THE FLUORIDATION CONTROVERSY

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ABSTRACT

Fluoridation of drinking water supply has been hailed as one of the top ten public health achievements of the twentieth century. At an optimal level of 1.0 ppm, it is considered the most cost-effective, safe and efficient strategy of reducing dental decay in all social strata of the community. The anticariogenic mechanism of fluoride does not differentiate between the benefits of topical fluoride or ingested fluoride.

Fluoride toxicity leads to dental and skeletal fluorosis. The irreversible, debilitating effects of fluoride toxicity, the transient effects with the continuous need of exposure to fluoride to maintain caries resistance and the fact that benefits of topical use of fluoride are as good as ingested fluoride are some of the leading contributing factors that have sparked the fluoridation controversy. Anti-fluoride lobby claims range from declaring fluoride as a slow, cumulative poison to fluoridation of community drinking water as a violation of human rights.

Adopting the precautionary principle categorizes fluoridation of community drinking water supply as an unreasonable risk. It is recommended to limit fluoride to dentifrices and mouthwashes

Key words: Fluoridation, fluorosis, anti-fluoride claims

FLUORIDATION

Fluoridation of drinking water supply has been hailed as one of the top ten public health achievements of the twentieth century. Fluoride is a mineral that occurs naturally in most water supplies and is of geological origin. Waters with high levels of fluoride content are mostly found at the foot of high mountains and in areas where the sea has made geological deposits. Known fluoride belts on land include: one that stretches from Syria through Jordan, Egypt, Libya, Algeria, Sudan and Kenya, and another that stretches from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. There are similar belts in the Americas and Japan.

Fluoridation can be defined as the upward or downward adjustment of the level of fluoride content in drinking water to an optimal level just enough to prevent caries but not to cause fluorosis. Optimum levels of fluoridation vary according to the climate and is universally calculated by applying the equation of Galagan and Vermillion, which permits the calculation of water intake as a function of temperature. Levels as low as 0.5 ppm are advised in warm climates because more water is consumed and levels as high as 1.5 ppm is considered optimum in cold climate where less water is consumed. However, on an average, the optimum fluoride level in drinking water is calibrated at 1.0 ppm (0.7-1.2 ppm)

According to the US Center of Disease Control and Prevention (CDC), fluoridation of community drinking water is a safe, cost-effective and efficient strategy of reducing dental decay among Americans of all ages and from all social strata. It forms the foundation for sound community caries-prevention programs. One of the health objectives contained in Healthy People 2010 calls for at least seventy five per cent of the population served by community water systems in the United States to have water fluoride levels of 0.7 to 1.2 ppm.

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States, to receive optimal levels of fluoride. The current level is sixty seven per cent. To reach this goal, approximately 14.3 million more Americans must gain access to fluoridated water through public water systems.5

MECHANISM OF ACTION OF FLUORIDE

Currently there are three major theories to explain the anticariogenic mechanism of fluoride. The ‘Increased Resistance of Enamel Theory’ suggests that fluoride, whether ingested or topically applied gets incorporated into the enamel crystalline structure in form of fluorapatite crystals which confer the characteristic of reduced solubility of apatite, hence increased resistance to the acidogenic activities of cariogenic bacteria. This theory however implies that once caries resistance has been obtained, it will last a lifetime but this is not the case. It has been observed that once fluoride exposure is stopped, the resistance to caries reduces, thereby increasing the risk of caries.

The second theory is the ‘Theory of Remineralization-Demineralization Balance’ that indicates the ionic fluorides present in saliva and aqueous solutions in the oral cavity, release fluorine ions that shift the equilibrium balance towards remineralization rather than towards demineralization. The process of caries is characterized by alternate phases of demineralization followed by remineralization, which are antithesis of each other. When the phase of demineralization exceeds in duration and frequency, the caries progress is rapid. Therefore, the remineralization phase is by far the most important factor in caries prevention.

