Optimal fluoride concentration in water

The appropriate concentration of fluoride for public water supplies is the concentration at which maximum caries reduction can be achieved while limiting dental fluorosis to acceptable levels of prevalence and severity. Water consumption directly affects the amount of fluoride ingested daily, and thus the recommended concentration of fluoride in public water supplies is higher in cooler climates, where it is likely that less water is consumed, and lower in the tropics, where larger volumes of water are consumed per person. Australia has a temperate climate for which concentrations ranging from 0.6 ppm in Darwin to 1.1 ppm in Hobart have been confirmed by the National Health and Medical Research Council (NHMRC) as safe and effective. Minor variations around these figures are quite acceptable; however, some loss of efficacy in preventing caries can be expected if levels fall to below 0.5 ppm.

Who benefits from fluoride?
The belief that only children benefit from fluoride is outdated. While fluoride incorporated into forming tooth enamel before eruption helps to prevent later decay, the presence of fluoride at the surfaces of teeth after eruption has been shown to be of equal importance (Fejerskov et al. 1981; Beltran & Burt 1988). Thus, the beneficial effect of fluoride is available to dentate individuals of all ages. This is fortunate because research is indicating that the incidence of dental caries can be high among adults, in particular older adults (Hand et al. 1988). Exposed root surfaces in older people are more likely to decay, and the risk may be even greater in those whose salivary flow has diminished. Research also indicates that fluoride may have benefits in reducing the incidence of secondary or recurrent caries activity (Kidd et al. 1992), which is thought to be responsible for approximately half of all fillings placed in adults. The use of fluoride to prevent dental caries is therefore beneficial to young children and adults alike, with even greater importance for people at higher risk of dental caries.
Two mechanisms have been proposed to explain the benefits of exposure to fluoride in water and in toothpaste are carried into adulthood. A meta-analysis of three studies of adults by Griffin et al. (2007) supports the finding that the benefits of exposure to fluoride in water and in toothpaste are carried into adulthood.

**Anticaries mechanisms of fluoride**

Two mechanisms have been proposed to explain the influence of fluoride on caries activity—the ‘pre-eruptive’ mechanism and the ‘post-eruptive’ mechanism.

**Pre-eruptive mechanism**

Fluoride is ingested and incorporated into the enamel during mineralisation of the developing tooth, favouring the crystallisation of larger and more regular fluorapatite crystals, which are less susceptible to acid dissolution than hydroxyapatite. Recent studies have confirmed the importance of pre-eruptive fluoride exposure (Singh et al. 2003). Fluoride is incorporated into the enamel before eruption (during early childhood), providing some protective benefit. This pre-eruptive exposure seems particularly important for the occlusal surfaces (Singh et al. 2004).

**Post-eruptive mechanism**

Fluoride also works through a post-eruptive mechanism where the maintenance of a low fluoride concentration at the tooth/plaque interface confers caries prevention benefits throughout life. Because it is consumed daily, drinking water is the most effective way to maintain exposure to fluoride throughout life (Fejerskov et al. 1981, Beltran & Burt 1988).

Post-eruptively, fluoride also affects plaque and saliva. Acid produced by acidogenic bacteria releases fluoride from the dental plaque, which is then taken up by demineralised enamel to form a more stable enamel structure (Rolla et al. 1990). Other mechanisms include:

- Inhibiting demineralisation by lowering the critical pH for dissolution of tooth enamel (van Dijk et al. 1979)
- Enhancing remineralisation by lowering the energy needed for reformation of apatite crystals or calcium fluoride (Margolis 1990)
- Inhibiting acid formation by micro-organisms involved in caries formation (Hamilton 1990)
- Interfering with the growth and metabolism of these same micro-organisms at higher fluoride concentrations (Hamilton 1990).

Fluoride prevents caries on both smooth surfaces and occlusal surfaces of teeth. Water fluoridation reduces caries by approximately 38% on approximal surfaces and 26% on occlusal surfaces; however, in the study of Australian Army recruits the reduction in smooth surface caries was not significant (Hopcraft et al. 2006).

The timing of the exposure to fluoride is also important, with exposure during crown completion being effective irrespective of exposure at maturation and post-eruption (Singh et al. 2007).

**Substitution of non-public water for fluoridated water**

The widespread use of non-fluoridated bottled water for drinking will dilute the effects of water fluoridation, as will the use of tank water for drinking and cooking. A study by Arnfield et al. (2004) found that caries in the deciduous dentition increased markedly with increasing use of non-fluoridated water. The results for the permanent dentition were less clear. Use of fluoridated public water in bottles should be encouraged, as should the use of bottled water containing fluoride where it is available.

**Importance of water fluoridation in relation to other fluoride vehicles**

The most widely used fluoride product is toothpaste. Over 95% of all toothpastes sold in Australia contain fluoride, and the habit of brushing teeth with a toothpaste at least daily is almost universal. Widely available yet less frequently used are fluoride mouthrinses and gels. These sources of fluoride vary in the extent to which they prevent caries in populations. This is largely because of differences in the proportion of the population using each form of fluoride and compliance of individuals with any special guidelines on use.

The original studies on water fluoridation estimated a 50–60% reduction in dental caries among US children. Studies of the effects of water fluoridation since the introduction and widespread use of fluoride toothpastes and, to a lesser extent, mouthrinses have found that the benefit of water fluoridation is additive to other forms of fluoride use. The effect contributed by water fluoridation is estimated to be a reduction in dental caries of between 20% and 40%.

In regard to water filters, those which use osmosis remove fluoride from the water and should be discouraged. However, carbon filters retain fluoride in the water and are the preferred filter for oral health.

**Recommendations for non-fluoridated areas**

For many years it was recommended that children living in non-fluoridated areas take fluoride supplements in the form of tablets, drops or chewable lozenges. However, evidence suggests that supplements increase the risk factor for dental fluorosis (Spencer et al. 2008, Pendrsey et al. 1989) because they can cause a spike in the fluoride concentration in the blood, which can cause damage to the forming enamel. Therefore the revised/current guidelines for use of fluorides in Australia, guideline number 12 (ARCPHO 2006), state that fluoride supplements in the form of drops or chewable/swallowable tablets should not be used. The current recommendation to use fluoride supplements to make fluoridated water (e.g. by adding 1 mg of fluoride to 1 litre of non-fluoridated water—see recommendation 5 below) is then used for drinking, alleviates this problem.

**Australian recommendations for water fluoridation**

In 2004 a workshop was held in Adelaide to develop some recommendations for fluoride use in Australia. Those relevant to water fluoridation are listed below.

1. Water fluoridation should be continued as it remains an effective, efficient, socially equitable and safe population approach to the prevention of caries in Australia.

2. Water fluoridation should be extended, with support from all levels of Government, to as many people as possible living in non-fluoridated areas of Australia.

3. The level of fluoride in the water supply should be within the range 0.6–1.1 mg/L, with variation within that range according to the mean maximum daily temperature.

4. So that people can choose to consume bottled or filtered waters containing fluoride, manufacturers should be encouraged to market bottled water containing approximately 1.0 mg/L fluoride and water filters that do not remove fluoride. An integral part of this guideline is that all bottled water and water filters should be labelled to indicate the concentration of fluoride in water consumed or resulting from the use of such products.