Artificial Water Fluoridation: Environmental and Human Health Effects

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ABSTRACT: Dental caries (i.e. infection of teeth enamel) is the most common chronic disease in the world. The benefits of fluoride for caries prevention have been substantiated by a variety of research studies over the past half a century. However, the initial approach for mass delivery of fluoride to teeth through artificial water fluoridation has been subjected to controversy over the past three decades due to potential adverse effects on the environment and human health. This review examined the evolution of water fluoridation, its positive impact on caries prevention, and studies on environmental and human health consequences of fluoridated water. Current consensus includes (1) artificial water fluoridation reduces dental caries by about 15%, (2) artificial water fluoridation is a major cause of fluorosis (3) while the impact of water fluoridation on the environment is negligible, solid waste in fluoridated water discharged into river systems with naturally low fluoride may impact adversely on some marine species such as salmon in North America; (4) it is difficult to justify water fluoridation on ethical grounds, especially given more efficient ways of fluoride delivery which pose less ethical problems. Greater efforts are required to improve preventive dental health practices globally, with efficient and safe fluoride delivery approaches implemented community-wide.

Keywords: Artificial water fluoridation, dental caries, human health effects, environmental health effects.

Introduction

Discovered by Henri Mossan in 1886, Fluorine (F) is a corrosive pale yellow gas which has an atomic number of 9, and atomic weight of 19. It is highly reactive, participating in reactions with virtually all organic and inorganic substances. Consequently, fluorine is usually found in soil and water as fluorides. Fluoride content of water systems varies widely, from 0.01mg/L - 50mg/L in most nations.

In industrial settings, fluorine and its compounds are used in producing uranium. Fluorochlorohydrocarbons are used in refrigeration applications. Fluorine is used to produce many chemicals, including several high-temperature plastics. The impact of fluorine on human teeth was recognised as early as 1909 in Colorado when two dental surgeons, Frederick McKay and Grant Black (1909), launched an investigation into the causes of mottled enamel ("Colorado brown stain") in dentistry. They found that the condition was more common among city residents who have not developed permanent teeth, and that children with mottled teeth had relatively low prevalence of dental caries.

In 1932, McKay trekked across Rocky Mountains to Oakley, Idaho to meet with

parents who had noticed peculiar brown stains on their children's teeth. The parents told McKay that the stains began appearing shortly after Oakley constructed a communal water pipeline to a warm spring five miles away. McKay analysed the water, but found nothing suspicious in it. Nonetheless, he advised town leaders to abandon the pipeline altogether and use another nearby spring as a water source. Within a few years, the younger children of Oakley were sprouting healthy secondary teeth without any mottling.

Further investigations showed that the mottling was strongly associated with high water fluoride levels. From 1931, Dr. Trendley Dean, head of the Dental Hygiene Unit at the National Institute of Health and his group began investigating the epidemiology of fluorosis. After 14 years of study, the investigators found that water levels of 1.0 part per million did not cause enamel fluorosis in most people. This study demonstrated a positive effect of water fluoridation – reduction of dental caries by up to 60% among almost 30,000 school children in Grand Rapids, Michigan (Cauley *et al*., 1995).

The United States' lead in instituting artificial water fluoridation was accepted by the World Health Organization (WHO) as an effective oral health intervention. At least 30 nations instituted artificial water fluoridation policies, with about 5% of the world's population, i.e. about 350 million people (including 200 million Americans) currently consuming artificially fluoridated water globally. The Malaysian government since 1972 had approved fluoridation of water as a primary caries prevention programme. In Australia, the artificial water fluoridation has covered the entire country (Childress *et al*., 2002).

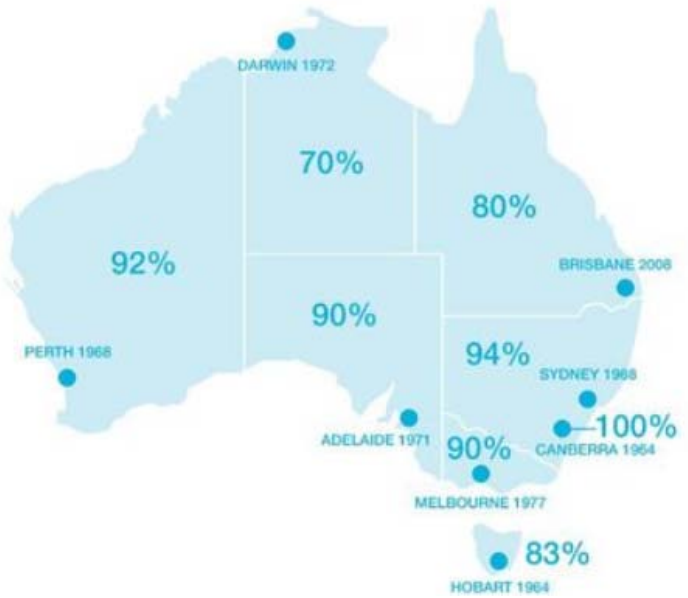

FIGURE 1: Water fluoridation coverage in Australia (Childress *et al*., 2002).

