Fluoride in water: An overview

Throughout many parts of the world, high concentrations of fluoride occurring naturally in groundwater and coal have caused widespread fluorosis - a serious bone disease - among local populations. We purposely fluoridate a range of everyday products, notably toothpaste and drinking water, because for decades we have believed that fluoride in small doses has no adverse effects on health to offset its proven benefits in preventing dental decay. But more and more scientists are now seriously questioning the benefits of fluoride, even in small amounts. This paper gives a brief introduction to fluoride issues, particularly as they relate to the quality of drinking water.

Basic facts about fluoride

Fluoride exists fairly abundantly in the earth's crust and can enter groundwater by natural processes; the soil at the foot of mountains is particularly likely to be high in fluoride from the weathering and leaching of bedrock with a high fluoride content.

According to 1984 guidelines published by the World Health Organization (WHO)[1], fluoride is an effective agent for preventing dental caries if taken in 'optimal' amounts. But a single 'optimal' level for daily intake cannot be agreed because the nutritional status of individuals, which varies greatly, influences the rate at which fluoride is absorbed by the body. A diet poor in calcium, for example, increases the body's retention of fluoride.

Water is a major source of fluoride intake. The 1984 WHO guidelines suggested that in areas with a warm climate, the optimal fluoride concentration in drinking water should remain below 1 mg/litre (1ppm or part per million), while in cooler climates it could go up to 1.2 mg/litre. The differentiation derives from the fact that we perspire more in hot weather and consequently drink more water. The guideline value (permissible upper limit) for fluoride in drinking water was set at 1.5 mg/litre, considered a threshold where the benefit of resistance to tooth decay did not yet shade into a significant risk of dental fluorosis. (The WHO guideline value for fluoride in water is not universal: India, for example, lowered its permissible upper limit from 1.5 ppm to 1.0 ppm in 1998)

In many countries, fluoride is purposely added to the water supply, toothpaste and sometimes other products to promote dental health. It should be noted that fluoride is also found in some foodstuffs and in the air (mostly from production of phosphate fertilizers or burning of fluoride-containing fuels), so the amount of fluoride people actually ingest may be higher than assumed.

It has long been known that excessive fluoride intake carries serious toxic effects. But scientists are now debating whether fluoride confers any benefit at all.

Fluoride: good or bad for health?

Fluoride was first used to fight dental cavities in the 1940s, its effectiveness defended on two grounds:

- *Fluoride inhibits enzymes that breed acid-producing oral bacteria whose acid eats away tooth enamel.* This observation is valid, but some scientists now believe that the harmful impact of fluoride on other useful enzymes far outweighs the beneficial effect on caries prevention.

- *Fluoride ions bind with calcium ions, strengthening tooth enamel as it forms in children*. Many researchers now consider this more of an assumption than fact, because of conflicting evidence from studies in India and several other countries over the past 10 to 15 years. Nevertheless, agreement is universal that excessive fluoride intake leads to loss of calcium from the tooth matrix, aggravating cavity formation throughout life rather than remedying it, and so causing dental fluorosis. Severe, chronic and cumulative overexposure can cause the incurable crippling of skeletal fluorosis.

Symptoms of fluorosis

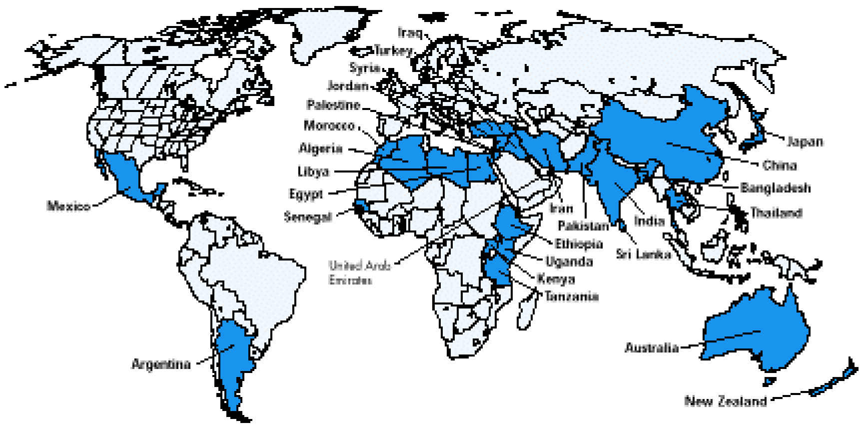
Dental fluorosis, which is characterized by discoloured, blackened, mottled or chalky-white teeth, is a clear indication of overexposure to fluoride during childhood when the teeth were developing. These effects are not apparent if the teeth were already fully grown prior to the fluoride overexposure; therefore, the fact that an adult may show no signs of dental fluorosis does not necessarily mean that his or her fluoride intake is within the safety limit.

