GreenFacts
Facts on Health and the Environment

Scientific Facts on

Fluoride

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GreenFacts

Level 2 - Details on Fluoride

This Digest is a faithful summary of the leading scientific consensus report produced in 2002 by the International Programme on Chemical Safety (IPCS): *"Environmental Health Criteria for Fluorides (EHC 227)"*

The full Digest is available at: https://www.greenfacts.org/en/fluoride/

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- Each question is answered in Level 1 with a short summary.
- These answers are developed in more detail in Level 2.
- Level 3 consists of the Source document, the internationally recognised scientific consensus report which is faithfully summarised in Level 2 and further in Level 1.

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1. What are fluorides?

1.1 Which fluorides are most relevant?

Fluorine (F) is an element of the halogen family, which also includes chlorine, bromine and iodine. It forms inorganic and organic compounds called fluorides. Living organisms are mainly exposed to inorganic fluorides through food and water. Based on quantities released and concentrations present naturally in the environment as well as the effects on living organisms, the most relevant inorganic fluorides are hydrogen fluoride (HF), calcium fluoride (CaF_2), sodium fluoride (NaF), sulfur hexafluoride (SF_6) and silicofluorides. They are the focus of this Digest.

1.2 What are fluorides used for in industry?

Fluorides are important industrial chemicals with a number of uses but the largest uses are for aluminium production, drinking water fluoridation and the manufacture of fluoridated dental preparations.

- Hydrogen fluoride (HF) is a colourless, pungent liquid or gas that is highly soluble in organic solvents (e.g., benzene) and in water. It is mainly used in the production of synthetic cryolite (Na_3AlF_6), aluminium fluoride (AlF_3), motor gasoline alkylates and chlorofluorocarbons (CFCs). It is also used in etching semiconductor devices, cleaning and etching glass, cleaning brick and aluminium and tanning leather, as well as in removing rust.
- Calcium fluoride (CaF_2) is a colourless solid that is relatively insoluble in water and dilute acids and bases. It is used to produce steel, glass and enamel (because it lowers the melting temperature), hydrofluoric acid and anhydrous hydrogen fluoride (as raw material), and aluminium (as electrolyte).
- Sodium fluoride (NaF) is a colourless to white solid that is moderately soluble in water. It is used in the fluoridation of drinking water and in the manufacture of dental preparations such as toothpaste. It is also used in the production of steel and aluminium (to lower the melting temperature), glass and enamel, or as an insecticide and a preservative (for glues and wood).
- Sulfur hexafluoride (SF_6) is a colourless, odourless, inert gas that is slightly soluble in water and readily soluble in ethanol and bases. It is used extensively in various electronic components and in the production of magnesium and aluminium.
- Silicofluorides such as fluorosilicic acid (H_2SiF_6) and sodium hexafluorosilicate (Na_2SiF_6) are also used for the fluoridation of drinking water supplies

2. Where are fluorides found?

2.1 How are fluorides released into the environment?

Naturally, fluorides are released into the environment through the weathering of rocks and through atmospheric emissions from volcanoes and seawater.

Human activities releasing fluorides into the environment are mainly the mining and processing of phosphate rock and its use as agricultural fertilizer, as well as the manufacture of aluminium. Other fluoride sources include the combustion of coal (containing fluoride impurities) and other manufacturing processes (steel, copper, nickel, glass, brick, ceramic, glues and adhesives). In addition, the use of fluoride-containing pesticides in agriculture and fluoride in drinking water supplies also contribute to the release of fluorides to the environment.

2.2 Where in the environment can fluorides be found?

In air, fluorides can be present as gases or particulates. They can be transported by wind over large distances before depositing on the earth's surface or dissolving in water. In general, fluoride compounds do not remain in the troposphere for long periods nor do they move up to the stratosphere. Only sulfur hexafluoride (SF_6) can stay in the atmosphere from 500 to several thousand years.

In water, when inorganic fluoride compounds dissolve they split up into ions although the speed at which they dissolve depends on the type of compound and on factors such as the acidity of the water. The transport and transformation of fluorides is influenced by pH, water hardness and the presence of materials such as clay, which exchange ions. In water with a neutral pH and low fluoride concentrations, fluoride is predominantly present in the form of fluoride ions (F^-). As they travel through the water cycle fluorides usually combine with aluminium.