According to the World Oral Health Report 2003, community water fluoridation was endorsed as a safe and effective method of reducing dental decay (i.e. caries), a major global public health problem affecting 60–90% of school children and the vast majority of adults. The report concluded that water fluoridation reduces the prevalence of dental caries by about 15% (Foulkes and Anderson, 1994). The Centers for Disease Control of United States regarded water fluoridation as among the top 10 beneficial global health innovations of the 20th century (George, 2011).

Environmental health effects of water fluoridation

Though water fluoridation can reduce dental caries, a global debate has been ongoing over the past several decades on the environmental and health impacts of water fluoridation. In relation to the environment, artificial fluoridation proponents posit that at a level of 1 ppm fluoride in community water supplies, river fluoride concentrations theoretically would be raised by 0.001-0.002 mg/L, which might not easily measured by common instruments. Fluoride is abundant in water systems (e.g. sea water contains 0.8 – 1.3mg/L) and the quantities being added to drinking water are imperceptible and innocuous (Goldman, 2008; Government of Victoria, 2011; IARC, 1987).

Opponents of water fluoridation posit that only 2% of artificially fluoridated water is ingested while 98% re-enters the environment as wastewater. Studies have shown high concentrations of fluoride in such wastewater. For example, a study found that 0.38 mg/L of fluoride in sewage from areas with no artificial water fluoridation and 1.16-1.25 mg/L of fluoride in sewage in areas where water is fluoridated (McDonagh *et al*., 2000). Although dilution reduces concentration over distance, the amount of fluoride in effluent is either deposited in sediment locally or is carried to the estuary where it may persist for centuries, thus posing a major threat to aquatic life. It has been surmised that discharges of artificially fluoridated water into river systems (in addition to industrial fluoride discharge) contribute to the decline in salmon stocks in the United States and Canada (MMWR, 1999).

Human health impact of water fluoridation

Since the Grand Rapid's study in the 1940s, the positive impacts of fluoride on reducing the risk of dental caries have been well documented. Fluoride reduces dental caries through several mechanisms: (i) it prevents demineralisation and promotes remineralisation; (ii) it displaces the hydroxyl ion in hydroxyapatite crystals to form fluoro apatite crystals that are more resistant to the acids that promote tooth decay; (iii) when present in high amounts, fluoride in dental plaque inhibits bacterial activity, thereby reducing the production of the acid and polysaccharides that constitute the matrix of dental plaque (NCI, 2011). Water fluoridation is currently estimated to contribute about 15% to caries reduction risk.

Opponents of artificial water fluoridation assert that the modest contribution of fluoride to caries prevention pales in comparison to adverse health effects. First, dental fluorosis is a well-established adverse effect of fluoride among exposed children between 12 and 60 months of life. Fluorosis is principally of aesthetic concern, but this adverse impact may have serious psychological impact on affected children, which may persist to adult life, leading to social and employment discrimination (NIDCR,2011) (**FIGURE 2**).

FIGURE 2: Shades of dental fluorosis (Source: School of Dental Medicine, University of New York).

According to a systematic scientific review on water fluoridation carried out at York University, about 48% of people living in fluoridated areas were affected by dental fluorosis, of which about 15% was of moderate to severe variety (Osterman, 1990). Opponents of water fluoridation also assert that at least a dozen major health problems were caused by water fluoridation. Hypothyroidism (Peterson and Lennon, 2004) and osteoporotic hip fractures (Rodd and Davidson, 1997) are among the most widely studied. Note that there is currently no consensus that water fluoridation is a risk factor for these conditions.

More than 50 population-based studies looking at the potential link between water fluoride levels and cancer have been reported in medical literature. Most of these have not found a strong link to cancer. In its review published in 1987, the International Agency for Research on Cancer labelled fluorides as "non-classifiable as to their ability to cause cancer in humans." While they noted that the studies "have shown no consistent tendency for people living in areas with high concentrations of fluoride in the water to have higher cancer rates than those living in areas with low concentrations," they also noted that the evidence was inadequate to draw conclusions one way or the other. The evidence linking fluorides with cancer was not strongly established (Contor, 1997).

Discussion and Conclusion

In appraising the health and environmental impacts of water fluoridation, a dispassionate approach is required to provide rational and policy-relevant options. Three arguments need to be resolved – cost-benefit, equity and ethics. The cost-benefit argument entails determining if the primary benefit of artificial water fluoridation i.e. 15% reductions in dental caries incidence – exceeds the financial health and environmental costs.

