996, Ekstrand et al 1994).

Implications of desalination

Desalination will remove virtually all fluoride from seawater thus the product water will be low in fluoride and other minerals unless it is reconstituted. Many natural drinking waters are also low in minerals, including fluoride. The public health implications of this will depend on the balance of benefits to risks locally.

There are substantial variations in the levels of dental decay both between and within the continents. WHO recommends the index DMFT at 12 years of age (mean number of **d**ecayed, **m**issing and **f**illed **t**eeth) as the most appropriate national indicator, and the WHO oral health database provides extensive information (http://www.whocollab.od.mah.se/countriesalphab.html).

The aetiological factors in dental caries involve the interplay on the tooth surface between certain oral bacteria and simple sugars (e.g. sucrose) derived from the diet. In the absence of those sugars in foods and drinks (an average national consumption of say less than 15 kg per person per year) dental caries will not be a public health problem. Under such circumstances, the public health concern will be to avoid the harmful effects of any excessive fluoride consumption from drinking water.

However, where caries risk is high (or increasing) the effects of a decision to remove fluoride from the public drinking water are more complex. In countries such as the Scandinavian countries, where public dental awareness is very high and alternative vehicles for fluoride (e.g. tooth paste) are widely available <u>and</u> widely used, a decision not to replace fluoride removed from the dinking water would be of no consequence. On the other hand in some developing countries, where public dental awareness might be much lower, water fluoridation at concentrations of 0.5-1.0 mg/litre would remain an important public health objective. In yet other countries (e.g. the UK) the situation is mixed. In parts, such as the South East of England, dental caries is mainly under control without water fluoridation; in other regions, such as the North West of England, the prevalence of dental caries is substantially higher and water fluoridation remains an important public health objective.

In conclusion the significance of a decision to use demineralized water as a drinking water source without addition of fluoride during remineralization will depend upon:

-the existing concentration of fluoride in the local supply;
-climatic conditions and the volume of water consumed;
-dental caries risk (i.e. sugar consumption);
-the level of public dental awareness and the general availability of
-alternative vehicles for fluoride available to the whole population.

However, total fluoride intake from other sources and the need to ensure an appropriate minimum intake of fluoride to prevent loss from bone also need to be considered.

Table 1: Countries with water fluoridation schemes covering populations of 1 million or more

Country	Population (millions)	Adjusted fluoride	
		Population covered (millions)	Population covered (%)
Argentina	35.9	3.1	9.0
Australia	19.3	11.7	60.6
Brazil	172.5	65.6	38.0
Canada	31.0	13.3	42.9
Chile	15.4	5.4	35.1
Colombia	42.8	29.4	68.7
Guatemala	11.7	1.8	15.4
Hong Kong	6.7	6.7	100.0
Ireland	3.8	2.3	60.5
Israel	6.4	4.3	67.2
Korea	46.1	5.4	11.7
Malaysia	22.6	15.8	69.9
New Zealand	3.8	2.3	60.5
Philippines	77.1	5.0	6.5
Singapore	4.1	4.1	100.0
Spain	39.9	4.0	10.0
UK	59.5	5.4	9.1
USA	281.4	171.0	60.8
Vietnam	79.7	4.4	5.5

Table 2: Countries with drinking water supplies with a natural fluoride concentration of around 1 mg/litre covering populations of 1 million or more

Country	Population (Millions)	Natural fluoride at or around 1mg/litre	
		Population covered (millions)	Population covered (%)
Argentina[a]	35.9	4.5	12.5
France	59.4	1.8	3.0
Gabon	1.3	1.3	100
Libya	5.4	1.0	18.5
Mexico	100.4	3.0	3.0
Senegal	9.7	1.0	10.3
Sri Lanka	19.1	2.8	14.7
Tanzania	35.0	12.2	34.9
USA	281.4	10.0	3.6
Zimbabwe	13.0	2.6	20.0

Table 3: Mean number of decayed, missing and filled teeth in children resident in fluoridated (f) and non-fluoridated (nf) parts of the republic of Ireland (RoI) and in non-fluoridated (nf) Northern Ireland (NI)

Age	**RoI (f)**	**RoI (nf)**	**NI (nf)**
5 years	1.0	1.7	1.8
15 years	2.1	3.2	3.6

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