The third theory is the ‘The Theory of Fluoride and Plaque Mechanism’ that indicates the fluoride from the saliva, diet and topical applications accumulates in the dental plaque and inhibits the carbohydrate metabolism of acidogenic plaque micro flora. Fluoride enters the microorganisms against a concentration gradient and accumulates intracellularly. Intracellular fluids have an alkaline medium that cause ionic dissociation of Hydrogen Fluoride (HF) into H+ and F+ ions. Ionic Fluoride induces enzyme inhibition, leading to a slower rate of acid production. It also increases cellular permeability thereby facilitating rapid diffusion of F+ out of the cariogenic bacterium back into the plaque matrix where it combine again to for HF hence re-enter back into the cycle.6

The three theories are not mutually exclusive but show an overlap. They cannot separate or differentiate the independent benefits from the different delivery systems of fluoride. Instead, studies have shown that the maximal benefit is achieved when simultaneous use of multiple delivery systems is adopted because this strategy has additive effects.7

HISTORY OF FLUORIDATION IN THE UNITED STATES

The role of fluoride in the prevention of dental caries was well under discussion as early as the nineteenth century in Europe.8 At the beginning of the twentieth century, in 1909, Dr Fredrick Mc Kay surveyed nearly three thousand children from Pikes Peak region of Colorado and found 87.5% of them suffering from some degree of enamel staining or mottling which he referred to as the ‘Colorado Stain’. An interesting find was that children with stained teeth also had fewer cavities than other children.9 These findings led to intensive research and in 1931; the cause of the Colorado stain was concluded to be the high concentration of fluoride ions in the region’s drinking water (2.0-13.7 ppm). Pike’s Peak rock formations contain the mineral ‘Cryolite’, one of whose constituent is fluoride. As the rain and snow fell, the resulting runoff water picked up the fluoride as it migrated to the community water supply. The ‘Colorado stain’ was replaced with the term ‘dental fluorosis’.10

Later, in 1934, seven thousand children from the states of Colorado, Ohio, Illinois and Indiana participated in a classic epidemiology study that determined the optimal level of fluoride to be 1.00 ppm as just enough to prevent caries and not cause fluorosis.11 Over the next couple of years several studies were carried out, all of which reaffirmed the association of optimal levels of fluoride with reduced dental decay.12,13 Results from these array of studies led to the formulation of an oral health program intervention in 1945, when Grand Rapids, Michigan became the first community to have fluoridated drinking water supply and became one of the four classic community wide study cases for effectiveness of community water fluoridation.5 The other three case studies were Newburgh, New York (1945), Brantford, Ontario (1945) and Evanston, Illinois (1947). The astounding success of these four case studies firmly established community
drinking water fluoridation as an effective, practical and safe public health measure to prevent dental decay. So by 1950, American Dental Association and United States Public Health Service unreservedly endorsed fluoridation of drinking water.\textsuperscript{14}

Today, of the fifty largest cities in the United States, forty two have community water fluoridation. Two cities have natural fluoride levels that are in optimal range. Fluoridation reaches 67 per cent of the population on public water supplies—more than one hundred and seventy million people. The annual cost of fluoridation is approximately $0.50 in communities of $\geq 20,000$ to approximately $3.00$ per person in communities’ $\leq 5,000$ for all but the smallest water systems. However, today, a hundred million Americans still do not have access to fluoridated water.\textsuperscript{15}

Community Water System fluoridation programs in the United States use three main additives: fluorosilicic acid (FSA), sodium fluoride and sodium fluorosilicate. FSA is the main additive. FSA is produced as a co-product in the manufacture of phosphate fertilizer. This source is used because of the favorable low cost and high purity of FSA obtained. FSA is further processed to derive dry fluoride additives, including sodium fluorosilicate or sodium fluoride. FSA that is sold to the water industry is occasionally processed further by activated carbon adsorption to reduce color, much of which is a result of iodine.\textsuperscript{5} Most water treatment additives are toxic to humans in their concentrated form. To ensure the public’s safety, all these additives must meet strict quality standards, hence are subject to a system of standards, testing, and certificates by the American Water Works Association and the National Sanitation Foundation/American National Standards Institute.\textsuperscript{5} The U.S. Environmental Protection Agency (EPA) sets the standards of drinking water in accordance with the Safe Drinking Water Act.

Monitoring of the quality of community water fluoridation in the US is made possible by a tool called ‘Water Fluoridation Reporting System’ (WFRS) which provides each state with a comprehensive, web-based system to track water fluoridation program information all over the United States. Each water system in the WFRS database includes information including population served, fluoridation status (e.g., not adjusted, adjusted, natural, variable, or consecutive), natural fluoride concentrations, counties and communities served, system type, and which systems buy or sell water to other systems.\textsuperscript{5} Additional information includes results from the ‘Water Fluoride Laboratory Proficiency Testing Program’ that shows the average fluoride concentrations, results of daily testing, and laboratory split sample results and the dates of facility inspections for each water treatment facility. Access to WFRS is available, on permission, to employees of State Oral Health and Drinking Water Programs. The general public can avail this information from their respective State Oral Health Program or from their local water utility provider.

