World Health Organization

PREVENTING DISEASE THROUGH HEALTHY ENVIRONMENTS

INADEQUATE OR EXCESS FLUORIDE: A MAJOR PUBLIC HEALTH CONCERN

Fluoride intake has both beneficial effects—in reducing the incidence of dental caries—and negative effects—in causing tooth enamel and skeletal fluorosis following prolonged exposure to high concentrations. The ranges of intakes producing these opposing effects are not far apart. Public health actions are needed to provide sufficient fluoride intake in areas where this is lacking, so as to minimize tooth decay. This can be done through drinking-water fluoridation or, when this is not possible, through salt or milk fluoridation. Excessive fluoride intake usually occurs through the consumption of groundwater naturally rich in fluoride or crops that take up fluoride from high-fluoride irrigation water. In these areas, means should be sought to manage intakes by providing drinking-water with a moderate (i.e. safe) fluoride level or using alternative sources of water for irrigation. Although removal of excessive fluoride from drinking-water may be difficult and expensive, low-cost solutions that can be applied at a local level do exist.

Sources of exposure to fluoride

Fluoride can be released to the environment in a number of different ways:

- natural activities, such as volcanic emissions, weathering of minerals and dissolution, particularly into groundwater and marine aerosols;
- human activities, such as the production of phosphate fertilizers, the manufacture and use of hydrofluoric acid, the production of aluminium, steel and oil, and the burning of fluoride-rich coal, especially indoors;
- remobilization of historic sources, such as water flow and sediment movement from aluminium production plants.

Natural sources

Elemental fluorine almost never occurs in nature, but fluoride is widely distributed in Earth's crust, mainly as the minerals fluorspar, fluorapatite and cryolite.[1] Some regions have particularly high concentrations of fluoride. Fluoride can exist in the atmosphere in gaseous form, attached to particles or in aerosols that can be transported by wind over large distances before being deposited. Fluoride can also be transported by water, usually complexed with aluminium, but it is immobile in soil.[1]

Industrial processes

Most airborne fluoride in urbanized areas comes from industrial sources. Of this, 10% derives from the aluminium industry, and high concentrations can be found around aluminium smelters. Another major source of environmental fluoride is phosphate fertilizer production, where much of the associated fluoride is lost to the atmosphere. Use of phosphate fertilizers contaminates soil with fluoride, as does use of fluoride-containing pesticides. Other sources include glassworks, exhaust fumes and the production of metals (e.g. steel, copper and nickel), bricks, ceramics and adhesives.[2] Hydrogen fluoride is used in the semiconductor industry and

in commercial laundries. It is highly soluble in water, forming hydrofluoric acid, which is very corrosive. Sulfuryl fluoride is used as a fumigant—for example, in flour mills.

Drinking-water

In certain parts of the world where groundwater naturally contains high fluoride levels, intake of fluoride via drinking-water exceeds that via food. The intake is determined by the fluoride level in the water and the daily water consumption.

Water fluoridation has been adopted by several countries as a cost-effective public health measure for the prevention of dental caries. The dental health benefits are obtained when the concentration of fluoride in drinking water is 0.8-1.0 mg/l.[3,4]

Food

In most parts of the world, food is the primary source of fluoride intake. While almost all foodstuffs contain trace amounts of fluoride, levels can be high in the bones of canned fish, such as salmon and sardines. Levels in meat, fruit and vegetables are usually low. However, tea leaves may contain high levels of fluoride, and consumption of brick tea (popular in parts of Asia) can lead to high fluoride intake.[1,5]

The use of fluoride-rich fuel (e.g. coal) for cooking can lead to fluoride intake from the cooked food, as well as inhalation exposure.

Fluoride is sometimes added to cooking or table salt for dental caries prevention in countries or regions where drinking-water fluoridation is not feasible.[4,5] The optimal concentration of fluoride ranges from 200 to 250 mg/kg salt.[6] In some countries, fluoride is also added to milk for dental caries prevention.[7]

Dental care products

In many countries, dental care products, such as toothpaste, mouthwash and mouth rinse, contain fluoride. The contribution of fluoride-containing dental products to overall fluoride intake is minimal.

