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 intake ranges that produce 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 or use of dental care products containing fluoride. Excessive fluoride intake usually occurs through the consumption of groundwater naturally rich in fluoride, particularly in warm climates where water consumption is greater, or where high-fluoride water is used in food preparation or irrigation of crops such as rice. 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 drinking or cooking or 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. The preparation of food using fluoride-rich coal also contributes to excess fluoride intake via ingestion and inhalation.

Sources of exposure to fluoride

Fluoride can be released into 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 and use of phosphate fertilizers; manufacture and use of hydrofluoric acid; production of aluminium, steel and oil; and 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 the Earth's crust, mainly as the minerals fluorspar, cryolite, apatite, mica, hornblende and fluorite.[1,2] Fluoride concentrations vary and some regions have particularly high concentrations of fluoride. Fluoride can exist in the atmosphere, as dust from fluoride-containing soils and from gaseous industrial waste and pesticides containing fluoride. It can be distributed widely and can be transported by wind over long distances before being deposited.[2] Fluoride can also be transported

by water, usually complexed with aluminium, which is not usually bioavailable and is immobile in soil.[1] Levels in groundwater can vary significantly, depending on the presence in geological formations at different depths.[2] High levels of fluoride in water sources have been found in at least 25 countries.[3]

Industrial processes

Most airborne fluoride in urbanized areas comes from industrial sources. Key sources include the production and use of phosphate fertilizers and phosphate ores, as well as aluminium, steel and other metal production facilities. Other sources include glassworks, bricks, ceramics and adhesives manufacturing[4] and the burning of coal rich in fluoride. The use of phosphate fertilizers contaminates soil with fluoride, as does the use of fluoride-containing pesticides. Hydrogen fluoride is used in the semiconductor industry and in the chemical industry in the production of fluorinated organic chemicals. Hydrogen fluoride 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. In warm climates where drinking-water consumption is generally greater, naturally high fluoride levels in drinking-water supplies can result in particularly high daily intake of fluoride.

Water fluoridation has been adopted by several countries as a cost-effective public health measure for the prevention of dental caries. The optimal concentration in drinking-water is normally within the range of 0.5–1.0 mg/L.[2,5]

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 fish products that contain bones, such as canned salmon and sardines. Levels in meat, fruit and vegetables are usually low. However, tea plants may take up fluoride from soil in considerable amounts; therefore, consumption of teas (particularly brick tea, popular in parts of Asia) can lead to high fluoride intake.[1,5,6]

The use of fluoride-rich coal for cooking, heating and drying of foodstuffs can lead to fluoride intake from the cooked food, as well as inhalation exposure. The use of fluoridated water during cooking or processing food can also contribute to fluoride ingestion.[2]

Fluoride is sometimes added to cooking or table salt for dental caries prevention in countries or regions where drinking-water fluoridation is not feasible;[7,8] consumption of fluoridated salt is particularly prevalent in the Caribbean and Latin American countries.[2] The optimal concentration of fluoride must be determined on the basis of salt intake studies and consideration of total fluoride exposures; generally, a concentration of 200–250 mg/kg salt is regarded as a minimum.[2] In some countries, fluoride is also added to milk for dental caries prevention,[9] with daily dosage

varying from 0.50 to 0.85 mg fluoride per child.[2]

Dental care products

In many countries, dental care products, such as toothpaste, mouthwash and mouth rinse, varnishes and gels contain fluoride as an effective means to control caries. Fluoridated toothpastes containing between 1000 and 1500 ppm fluoride is the standard recommended by WHO as a public oral health measure for the prevention of caries.[2] The contribution of fluoride-containing dental products to overall fluoride intake is minimal.

Supplements

Oral supplements – in the form of drops and chewable tablets – have been used in some countries for the control of dental caries. However, use of supplements as a public health measure is considered to have limited application; dosages should take into account exposure from other sources and the local prevalence of dental fluorosis.[2]

World Health Organization (WHO) fluoride guideline values

Drinking-water

The guideline value for fluoride in drinking-water is 1.5 mg/L, based on increasing risk of dental fluorosis at higher concentrations and that progressively higher levels lead to increasing risks of skeletal fluorosis. This value is higher than that recommended for artificial fluoridation of water supplies for prevention of dental caries, which is usually 0.5–1.0 mg/L. WHO recommends that, in setting a standard, Member States should take into account drinking-water consumption and the intake of fluoride from other sources.[5]