**FLUORIDATION AND PAKISTAN**

Based on the mean annual temperature in Pakistan, the optimum level of fluoride in drinking water is calculated at 0.7 ppm with a range of 0.6-0.8 ppm. Pakistan does not have the technical or financial resources to implement a community based water fluoridation system. In fact, only twenty per cent of the population gets piped water supply while the rest depend on natural sources.\textsuperscript{4}

A study showed that sixty four percent of the drinking water sources had fluoride levels of less than 0.3 ppm, twenty percent had a range of 0.3-0.7 ppm, six percent had 0.7-1.0 ppm and another six percent had 1.0-2.0 ppm. The remaining had levels of greater than 2.0 ppm. High fluoride levels were found to follow a distinct geographic pattern that correlates with the Salt range, a high mineral content geographical belt passing across the Punjab province.\textsuperscript{4}

**FLUORIDE TOXICITY**

Excess fluoride intake is undesirable. The most common presentation is ‘Enamel Fluorosis’, an irreversible condition which manifests as a mottled, brown stain appearance of the dental enamel. It is caused by excessive amounts of fluoride during critical stage of tooth development (from birth to five years) that results in disruption in enamel development manifesting in the characteristic mottled/speckled appearance.\textsuperscript{16} However, after tooth formation is complete, then fluorosis cannot develop even if excess fluoride is ingested, therefore older children and adults are not at risk of fluorosis.\textsuperscript{17}
Ninety four per cent of all fluorosis cases are very mild to mild which, according to the "Fluorosis Classification of H. Dean -1942", can be defined as white opaque spots found in about a quarter to half of the total tooth surface. In very mild to mild cases, the benefit is that the Fluorotic enamel is more caries resistant than normal. However in the remaining six percent of the cases of moderate and advanced fluorosis, the cosmetic appearance is large brown mottled stains and pits in more than three-quarter of the tooth surface. Such teeth have high caries susceptibility since the enamel is structurally weak and brittle, hence are prone to erosion and breakage, especially when drilled and filled. Fluorotic lesions are not just confined to enamel, but can be seen by microscope in dentin as well.

Advance dental fluorosis is one of the indications that fluoride intake has reached toxic levels. Fluoride toxicity can also manifest in a condition called 'skeletal fluorosis' which causes increased metabolic turnover of the bone, impaired bone collagen synthesis and increased avidity for calcium. Such fluoride toxicity takes place due to chronic high exposure to systemic fluoride where fluoride accumulates in the bone progressively over many years. Skeletal fluorosis impacts millions of people in India, China and Africa and is thought to be related to the geographical fluoride belts found in Africa and across Asia into China. Some of the early symptoms of skeletal fluorosis mimic the symptoms of arthritis. Full blown skeletal fluorosis is characterized by immobilization of joints of the axial skeleton and of the major joints of the extremities. A combination of osteosclerosis, osteomalacia and osteoporosis of varying degrees as well as exostosis formation characterizes the bone lesions. In some cases secondary hyperparathyroidism is observed. Alterations in hormones concerned with bone mineral metabolism are seen in fluorosis.

The kidney is the primary organ of excretion for fluorides. Hence, age, sex, calcium intake in the diet, dose and duration of fluoride intake and renal efficiency in fluoride handling are the factors which influence the outcome. Elevated urinary fluoride and increased bone fluoride content are pathological indicators of fluoride toxicity. Serum parameters rarely help in the diagnosis, so bone density measurement is a tool for early diagnosis No effective therapeutic agent is known to cure fluorosis.

THE FLUORIDATION CONTROVERSY

The controversy over fluoridation of drinking water supply began as early as the nineteen sixties, approximately a decade after the American Public Health Service officially launched the National Fluoridation Program. The controversy has gained momentum over the years as more research is released to support the stance of the anti-fluoride lobby. Several factors have spurred the present day controversy. The irreversible, debilitating effects of fluoride toxicity, the transient effects and hence the continuous need of exposure to fluoride to maintain caries resistance and the fact that benefits of topical use of fluoride are as good as ingested fluoride are some of the leading contributing factors.

