Australian Government

National Health and Medical Research Council

A SYSTEMATIC REVIEW OF THE EFFICACY AND SAFETY OF FLUORIDATION

PART A: REVIEW OF METHODOLOGY AND RESULTS

3 BACKGROUND

Fluorine (F) is an element of the halogen family, which also includes chlorine, bromine and iodine. It forms inorganic and organic compounds called fluorides. Living organisms are mainly exposed to inorganic fluorides through food and water. The most relevant inorganic fluorides are hydrogen fluoride (HF), calcium fluoride (CaF2), sodium fluoride (NaF), sulfur hexafluoride (SF6) and silicofluorides. Fluorides represent approximately 0.06-0.09% of the earth's crust.

This report is primarily concerned with the caries-reducing benefits and associated health risks of providing fluoride systemically (via addition to water, milk and salt) and the use of topical fluoride agents (such as toothpaste, gel, varnish and mouthrinse). These sources are the focus of the current review as they represent the main methods by which a widespread public health intervention for the prevention of dental caries would occur in Australia, or represent methods that groups or individuals may chose to supplement their fluoride intake (eg, amongst communities that do not receive an adequately fluoridated water supply).

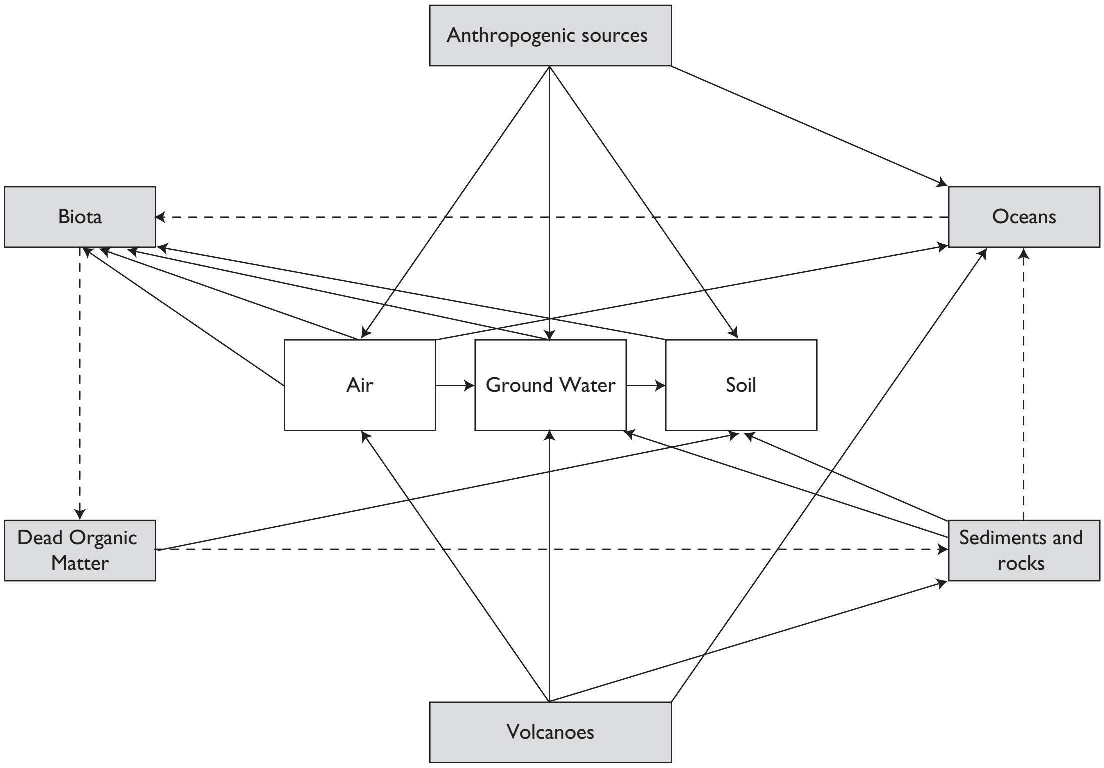
However, there are additional sources of fluoride in the environment which can occur naturally, or as a result of industrial processes. This chapter will provide a brief summary of the environmental sources of fluoride and the supplementation of fluoride. The background information included here has been principally garnered from the World Health Organization (WHO, 2006), and American National Academies of Science (NAS, 2006) reports on fluoride in drinking-water and the International Programme of Chemical Safety (IPCS, 2002) report on fluoride. Whilst environmental exposure is a relevant inadvertent source of fluoride, the extent of exposure to the individual is, under normal Australian circumstances, trivial relative to the extent of exposure from intentional supplementation. This does not obviate the need for careful assessment of the fluoride exposure from industry on a case by case basis.