World Health Organization (WHO) fluoride guideline values
Drinking-water 1.5 mg/l (WHO recommends that, in setting a standard, Member States should take into account drinking-water consumption)[8]
Air 1 µg/m^3 (to prevent effects on livestock and plants, as well as to protect human health)[2]

Health effects[1,2]

Beneficial effects of adequate fluoride

- Fluoride is a micronutrient. Adequate intake has a beneficial effect on oral health in both children and adults. Fluoride prevents caries by several different actions. When present in saliva constantly and at low concentrations, fluoride hastens the remineralization of tooth enamel lesions. Fluoride also interferes with glycolysis, the process by which cariogenic bacteria metabolize sugars to produce acid. In addition, it has a bactericidal action on cariogenic and other bacteria. Finally, when fluoride is

ingested during the period of tooth development, it makes the enamel more resistant to later acid attacks.[4,6,9]

Adverse effects of excess fluoride

- The toxic effects of high fluoride intake are due to the fact that it is a direct cellular poison, which binds calcium and interferes with the activity of proteolytic and glycolytic enzymes.
- Ingested fluoride reacts with gastric acid to produce hydrofluoric acid in the stomach. Thus, acute exposure to high concentrations of fluoride results in immediate effects: abdominal pain, excessive saliva, nausea and vomiting. Seizures and muscle spasms may also occur. Death due to respiratory paralysis is a possibility.
- The acute effects of inhalation of hydrogen fluoride are severe irritation of the respiratory tract, with coughing, choking and pulmonary oedema. Severe burns or prolonged visual defects may result from skin or eye contact. Inhalation or dermal exposure can be fatal.
- Repeated or prolonged exposure via inhalation of aluminium fluoride, primarily in occupational settings, may cause asthma.[10]
- The main effect of long-term ingestion or inhalation of high concentrations of fluoride is fluorosis:
  - *Enamel fluorosis* can develop only in children, as it results from intake of high levels of fluoride during the period of tooth development. It is characterized by the appearance of white areas in the enamel and in this form is considered an aesthetic issue. In the more severe form, reduced mineralization of the enamel results in stained and pitted teeth.
  - In *skeletal fluorosis*, fluoride accumulates progressively in the bone over many years. Early symptoms include stiffness and pain in the joints. Crippling skeletal fluorosis is associated with osteosclerosis, calcification of tendons and ligaments, and bone deformities. There is an elevated risk of skeletal effects at fluoride intakes above 6 mg/day. These intake levels occur in many areas of the world because of naturally high fluoride levels in the groundwater, notably in the Rift Valley of East Africa and in China.
  - While the global prevalence of dental and skeletal fluorosis is not entirely clear, it is estimated that excessive fluoride concentrations in drinking-water have caused tens of millions of cases of dental and skeletal fluorosis worldwide over a range of years.[11]

Risk mitigation recommendations

Two worldwide public health problems need to be addressed: the necessity to reduce dental caries and the need to mitigate the effects of excessive fluoride intake. Thus, public health actions are required to provide sufficient fluoride intake where this is lacking, so as to minimize tooth decay, and drinking-water with a moderate (i.e. safe) fluoride level in areas where groundwater contains high fluoride levels.[1,3,4]

The following actions are needed:

Adequate fluoride

- Reduce the incidence of dental caries by:
  - fluoridating low-fluoride drinking-water where possible, as well as considering alternatives, such as salt or milk fluoridation[3,4,6,7];
  - developing effective and affordable fluoridated toothpastes for use in developing countries;
  - promoting optimal oral hygiene, based on the use of effective fluoridated toothpaste;
  - advocating a low-sugar diet in accordance with the recommendations of WHO and the Food and Agriculture Organization of the United Nations (FAO) that free (added) sugars should not exceed 10% of energy intake and that food or drinks containing free sugars should be consumed no more than 4 times per day.[12]