Chronic intake of excessive fluoride can lead to the severe and permanent bone and joint deformations of skeletal fluorosis. Early symptoms include sporadic pain and stiffness of joints: headache, stomach-ache and muscle weakness can also be warning signs. The next stage is osteosclerosis (hardening and calcifying of the bones), and finally the spine, major joints, muscles and nervous system are damaged.

Whether dental or skeletal, fluorosis is irreversible and no treatment exists. The only remedy is prevention, by keeping fluoride intake within safe limits.

Fluorosis worldwide

The latest information shows that fluorosis is endemic in at least 25 countries across the globe (see map). The total number of people affected is not known, but a conservative estimate would number in the tens of millions. In 1993, 15 of India's 32 states were identified as endemic for fluorosis[2]. In Mexico, 5 million people (about 6% of the population) are affected by fluoride in groundwater[3]. Fluorosis is prevalent in some parts of central and western China, and caused not only by drinking fluoride in groundwater but also by breathing airborne fluoride released from the burning of fluoride-laden coal[4]. Worldwide, such instances of industrial fluorosis are on the rise.



Countries with endemic fluorosis due to excess fluoride in drinking water

Some governments are not yet fully aware of the fluoride problem or convinced of its adverse impact on their populations. Efforts are therefore needed to support more research on the subject and promote systematic policy responses by governments.

Fluoride in water
Since some fluoride compounds in the earth's upper crust are soluble in water, fluoride is found in both surface waters and groundwater. In surface freshwater, however, fluoride concentrations are usually low - 0.01 ppm to 0.3 ppm.

In groundwater, the natural concentration of fluoride depends on the geological, chemical and physical characteristics of the aquifer, the porosity and acidity of the soil and rocks, the temperature, the action of other chemical elements, and the depth of wells. Because of the large number of variables, the fluoride concentrations in groundwater can range from well under 1 ppm to more than 35 ppm. In Kenya and South Africa, the levels can exceed 25 ppm[5]. In India, concentrations up to 38.5 ppm have been reported[6].

Preventing fluoride poisoning

Fluoride poisoning can be prevented or minimized by using alternative water sources, by removing excessive fluoride from drinking water, and by improving the nutritional status of populations at risk.

Alternative water sources
These include surface water, rainwater, and low-fluoride groundwater.

Surface water. Particular caution is required when opting for surface water, since it is often heavily contaminated with biological and chemical pollutants. Surface water should not be used for drinking without treatment and disinfection. Many water treatment technologies are available, but the most effective are usually too expensive and complex for application in poor communities. Simple and low-cost technologies, such as sand filtration, ultraviolet water disinfection or chlorine water disinfection, are adequate in some but not all cases. Community capacity is an essential factor in ensuring successful utilization of these technologies. Water chlorination at household level is widely used only in emergencies.

Rainwater. Rainwater is usually a much cleaner water source and may provide a low-cost simple solution. The problem, however, is limited storage capacity in communities or households. Large storage reservoirs are needed because annual rainfall is extremely uneven in tropical and subtropical regions. Such reservoirs are expensive to build and require large amounts of space.

Low-fluoride groundwater. Fluoride content can vary greatly in wells in the same area, depending on the geological structure of the aquifer and the depth at which water is drawn. Deepening tubewells or sinking new wells in another site may solve the problem. The fact that fluoride is unevenly distributed in groundwater, both vertically and horizontally, means that every well has to be tested individually for fluoride in areas endemic for fluorosis: extrapolating sample tubewell tests to a larger area does not provide an accurate picture.