Anti-fluoride claims

Anti-fluoride lobbyists start with the fact that fluoride is not an essential nutrient and no disease has ever been linked to a fluoride deficiency. In fact fluoride is claimed to be a cumulative poison and biologically very active even at low concentrations because it interferes with hydrogen bonding and inhibits numerous enzymes. Only fifty percent of the daily ingested fluoride is excreted through the kidneys, so individuals with compromised kidneys are at risk of developing fluorosis even at normal recommended limit of 0.7 to 1.2 ppm.
Fluoride has been shown to be mutagenic by causing chromosome damage and interference with the enzymes involved with DNA repair in a variety of cell and tissue studies carried out in animals. Recent studies have also found a correlation between fluoride exposure and chromosome damage in humans. The only government-sanctioned animal study to investigate if fluoride causes cancer, in 1990 found a dose-dependent increase in cancer in the target organ (bone) of the fluoride-treated, male rats. This led to a 14-year research carried out by Harvard University that showed a significant link between fluoridation and a rare form of bone cancer called osteo-sarcoma in young boys, consistent with the results of the 1990 animal study.

Fluoride as a neurotoxin has been proven in several animal studies. A 2006 NRC (National Research Council) report stated that it is apparent that fluorides have the ability to interfere with the functions of the brain and the body by direct and indirect means. This finding was confirmed by a study where groups of children exposed to 8 ppm fluoride in water were found to have lower average IQ's, less children attaining high IQ, and more children affected by low IQ. While 8 ppm is much higher than the fluoride level added to water in fluoridation programs (0.7-1.2 ppm), these results are in congruence with previous studies from China that indicate that fluoride may affect IQ at lower levels.

If fluoride is added to water which contains aluminum, than aluminum fluoride complexes will form. Aluminum-fluoride complexes have the potential to interfere with many hormonal and some neuro-chemical signals. Aluminum fluoride was recently nominated by the EPA and National Institute of Environmental Health Sciences as a “high health research priority” due to its “known neurotoxicity”.

Dental fluorosis is not only a cosmetic defect. Its psychological impact on the child has been established by the US National Institute of Mental Health (NIMH). A study found that children with severe dental fluorosis are more likely to be perceived by their peers as less intelligent, less attractive, less social, less happy, less careful, less hygienic, and less reliable – characteristics which could have major effects on a child's self-esteem.

The US Center of Disease Control and Prevention declared that in the second half of the twentieth century, the steep decline dental decay in the United States can be attributed to fluoridation. However anti-fluoride lobbyists show that a similar decline in dental decay has been observed worldwide in countries that do not fluoridate their drinking water supplies. To overcome selection bias, the criteria of the countries selected for this comparison study was tri-pronged; countries with a mean annual per capita income of US$10,000 or more in the year 2000; a population in the year 2000 of greater than 3 million, and finally those countries that had WHO caries data available. The most common explanation for the world wide declining trend was the wide distribution of fluoridated toothpastes but serious research later attributed, at best, 40-50% of the caries reduction to fluoride products.

Once fluoride is put in the water it is impossible to control the dose each individual receives. This is because some people e.g. manual laborers, athletes, diabetics, and peoples with kidney disease drink more water than others. Additionally, the average person receives fluoride from sources other than the water supply such as fluoridated oral hygiene products, food and beverages processed with fluoridated water mechanically de-boned meat, and teas.

Some individuals appear to be highly sensitive to fluoride as shown by case studies and double blind studies. In one study, which lasted 13 years, the results showed that about one per cent of patients given 1.0 mg of fluoride each day developed negative reactions. According to the Agency for Toxic Substances and Disease Registry (ATSDR 1993), certain subsets of the population may be particularly vulnerable to fluoride’s toxic effects. These include: the elderly, the diabetics and people with poor kidney function. Also vulnerable are those who suffer from malnutrition e.g. calcium, magnesium, vitamin C, vitamin D and iodine deficiencies and protein poor diets. Those most likely to suffer from poor nutrition are the poor, who are precisely the people being targeted by new fluoridation programs. While being at a heightened risk, poor families are less able to afford avoidance measures e.g. bottled water or fluoride removal equipment.
Fluoridation of community drinking water is considered unethical because individuals are not being asked for their informed consent prior to medication. It is standard practice to obtain consent for all medication, and this is one of the key reasons why most of western Europe has ruled against fluoridation. It is a violation of human rights; a direct violation of the Nuremberg code that states that research or even routine medical procedures must be done with the voluntary cooperation of the subjects who must be fully informed of the risks or benefits of the procedure in which they are involved.50

Fluoridated drinking water is also used for consumption by animals which can have a detrimental effect. An example is seen in a case report of arthritis stiffness in horses, who also exhibited dental fluorosis. Research indicated ‘chronic fluoride intoxication’ as the causative factor.51