The financial cost of water fluoridation is significant. In general, it costs between USD0.5 and USD12 per capita annually to artificially fluoridate drinking water. Given its currently modest contribution to dental caries prevention, it is questionable that the benefits from the money spent are worthwhile. The economic argument is a major reason why many North American cities are reconsidering of discontinuing water fluoridation practices (Siripant and Srisawasdi, 2011). Cost-benefit analyses should be context-specific, and consider alternative approaches to fluoride distribution, especially for vulnerable populations.

In developed nations, fluoridated toothpaste is widely available and is generally affordable. In contrast, the poors in developing nations are generally unable to afford fluoride toothpaste and lack access to fluoridated water (Susheela *et al.*, 2005; Topaloglu-Ak *et al*., 2009). Given the significant variations on fluoride levels in most developing nations, the relatively small contribution of water fluoridation to caries prevention, and the cost of artificial water fluoridation, developing sustainable approaches to delivering fluoride toothpaste to adults; which contributes 25% to reducing the risk of dental caries (Foulkes and Anderson,1994) and ultra-low fluoride toothpaste for children aged less than six years, as well as improved integrated dental care services might have a greater impact on reducing the incidence of dental caries, compared to reliance on artificial water fluoridation perse.

The role of artificial water fluoridation in reducing socio-economic disparities in dental caries prevalence is highly contested. While proponents cite equity justifications, opponents cite evidence showing no or even negative effect of water fluoridation on reducing caries prevalence gap between rich and poor cohorts. Recent publications from Australia indicate that 40 years of artificial water fluoridation has not reduced social economic status disparities in caries prevalence. This controversy gap needs to be addressed globally.

More research is required to further elucidate the positive and adverse health impacts of water fluoridation. It is acknowledged that such research will be fraught with confounding factors associated with fluoride dilution effect – i.e. fluoride is ingested in most fluid products such as (e.g. carbonated drinks) and absorbed from fluoridated toothpaste by people living in non-artificial water fluoridated areas, making it difficult to isolate the effect of water fluoridation. Nevertheless, experimental studies may elucidate fluoride-calcium and fluoride-iodine interactions to guide population health studies on water fluoridation.

It is important to examine the ethical dimensions of artificial water fluoridation, given the fact that fluoride is essentially a drug used to prevent and treat infection of teeth enamel. Is it ethical to mass medicate entire populations, even if the objective of enhancing dental health is beneficial?

Childress *et al.* (in Wallis *et al*., 1996) developed a five-faceted approach to resolving such ethical controversies in public health, with considerations for the following: (1) *Effectiveness*: Is artificial water fluoridation effective in protecting populations from dental caries? (2) *Proportionality*: Are the positive effects of fluoride on prevention of dental caries proportional to its ethical complications, such as infringement on autonomy? (3) *Necessity:* Is artificial water fluoridation a necessary vehicle for communitywide fluoride delivery in the 21st century, or can this objective be achieved using alternative vehicles such toothpaste, milk and salt? (4) *Least infringement:* Does artificial water fluoridation represent the best approach to provide dental health benefits at the least ethical cost in relation to harm that may occur to those already having excess fluoride (e.g. from black tea consumption), children aged 1 to six years who are at high risk of fluorosis, and those with chronic kidney disease who may have impaired ability to excrete ingested fluoride; (5) *Public justification*: Have public officials in communities where artificial water fluoridation is being practiced or envisaged provided adequate information to consumers to justify artificial water fluoridation?

The approaches adopted by Asian nations to address some several of these ethics yardsticks in relation to fluoride delivery are illustrated in **TABLE 1**:

TABLE 1: Fluoridation initiatives in Asian nations (WHA, 2007)

	Community Administration			Professional Administration		Self-administration	
Countries	Water F	Salt F	Milk F	F gel	F varnish	F toothpaste	F mouthrinse
Bhutan				x		x	
Brunei	x				x	x	
Cambodia					x	x	x
China				x	x	x	
Hong Kong	x			x	x	x	
India					x	x	
Indonesia						x	
Japan				x		x	x
Korea	x			x	x	x	x
Laos		x				x	
Malaysia	x			x	x	x	x
Mongolia					x	x	
Myanmar						x	
Nepal						x	
Pakistan						x	
Philippines						x	
Singapore	x			x	x	x	
Sri Lanka					x	x	
Thailand			x	x	x	x	
Vietnam	x	x				x	x

Resolution 4 of the 2007 World Health Assembly resolution 60.17 urges member states to; "consider the development and implementation of fluoridation programmes" (WHO, 2002). This statement is a reflection of current realities that artificial water fluoridation is not necessarily the most economical, effective or affordable way to deliver fluoride to teeth in the 21st century. The statement contrasts with the ringing endorsement provided by the World Health organization for artificial water fluoridation as recently as 1994 (WHO, 1994).

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