In soils, fluoride is predominantly combined with aluminium or calcium. When the soil is slightly acidic, fluoride tends to adsorb more strongly to soil particles. Fluorides are very immobile in soil and are not easily leached from it.

In living organisms, the quantity of fluoride taken-up depends on the route of exposure, on how well the particular fluorides are absorbed by the body and on how quickly they are both taken up and excreted. Fluoride released from soluble fluorides tend to bioaccumulate in some aquatic and terrestrial plants or animals. However, there is no known information on the biomagnification of fluoride, i.e. fluoride build-up in aquatic or terrestrial food-chains.

2.3 How much fluoride is there in environment?

In surface waters, such as rivers, fluoride levels depend on the proximity to human or natural emission sources; they generally range from 0.01 to 0.3 mg/litre. In seawater fluoride concentrations are higher, i.e. 1.2 to 1.5 mg/litre. In areas where the natural rock is rich in fluoride or where there is geothermal or volcanic activity, very high fluoride levels, up to 50 mg/litre, may be found in groundwater or hot springs.

In air, fluoride emitted both naturally and from human activities in gaseous and particulate forms generally deposits relatively near its emission source. In areas without nearby emission sources, the mean concentrations of fluoride in ambient air are generally less than 0.1µg/m^3. Even near emission sources, the levels of airborne fluoride usually do not exceed 2–3 µg/m^3.

In most soils, fluoride is present at concentrations ranging from 20 to 1000 µg/g. This figure can reach several thousand µg/g in mineral soils with natural phosphate or fluoride deposits.

2.4 How much fluoride can be found in living organisms?

Aquatic organisms take up fluorides directly from water or to a lesser extent via food, and tend to accumulate fluoride in their exoskeleton or bone tissue. Mean fluoride concentrations of more than 2000 mg/kg have been measured in the exoskeleton of krill while mean bone fluoride concentrations in aquatic mammals, such as seals and whales, ranged from 135 to 18 600 mg/kg dry weight.

Fluoride levels **in terrestrial animals and plants** are higher near natural and human fluoride emission sources. Lichens, which have been used extensively as biomonitors for fluorides, generally contain less than 1 mg fluoride/kg (background level), but at a distance of 2 to 3 km from fluoride emission sources mean concentrations range from 150 to 250 mg/kg.

Most of the fluoride in the soil is insoluble and, therefore, less available to **plants**. But the fluoride that is present in soil solution is taken up through the root and accumulates in leaves.

Fluoride accumulates in the bone tissue of **terrestrial vertebrates**, depending on factors such as diet and the proximity of fluoride emission sources. For example, mean fluoride concentrations of 7000 to 8000 mg/kg have been measured in the bones of small mammals living near an aluminium smelter.

3. How are humans exposed to fluorides?

3.1 How much fluoride is there in drinking water?

The amount of fluoride present naturally in drinking water is highly variable, depending on the specific geological environment from which the water is obtained. In non-fluoridated drinking water (i.e., drinking water to which fluoride has not been intentionally added for the prevention of dental caries) levels may reach up to about 2.0 mg/litre. However, some places can have fluoride levels in drinking water of up to 20 mg/litre. In areas in which drinking water is fluoridated, the concentration of fluoride in drinking water generally ranges from 0.7 to 1.2 mg/litre.

3.2 How much fluoride is there in food?

Virtually all foodstuffs contain at least trace amounts of fluoride. Elevated levels are present in fish and in tea leaves, which are particularly rich in fluoride. Although the concentration of fluoride in food products is not significantly increased by the addition of superphosphate fertilizers (containing fluorides as impurities) to agricultural soil, a recent study shows that plant uptake of fluoride could increase given certain conditions. The use of water containing relatively low levels (less than about 3 mg/litre) of fluoride for crop irrigation generally does not increase fluoride concentrations in foodstuffs, but this depends on plant species and fluoride concentrations in soil and water. However, the level of fluoride in foods is significantly affected by the fluoride content of the water used in food preparation or processing, particularly in beverages and dry foodstuffs to which water is added prior to consumption, such as powdered baby formula. The concentrations of fluoride in unwashed or unprocessed foods grown near industrial fluoride sources may be greater than the levels in the same foods grown in other non-industrially exposed areas. Fluoride has been detected in breast milk at concentrations up to 100 µg /litre, with most measurements ranging between 5 and 10 µg/litre.