3.1 ENVIRONMENTAL SOURCES OF FLUORIDE

Fluorides are released into the environment through a combination of natural and anthropogenic processes. Natural processes include the weathering of fluoride containing minerals and emissions from volcanoes. Additionally, a number of industrial processes such as coal combustion, steel production, and other manufacturing processes (aluminium, copper and nickel production, phosphate ore processing, phosphate fertilizer production, glass, brick and ceramic manufacturing) further contribute to fluoride levels.

These processes result in the dispersion, accumulation, and ubiquitous prevalence of fluoride at various concentrations in all surface and groundwater reserves, mostly as fluoride ions or combined with aluminum; in the air, as gases or particulates; in soils, mainly combined with calcium or aluminum; and in living organisms. The cycle of fluoride through the environment in summarised in **Figure 1**.

Figure 1 Environmental and anthropogenic sources of fluoride and their interaction with the environment



Adapted from the ICPS report on fluoride

3.1.1 FLUORIDE LEVELS IN NATURALLY-OCCURRING WATER

Fluoride levels in surface waters vary widely according to geographical location and proximity to emission sources but are generally low, ranging from 0.01 to 1.5 mg/L. Concentrations in seawater commonly range from 1.2 to 1.5 mg/L. Freshwater concentrations are usually lower than seawater ranging from 0.01 to 0.3 mg/L.

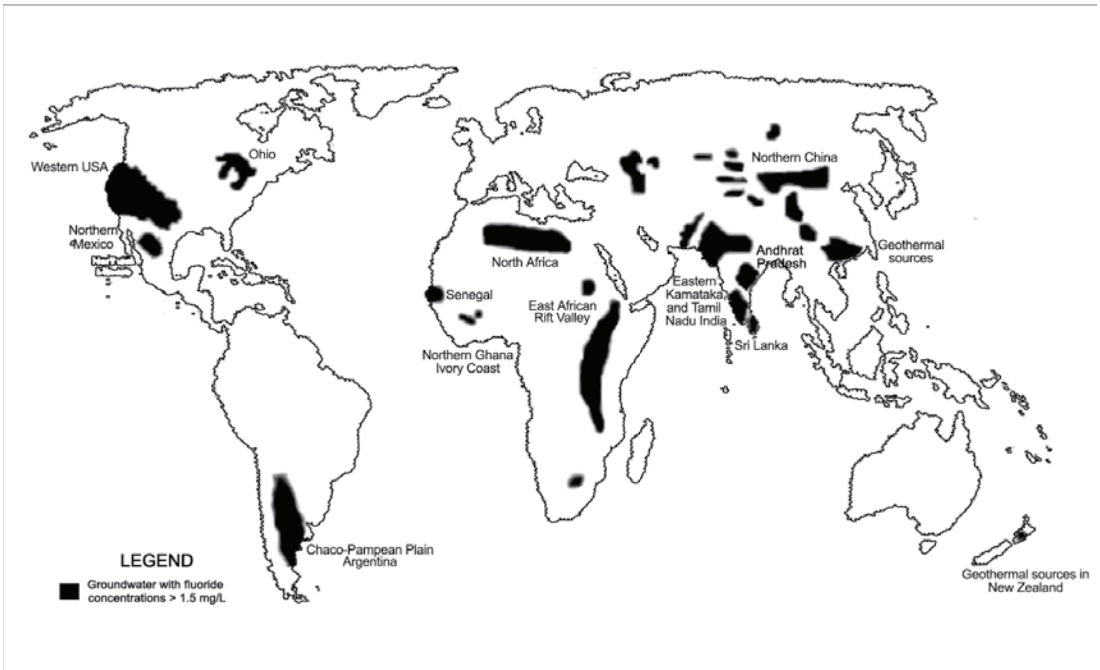
Factors known to influence water fluoride levels include the presence of natural rock rich in fluoride (such as granites and gneisses and sediment of marine origin). Additionally, elevated inorganic fluoride levels are often seen in regions where there is geothermal or volcanic activity. Low levels of calcium in water supplies may also lead to higher levels of fluoride solubility.