Excess fluoride

- Carefully consider the causes of fluorosis to select the best and most appropriate means of dealing with excess fluoride exposure, taking into account the local conditions and sensitivities.
- Provide drinking-water with fluoride levels that do not produce adverse health effects, by:
  - seeking alternative water sources in areas with fluoride-rich groundwater, particularly where water consumption is high due to elevated temperatures[5];
  - defluoridating water for drinking and cooking, using methods such as bone charcoal adsorption, contact precipitation, coagulation–flocculation, sedimentation using aluminium sulfate (Nalgonda process) and activated alumina adsorption.[5]
- Research the appropriateness of various community fluoridation schemes in view of natural fluoride levels in water.
- Monitor fluoride levels in the environment, especially in areas where there is exposure to elevated fluoride levels due to human activities, and determine the overall exposure to fluoride.
- Encourage mothers to breastfeed, even in areas with high fluoride intake, as breast milk is optimal for infant health and usually low in fluoride.
- Discourage the use of fluoride-rich coal for cooking purposes.

References

1. IPCS (2002). *Fluorides*. Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 227; http://www.inchem.org/documents/ehc/ehc/ehc227.htm).
2. WHO (2000). Fluorides. In: *Air quality guidelines for Europe*, 2nd ed. Copenhagen, World Health Organization Regional Office for Europe, pp. 143–146 (http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf).
3. WHO (1994). *Fluorides and oral health. Report of a WHO Expert Committee on Oral Health Status and Fluoride Use*. Geneva, World Health Organization (WHO Technical Report Series, No. 846; http://whqlibdoc.who.int/trs/WHO_TRS_846.pdf).

4. Petersen PE, Lennon MA (2004). Effective use of fluorides for the prevention of dental caries in the 21st century: The WHO approach. *Community Dentistry and Oral Epidemiology*, 32:319–321 (http://www.who.int/oral_health/media/en/orh_cdoe_319to321.pdf).

5. WHO (2006). *Fluoride in drinking-water*. Geneva, World Health Organization (https://www.who.int/water_sanitation_health/publications/fluoride_drinking_water_full.pdf).

6. Marthaler T, Petersen PE (2005). Salt fluoridation—an alternative in automatic prevention of dental caries. *International Dental Journal*, 55:351–358 (http://www.who.int/entity/oral_health/publications/orh_IDJ_salt_fluoration.pdf).

7. WHO (2009). *Milk fluoridation for the prevention of dental caries*. Geneva, World Health Organization (http://whqlibdoc.who.int/publications/2009/9789241547758_eng.pdf).

8. WHO (2004). *Fluoride in drinking-water. Background document for preparation of WHO Guidelines for Drinking-water Quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/96; http://www.who.int/water_sanitation_health/dwq/chemicals/fluoride.pdf).

9. WHO (2008). *Guidelines for drinking-water quality*, 3rd edition incorporating 1st and 2nd addenda. *Vol. 1. Recommendations*. Geneva, World Health Organization, pp. 375–377b (http://www.who.int/water_sanitation_health/dwq/GDW12rev1and2.pdf).

10. IPCS (1999). *Aluminium fluoride (anhydrous)*. Geneva, World Health Organization, International Programme on Chemical Safety (International Chemical Safety Card 1324; http://www.inchem.org/documents/icsc/icsc/eics1324.htm).

11. Fewtrell L et al. (2006). An attempt to estimate the global burden of disease due to fluoride in drinking water. *Journal of Water and Health*, 4(4):533–542 (http://www.iwaponline.com/jwh/004/0533/0040533.pdf).

12. WHO (2003). *Diet, nutrition and the prevention of chronic diseases*. Geneva, World Health Organization (WHO Technical Report Series, No. 916; http://whqlibdoc.who.int/trs/WHO_trs_916.pdf).

Printed by the WHO Document Production Services, Geneva, Switzerland

Public Health and Environment

World Health Organization

20 Avenue Appia, 1211 Geneva 27, Switzerland