3.3 How much fluoride is there in toothpaste?

Dental products such as toothpaste, mouthwash and fluoride supplements have been identified as significant sources of fluoride. Toothpastes for adults that are commercially available generally contain fluoride at concentrations ranging from 1000 to 1500 µg/g, whereas those designed for children contain 250 to 500 µg. The concentration of fluoride in mouth rinses varies with the recommended frequency of use from 230 to 1000 mg/litre.

3.4 How much fluoride are humans exposed to?

Individual exposure to fluoride is highly variable depending on the levels of fluoride in foodstuffs and drinking water, on the use of fluoridated dental preparations, and in certain cases on the levels of fluoride in indoor air.

For adults, the consumption of **foodstuffs** and **drinking water** is the principal route of exposure to fluoride. Formula-fed infants receive 50–100 times more fluoride than exclusively breast-fed infants. The ingestion of **toothpaste** by young children makes a significant contribution to their total intake of fluoride. In general, estimated intakes of fluoride by children and adolescents do not exceed about 2 mg/day. Although adults may have a higher absolute daily intake of fluoride in milligrams, the daily fluoride intake of children, expressed on a milligram per kilogram body weight basis, may exceed that of adults. In geological areas rich in fluoride, drinking water obtained from groundwater wells can be the principal source, leading to estimated intakes of fluorides in adults up to 27 mg/day.

The **inhalation** of airborne fluoride generally does not contribute much to the total intake of this substance, save in areas of the world in which coal rich in fluoride is used indoors on open fires for heating and cooking or where certain wood preservatives are used.

Workers in the aluminium, iron ore or phosphate ore processing industry may be exposed via inhalation or **dermal contact**.

3.5 What happens to fluorides absorbed by the body?

When fluorides are ingested by humans or laboratory animals, they are absorbed in the stomach and/or the intestine. Fluoride from soluble fluorides is almost completely absorbed (either as HF or F^-, depending on stomach acidity). However, when fluoride is bound to aluminium, calcium etc., its release and subsequent absorption may be reduced because this combination is less soluble. When fluorides in gaseous or particulate form are breathed in, the respiratory tract, they are partially or completely absorbed depending on how soluble they are or on how big the fluoride-containing particles are.

Fluoride is then rapidly distributed in tissues. In humans and laboratory animals, fluorides mostly build up in bones and teeth, which retain about 99% of the total fluoride body burden.

Fluoride is eliminated from the body primarily through the urine. Infants retain 80 to 90% of fluoride ingested, while adults retain approximately 60%.

However, the balance of fluoride in the body (i.e. the difference between the amount of fluoride ingested and the amount excreted) can be positive or negative. This physiological balance is determined by earlier fluoride exposure, the degree of accumulation in bone, the rate at which it is released from bone and the efficiency of the kidneys in excreting fluoride. When fluoride intakes are low excretion through urine can exceed intake.

Fluoride can be transferred from mother to foetus through the placenta.

4. Can fluorides affect health?

4.1 Does fluoride affect bones in test animals?

Various effects on bones were observed in a series of studies carried out on rats and mice fed with significant amounts of fluoride for varying time periods. Effects included inhibition of bone formation and hardening, delayed fracture healing, and reductions in bone volume and collagen synthesis.

4.2 Does fluoride cause cancer in test animals?

A series of studies carried out on various types of rats and mice fed with significant amounts of fluoride for long periods showed no statistically significant increase in the incidence of any tumour. In one study there was a significant trend for bone tumours in male rats only. However, the incidence of these tumours was not greater than what had been observed in previous studies on rats that had not been exposed to fluoride (historical controls).

4.3 Does fluoride cause genetic mutations in cells or test animals?

In bacteria, fluoride generally does not cause mutations, i.e. permanent change to DNA. Although fluoride has been shown to cause damage to DNA in a variety of cell types in in vitro tests, this appears to be due to an effect on the synthesis of proteins involved in forming or repairing DNA and not to a direct interaction with DNA. In most studies on test animals fed with fluoride, it had no effect on chromosomes, but chromosomal changes or effects on sperm were reported when fluoride was injected into the abdominal cavity.