Defluoridation of water
There are basically two approaches for treating water supplies to remove fluoride: flocculation and adsorption.

- ***Flocculation.*** The Nalgonda technique (named after the village in India where the method was pioneered) employs this principle. Alum (hydrate aluminium salts) - a coagulant commonly used for water treatment - is used to flocculate fluoride ions in the water. Since the process is best carried out under alkaline conditions, lime is added; bleaching powder can also be added to disinfect the water. After a thorough stirring, the chemical elements coagulate into flocs that are heavier than water and settle to the bottom of the container. The operation can be carried out on a large or small scale, and the technique is suitable for both community or household use. One household version uses a pair of 20-litre buckets, with a settling time of one hour and not more than two hours: after coagulation and settling are complete, the treated water is withdrawn through a tap 5 cm above the bottom of the first bucket, safely above the sludge level, and stored for the day' s drinking in the second bucket.

- ***Adsorption.*** The other approach is to filter water down through a column packed with a strong adsorbent, such as activated alumina (Al_2O_3), activated charcoal, or ion exchange resins. This method, too, is suitable for both community and household use. When the adsorbent becomes saturated with fluoride ions, the filter material has to be backwashed with a mild acid or alkali solution to clean and regenerate it. The effluent from backwashing is rich in accumulated fluoride and must therefore be disposed of carefully to avoid recontaminating nearby groundwater.

Both the community and household defluoridation systems have pros and cons. Defluoridation equipment connected to a community handpump is theoretically cheaper per capita than a household unit because of economies of scale; but ensuring proper maintenance of a commonly owned facility is often problematic, so good community organization is necessary. The household units are more convenient for filtering the small amounts of water intended for drinking only, and people usually take better care of them; but an extensive and efficient service system is required to ensure that the filters are replaced or regenerated at the right time. Technology is only part of the issue: local capacity building, including entrepreneurial capabilities, can be a far more critical and difficult task.

Better nutrition
Clinical data indicate that adequate calcium intake is clearly associated with a reduced risk of dental fluorosis. Vitamin C may also safeguard against the risk. In consequence, measures to improve the nutritional status of an affected population - particularly children - appear to be an effective supplement to the technical solutions discussed above.

Defluoridation and UNICEF

UNICEF has worked closely with the Government and other partners in defluoridation programmes in India, where excessive fluoride has been known for many years to exist in much of the nation' s groundwater. In the 1980s, UNICEF supported the Government' s Technology Mission in the effort to identify and address the fluoride problem: the Government subsequently launched a massive programme, still under way, to provide fluoride-safe water in all the areas affected.

Over the past five years, UNICEF' s focus in the India programme has been on strengthening the systems for monitoring water quality, facilitating water treatment by households, and advocating alternative water supplies when necessary. Education - both of households and communities - is key to the strategy. A number of demonstration projects have been initiated in fluorosis-affected areas, with the emphasis currently on introducing household defluoridation. UNICEF has also sponsored research and development on the use of activated alumina for removal of fluoride from water.

Since fluoride must now be considered an issue of worldwide importance, the years of experience in India should help UNICEF and its partners provide four types of assistance towards an eventual solution:

- Promoting a better understanding of the problem and its impact on children;
- Raising the awareness of relevant governments and the public on the fluoride issue in particular and the importance in general of monitoring water quality;
- Demonstrating, through pilot projects, the efficacy of low-cost fluoride removal technologies;
- Strengthening community and government capacity for fluorosis prevention, including a credible system for risk assessment that comprises both water quality monitoring and health monitoring.

Notes:

1. 'Fluorine and fluorides', Environmental Health Criteria 36, IPCS International Programme on Chemical Safety, WHO, 1984. The WHO guideline values for fluoride in drinking water were reevaluated in 1996, without change, and the issue is currently under further review.
2. Prevention and control of fluorosis in India, Rajiv Gandhi National Drinking Water Mission, 1993.
3. 'Endemic fluorosis in Mexico', Fluoride, vol. 30, no. 4, 1997.
4. Data from a national research project under the eighth Five-Year Economic and Social Development Plan, 1995.
5. 'Fluorine and fluorides', see note 1 above.
6. Information supplied by UNICEF India.