Studies have shown an association between the use of FSA and its sodium salt to fluoridate water and an increased uptake of lead into children’s blood. Lead is acknowledged as a neurotoxin that damages the child’s developing brain and lead toxicity is unaddressed especially in developing countries. Sodium fluoride is an extremely toxic substance — just 200 mg of fluoride ion is enough to kill a young child, and just 3-5 grams (e.g. a teaspoon) is enough to kill an adult.52

The US Food and Drug Administration (FDA) has never approved of any fluoride product designed for ingestion as safe or effective is a popular claim by the anti-fluoride lobby but according to the EPA-FDA Memorandum of Agreement, the FDA’s regulatory purview is limited to the safety and efficacy of food, drugs, or cosmetic-related products, as well as bottled water which is marketed as a consumer beverage. Thus if bottled water has fluoride additives and is approved by FDA, then this comes under the category of fluoride product meant for ingestion.5

The ADA recommends that water with added fluoride, bottled or otherwise, should not be used to mix

<table>
<thead>
<tr>
<th>Country</th>
<th>DMFT</th>
<th>Year</th>
<th>Fluoridation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.8</td>
<td>1998</td>
<td>More than 50% fluoridated water</td>
</tr>
<tr>
<td>Zurich, Switzerland</td>
<td>0.84</td>
<td>1998</td>
<td>Un-fluoridated water; fluoridated salt</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.9</td>
<td>1992-3</td>
<td>No water fluoridation or salt fluoridation</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.9</td>
<td>1999</td>
<td>No water fluoridation or salt fluoridation</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.9</td>
<td>2001</td>
<td>No water fluoridation or salt fluoridation</td>
</tr>
<tr>
<td>UK</td>
<td>0.9</td>
<td>1996-7</td>
<td>11% of water supplies are fluoridated</td>
</tr>
<tr>
<td>Ireland</td>
<td>1.1</td>
<td>1997</td>
<td>More than 50% of water is fluoridated</td>
</tr>
<tr>
<td>Finland</td>
<td>1.1</td>
<td>1997</td>
<td>No water fluoridation or salt fluoridation</td>
</tr>
<tr>
<td>Germany</td>
<td>1.2</td>
<td>2000</td>
<td>No water fluoridation; salt fluoridation common</td>
</tr>
<tr>
<td>US</td>
<td>1.4</td>
<td>1988-91</td>
<td>More than 50% of water is fluoridated</td>
</tr>
<tr>
<td>Norway</td>
<td>1.5</td>
<td>1998</td>
<td>No water fluoridation or salt fluoridation</td>
</tr>
<tr>
<td>Iceland</td>
<td>1.5</td>
<td>1996</td>
<td>No water fluoridation or salt fluoridation</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1.5</td>
<td>1993</td>
<td>More than 50% of water is fluoridated</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.6</td>
<td>1998</td>
<td>No water fluoridation; salt fluoridation common</td>
</tr>
<tr>
<td>Austria</td>
<td>1.7</td>
<td>1997</td>
<td>No water fluoridation; salt fluoridation common</td>
</tr>
<tr>
<td>France</td>
<td>1.9</td>
<td>1998</td>
<td>No water fluoridation; salt fluoridation common</td>
</tr>
</tbody>
</table>

concentrated formula or foods intended for babies age 1 and younger to prevent tooth damage. Fluoridated bottled water comes with special instruction for infant consumption. The ADA stance is in congruence with the anti-fluoride lobby who report that the level of fluoride put into water (1 ppm) is up to nearly fifty times higher than normally found in mothers’ milk (0.019 +/- 0.004 ppm). Therefore there are no benefits, only risks, for infants ingesting this heightened level of fluoride at such an early age.

CONCLUSION

Since topical benefits of fluoride are as good as systemic but the risks are maximal on ingestion, the ideal recommendation would be to limit fluoride to dentifrices and mouthwashes. Adopting the Precautionary principle categorizes fluoridation of community drinking water supply as an unreasonable risk. On the international front, most of the west European countries have rejected water fluoridation including Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Italy, Luxembourg, Netherlands, Norway, Sweden, and Switzerland. The only three western European countries which still practice water fluoridation are Ireland (100%), Spain (10%), and the United Kingdom (11%). The WHO collected DMFT (Decayed, Missing & Filled teeth) status for 12-yr-olds from developed countries and found no significant association of DMFT index with fluoridation. (Table 1)

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