4.4 Does fluoride affect reproduction or development in test animals?

In recent studies, animals exposed to fluoride via drinking water showed neither reproductive nor developmental effects. However, changes in reproductive organs and reproductive function have been reported in test animals administered significant doses of fluoride orally or via injections for varying periods of time.

5. What effects have actually been seen in humans?

5.1 Has fluoride exposure caused cancer?

Various studies of fluoride-exposed workers, primarily from the aluminium smelting industry, showed an increased incidence of lung and bladder cancer and increased mortality due to cancer. However, no consistent pattern has been observed and in certain cases the greater frequency of cancers can be attributed to substances other than fluoride.

The numerous studies carried out in many countries on populations consuming fluoridated drinking water did not show any consistent evidence of an association between the consumption of controlled fluoridated drinking water and increased frequency of cancer.

5.2 What are the effects on teeth and bones?

Fluoride can have both a positive and a negative impact on tooth enamel. Generally, the higher the concentrations of fluoride in drinking water the smaller the likelihood to develop dental caries. However, the prevalence and severity of dental fluorosis within the population increases with the concentration of fluoride in drinking water.

Bones can be negatively affected by fluoride. Cases of skeletal fluorosis are associated with high levels of fluoride in drinking water or in ambient air at work or at home, for instance in areas of China in which coal rich in fluoride is used indoors on open fires for heating and cooking. Although fluoride is the cause of skeletal fluorosis in these cases, many other factors, including nutritional factors, can play a significant role in the severity of the health condition. Evidence for an association between the consumption of fluoridated water and hip fractures is mixed; some studies support the association, others do not, some even report protective effects of fluoride on bones. Two comparative studies carried out on groups of people drinking water with different levels of fluoride showed greater risks of fracture at higher fluoride levels.

5.3 Has fluoride caused other health problems?

Studies on human populations did not show any association between the consumption of fluoridated drinking water by mothers and increased risk of spontaneous abortion or congenital malformation. Studies on workers exposed to airborne fluorides have provided no reasonable evidence of effects upon lungs, blood system, liver or kidneys attributable to fluoride exposure alone.

6. To what extent can fluoride exposure be harmful to organisms in the environment?

6.1 What levels of fluoride exposure are harmful to aquatic organisms?

Fluoride can be toxic to aquatic life but some organisms are more sensitive to its effects than others. Its toxicity is very low for bacteria involved in wastewater treatment and appears to be low for **algae**.

Fluoride toxicity is low for an aquatic floating **plant**, common duckweed, with a concentration giving a 50% reduction in growth (EC50) greater than 60 mg fluoride/litre.

How easily **invertebrates** are affected depends on the species. The most sensitive appear to be caddisfly species with calculated "safe concentrations" varying between 0.2 mg/litre and 1.79 mg/litre [see Annex 1, p. 16] .

The data on **fish** are quite variable but fluoride toxicity to fish appears to be less in hard water than soft water and greater at high temperatures than low temperatures. The concentration of fluoride lethal to 50% of groups of rainbow trout (LC_{50}) exposed for 20 days in laboratory experiments carried out in soft water, ranged from 2.7 to 4.7 mg/litre. However, for a wild fish population in a specific river with hard water, safe concentrations for rainbow and brown trout were calculated to be 5.1 and 7.5 mg/l respectively.

6.2 What levels of fluoride exposure are harmful to microbes and plants?

There is evidence that fluoride may be toxic to **microbiological processes** in soils at concentrations found in moderately polluted areas.

Signs of harmful effects on **plants** include the yellowing of leaves and slowed growth. When plants take up fluoride from soil its toxic effects depend on the ionic species of fluoride present and on the type of soil.

Many studies have assessed the effects of fluoride emissions on plants by exposing them to hydrogen fluoride (HF) gas. Leave tissue starts to die (leaf necrosis) above certain concentrations in air, e.g. 0.17 and 0.27 µg/m^3 in the case of grapevines (for an exposure of 99 and 83 days). Airborne fluoride can also have an impact on the development of plant diseases, but the type and magnitude of the effects depend on the specific plant and its disease.