Geographical areas associated with high groundwater fluoride concentrations include the East African Rift system (running from Jordan in northern Africa to Kenya and Tanzania in east Africa), large tracts of the Middle East (Iran, Iraq, and Syria) and Indian sub-continent (India, Pakistan, Sri-Lanka), parts of Asia (China), and parts of the USA (**Figure 2**).

Fluoride concentrations greater than 8 mg/L are not uncommon in many of these areas and have been measured as high as 2800 mg/L at Lake Nakuru in Kenya

In Australia, naturally-occurring fluoride levels are generally very low (<0.1 mg/L), with the exception of some remote well water supplies in South Australia.

Figure 2 Geographical areas with high natural fluoride levels



3.1.2 FLUORIDE LEVELS IN AIR

Airborne fluoride enters the atmosphere in gaseous and particulate forms from a variety of natural and anthropogenic sources including volcanic eruptions and combustion of fluoride containing coal. Airborne concentrations are highest in areas close to emission sources and range from 2–3 μg/m^3 in urban and industrialized zones to 0.05-1.90 μg/m^3 in non-industrial areas. Prevailing weather conditions, the type and strength of emission sources and chemical reactivity of the particulate matter may influence the distribution and deposition of airborne fluoride. High concentrations of airborne fluoride (16-46 μg/m^3) are noted in some communities that burn high-fluoride coal for cooking and curing food.

3.1.3 FLUORIDE LEVELS IN SOIL

Fluoride is a component of most types of soil, with total fluoride concentrations ranging from 20 to 1000 μg/g in areas without natural phosphate or fluoride deposits and up to several thousand micrograms per gram in mineral soils with deposits of fluoride. The clay and organic carbon content as well as the pH of soil are primarily responsible for the retention of fluoride in soils. In general, fluoride bound to soil is relatively resistant to leaching and it is the soluble content that is most important to terrestrial animals and plants.

According to the IPCS (2002) report the relative contribution of various anthropogenic sources to total emissions of fluoride to air, water and soil in industrialized countries such as Canada are estimated at 48% for phosphate fertilizer production, 20% for chemical production, 19% for aluminium production, 8% for steel and oil production and 5% for coal burning.

3.1.4 FLUORIDE LEVELS IN FOOD

The levels of fluoride in most fruits, vegetables, meats are very low (0.1 – 5 mg/kg) and are unlikely to contribute significantly to daily fluoride exposure. Exceptions to this general rule include tea, and trona, a vegetable tenderizer used in parts of Tanzania.

Tea contains relatively high levels of fluoride with the highest concentrations found in mature and fallen tea leaves. Concentrations of fluoride in black and green teas, made from the buds and younger tea leaves, range from ~170-400 mg/kg dry weight. Brick tea, made from the mature tea leaf and other parts of the tea plant may have fluoride concentrations 2-4 times as much as black and green leaf tea. Tea infusions made from green, black or brick tea typically have fluoride concentrations 100 fold lower than the dry weight product. Therefore, tea drinks made with brick tea contain fluoride at 2-4 times the concentration of black and green tea infusions. Consumption of brick teas is associated with significant fluoride ingestion and fluorosis in some countries.