Air

The guideline is 1 µg/m^3 (developed to prevent effects on livestock and plants, and also considered sufficiently protective of human health).[4]

Health effects[1,2,4]

Beneficial effects of adequate fluoride

The Global Burden of Disease Study 2016 estimated that caries of the permanent teeth is the most prevalent of all conditions assessed. Globally, it is estimated that 2.4 billion people suffer from caries of permanent teeth and 486 million children suffer from caries of primary teeth.[10]

- Adequate intake of fluoride has a beneficial effect on oral health in both children and adults. Fluoride prevents caries by several different actions. When present in saliva and dental plaque constantly and at low concentrations, fluoride delays the demineralization

and 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, fluoride 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 and subsequent development of caries.[2,7,8]

Adverse effects of excess fluoride

- High fluoride intake can induce toxic effects by binding with calcium and interfering 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 the most soluble fluoride compounds results in immediate effects, including 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 asthma-like reactions and pulmonary oedema. Severe burns or damage may result from skin or eye contact. Inhalation, ingestion or dermal exposure can be fatal.[11]
- Repeated or prolonged exposure via inhalation of aluminium fluoride, primarily in occupational settings, may cause asthma.[12]
- 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. Enamel fluorosis, with a prevalence of 12–33%, may occur at low levels of fluoride in drinking-water, depending on total intake, and will only be detectable by specialist examination.[5] It can be difficult to achieve effective fluoride-based caries prevention programmes at the community level without some degree of very mild or mild enamel fluorosis.[2]
  - In skeletal fluorosis, fluoride accumulates progressively in the bone over a number of 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 evidence from India and China of excess risk of skeletal fluorosis and bone fractures at a total fluoride intake of 14 mg/day, and suggestive evidence of increased risk of skeleton effects at a total intake above about 6 mg/day.[5]
  - While the global prevalence of dental and skeletal fluorosis is not entirely clear, based on analysis of data published between 1953 and 2000, it was estimated in 2006 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.[13] Children whose teeth and bones are still developing are most susceptible; poor nutritional status can aggravate this situation.[14]

- Although administration of very high doses of fluoride to rats in a two-year cancer bioassay was associated with increased incidence of osteosarcoma,[15] there is no evidence in recent and peer-reviewed publications that fluoride levels in drinking-water aimed at controlling dental caries is associated with increased risk of bone cancers in humans.[2] No relation was found between rates of Down syndrome or congenital malformation and the consumption of fluoridated drinking-water, based on review of several epidemiological studies of pregnancy outcome.[5]

Risk mitigation recommendations

Two worldwide public health problems related to fluoride 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, as well as to provide drinking-water with a moderate (i.e. safe) fluoride level in areas where groundwater contains high fluoride levels.[1,7,16,17]

To provide guidance on the need to control population exposures to fluoride and establish the important balance between caries prevention and protection against adverse effects, community health programmes can estimate total exposure by measuring renal fluoride excretion and compare these measurements with established optimal levels using methods published by WHO.[18] However, risk mitigation measures implemented should also take into consideration local contexts and sensitivities.

In addition, 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;[7–9,16,17]
  - developing effective and affordable fluoridated toothpastes for use in developing countries;
  - promoting optimal oral hygiene, based on the use of effective fluoridated toothpaste; guidance on the amount of fluoridated toothpaste to be used and the concentration of fluoride present in the toothpaste should take into consideration the age of the user (especially for children) and the exposure to other sources of fluoride in the community;[17]
  - supporting the use of silver diamine fluoride and atraumatic restoration treatment, and other minimally invasive techniques, using glass ionomer cement to stabilize caries lesions;[17]

- irrespective of fluoride exposure, advocating a low-sugar diet in accordance with the recommendation of WHO that free (added) sugars should not exceed 10% of total energy intake by both adults and children (strong recommendation); WHO further suggests reduction to below 5% of total energy intake (conditional recommendation).[19]

Excess fluoride

- Where practicable, monitor the prevalence of enamel fluorosis using scoring guidance systems such as those developed by WHO.[20]
- 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;[21]
  - where an alternative source is not an option, defluoridating water for drinking and cooking, using methods such as bone charcoal adsorption, contact precipitation, coagulation–flocculation/sedimentation using aluminium sulfate (Nalgonda process), activated alumina adsorption and clay.[2,21] However, removal techniques may depend on local context; for example, the use of clay requires testing to ensure that local clay is free of toxic materials and other possible pollutants.[2]
- 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.