Trona, is a sedimentary salt commonly added in cooking to tenderise certain vegetables and beans in regions of Tanzania. Concentrations of fluoride in trona are high and may range from 36-6800 mg/L. Severe fluorosis is endemic in children aged 12 to 17 in villages which regularly consume trona.

Silva and Reynolds (1996) measured the fluoride content of milk-based formulae commonly used in Australia. The fluoride content of milk-based powders ranged from 0.23 to 3.71 g/kg and soy-based powders ranged from 1.08 to 2.86 g/kg. When reconstituted according to manufacturers instructions, with water not containing fluoride, the fluoride content of the liquid formulae ranged from 0.031 to 0.532 ppm (average 0.240 ppm). Assuming average body weights and formula consumption, in all cases this equated to a fluoride exposure of below the suggested threshold for fluorosis avoidance of 0.1 mg F/kg body mass ('optimal' being 0.05–0.07 mg F/kg body mass/day, Riordan 1993). However, if reconstituted with water fluoridated at 1.0 ppm, all brands of formula would have provided a daily fluoride intake above this suggested threshold - with the majority of the fluoride coming from the water rather than the formula. Subsequent to the Silva and Reynolds study, the Australia New Zealand Food Standards Code, 2004 (Standard 2.9.1) recommends that infant formula should contain a low concentration of fluoride in infant formula, and that infant formula containing more than 17 µg F/100 kJ of powder must include a warning about dental fluorosis on the label. This allows for reconstitution with fluoridated water. Measurements were made of 49 samples of formula available at supermarkets, finding that the fluoride concentrations have fallen considerably since the Silva and Reynolds study to a mean of 0.37 (SD 0.19) mg/kg (unpublished data, personal communication with author). These data may somewhat overestimate the actual fluoride exposure to the infant, as a result of reduced bioavailability of fluoride in milk-based products.

Another consideration with respect to the association between infant formula consumption and fluorosis is the timing of the exposure. It is understood that the critical period for fluorosis of the anterior permanent teeth is after the first twelve months of life (Osuji et al, 1988; Evans & Stamm, 1991), by which time the majority of Australian children have ceased exclusive formula consumption.

3.2 INTENTIONAL FLUORIDE SUPPLEMENTATION

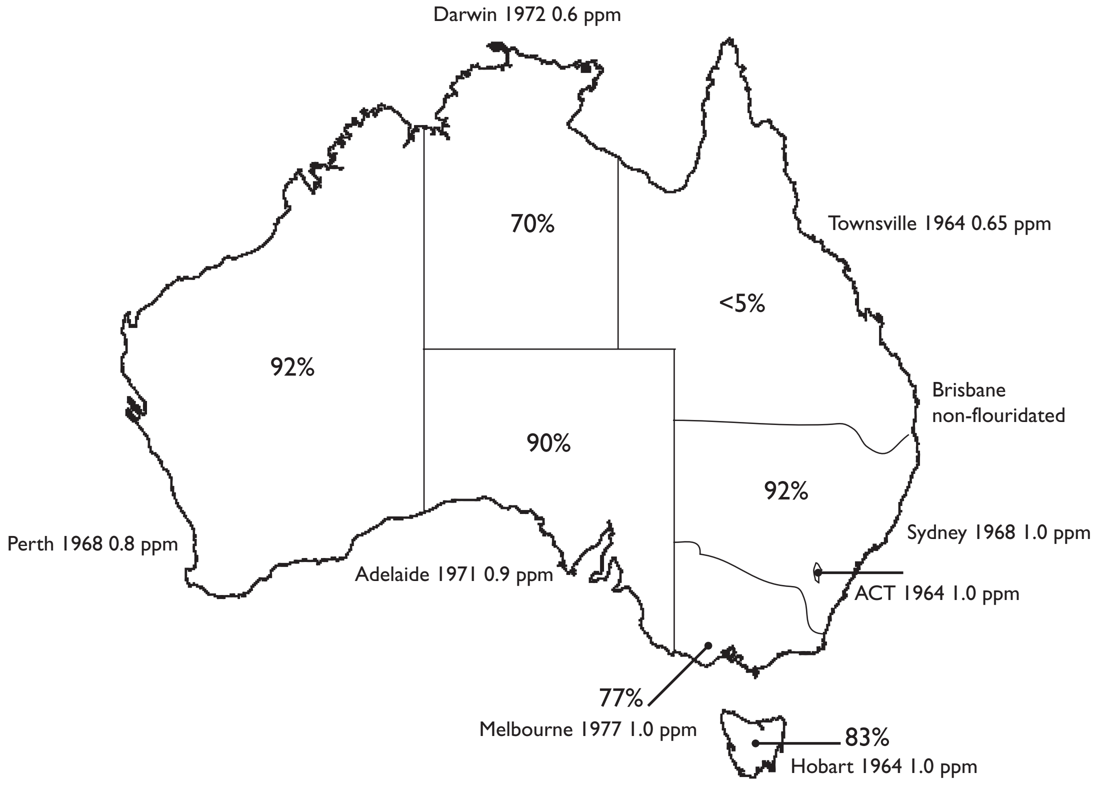
3.2.1 WATER FLUORIDATION

Although research into the beneficial effects of fluoride began in the early 1900's the first community fluoridation program did not begin until 1945 in Grand Rapids Michigan, USA. Three other studies followed in Newburgh, New York (USA) in May 1945, Brantford, Ontario (Canada) in June 1945, and Evanston, Illinois (USA) in February 1947. The results from these studies were used to establish the effectiveness and safety of fluoridation of public water supplies.

In Australia, the first inclusion of fluoride into a municipal water supply occurred in Beaconsfield, near Launceston, Tasmania in 1953. Subsequently all Australian capital cities, including Canberra but excluding Brisbane, have implemented water fluoridation (**Figure 3**).

The aim of water fluoridation is the adjustment of the natural fluoride concentration in fluoride-deficient water to that recommended for optimal dental health (ie, representing a trade-off between maximal prevention of caries and minimal levels of fluorosis). In Australia, nominal target fluoride levels vary according to climate and local water needs but range from 0.6 parts per million (ppm) to 1.0 ppm. Fluoride supplementation levels are lower in hot and humid areas, eg, Darwin, and higher in temperate zones, eg, Hobart. Approximately 76% of Australians have access to fluoridated water supplies. The highest coverage rate of fluoridation is in the Australian Capital Territory (100%) and the lowest is in Queensland at less than 5%.

Figure 3 Dates of introduction of water fluoridation to Australian capital cities and percentage of the population who have access to fluoridated water



Source: Water fluoridation information for health professionals, State of Queensland, Queensland Health 2005.

Percentages confirmed from personal communication with State/Territory offices in September 2007.

The compounds most commonly used for water fluoridation of public water supplies are sodium hexafluorosilicate (Na2SiF6), fluorosilicic acid (H2SiF6) and sodium fluoride (NaF).

3.2.2 OTHER FLUORIDE SUPPLEMENTATION

A range of topical agents and supplements designed to reduce dental decay contain fluoride, including toothpaste; dental varnishes, gels, rinses, tablets and drops. Fluoride concentrations in these products vary according to frequency of use and application.

Fluoride containing toothpastes typically contain 0.1% or 1000 ppm fluoride and are recommended for use by all age groups by the Australian Dental Association (ADA). For children under the age of six the ADA recommends only a 'pea' size amount of paste should be placed on the brush.

Fluoride solutions and gels for topical treatment generally contain much higher concentrations of fluoride than toothpaste (up to 24000 ppm). These products are not intended to be used regularly.

Fluoride supplements available as drops, chewable tablets and chewing gum tablets have not been explicitly included within the current review. However, these individual-level interventions may be used in areas where it is not feasible or not acceptable to fluoridate drinking water. The effectiveness of fluoride supplementation by these methods may be influenced by poor compliance, a factor which is less of an issue in interventions implemented at the population level, such as water fluoridation.