Evidence shows that the smaller the distance from great fluoride sources such as aluminium smelters or phosphorus plants, the higher the fluoride levels in soils and hence the degree of damage to vegetation. Mean levels of fluoride in vegetation near one of these large fluoride sources ranged from 281 mg/kg in severely damaged areas to 44 mg/kg in slightly damaged areas. Near an aluminium smelter, differences in plant community composition and structure were observed due partly to variations in fluoride tolerance, but other variables such as other atmospheric pollutants must also be taken into account when interpreting the many field studies on fluoride pollution.

6.3 What levels of fluoride exposure are harmful to birds and mammals?

In birds, laboratory tests were carried out on European starling chicks to determine at what levels fluoride would affect their growth or be lethal. In the case of 1-day-old laboratory chicks, growth rates were significantly reduced at 13 mg fluoride/kg and half of the chicks died within the next 24h when administered a fluoride dose of 50 mg/kg body weight. That figure dropped to 17 mg/kg body weight for 16-day-old nestlings.

In mammals, the lowest concentration of fluoride in food to cause dental fluorosis was 35 mg/kg food in wild white-tailed deer. Fluorosis has also been observed in cattle and sheep, with dairy cattle having the lowest tolerance value at 30 mg/kg feed or 2.5 mg/litre drinking water.

Symptoms of fluoride toxicity include emaciation, stiffness of joints and abnormal teeth and bones. Other effects include lowered milk production and detrimental effects on reproduction. Near smelters, animal lameness has also been observed.

7. What are the risks posed by fluorides?

7.1 What are the risks to humans?

Fluoride has both positive and negative effects on human health, but there is a narrow range between intakes which are beneficial and those which are detrimental. It is important to take into account all sources of exposure to fluoride, including through drinking water and foodstuffs.

It is difficult to determine dose-response relationships between fluoride exposure and different adverse effects. This is due to the limited information available on total fluoride exposure, particularly with respect to fluoride intake and absorption.

The most serious effect is the accumulation of fluoride in bones from long-term excessive exposure and the potential for skeletal fluorosis and bone fractures. At total intakes of 14 mg fluoride/day, there is clear evidence of skeletal fluorosis and an increased risk of bone fractures; at total intake levels above about 6 mg fluoride/day the evidence is suggestive of an increased risk of adverse effects on bone.

7.2 What are the risks to the environment?

Natural fluoride concentrations in freshwater are usually lower than those expected to cause toxicity in aquatic organisms, which may, however, be adversely affected by nearby discharges from human activities.

The release of fluoride from human activities poses a risk to local sensitive plant species. However, damage to local terrestrial plant communities is often difficult to attribute to the presence of fluoride alone as other atmospheric pollutants also have an impact on vegetation.

Concentrations of fluoride in vegetation near fluoride emission sources, such as aluminium smelters, can be higher than the lowest dietary effect concentration reported for mammals in laboratory experiments.

Fluorosis has been reported in domesticated animals and in livestock due to the uptake of fluoride from fluoride-rich mineral supplements and drinking water. Furthermore, there is a potential risk from the ingestion of fluoride-contaminated pasture after the long-term use of phosphate fertilizers containing high levels of fluoride. Fluoride-induced effects, such as lameness and tooth damage, have also been reported in wild mammals close to fluoride natural emission sources, such as volcanoes, and those linked to human activities.

8. What are the beneficial effects of fluoride on teeth?

Fluoride can have both beneficial and potentially detrimental effects on dental health. While an increase in the concentration of fluoride in drinking water means less chances of developing dental caries, it also means greater chances of developing dental fluorosis. The "optimum" level of fluoride in drinking water, associated with the maximum level of dental caries protection and minimum level of dental fluorosis, is considered to be approximately 1 mg/litre.

8.1 Does fluoride protect teeth from cavities?

Today, oral fluoride is still considered as an effective means of reducing dental caries.


Oral fluoride is considered as an effective means of reducing dental caries.

Historically, populations consuming fluoridated drinking water have shown a much lower prevalence of dental caries than have those consuming non-fluoridated drinking water, but the difference in caries prevalence between those two groups has narrowed significantly over time. This apparent decrease in the protective virtue of fluoridated drinking water may be explained by the fact that individuals who do not have access to fluoridated drinking water may consume other fluoridated products in significant amounts, for example beverages prepared elsewhere with fluoridated drinking water and dental products such as fluoridated toothpaste.

There is now ample evidence that fluoride inhibits the development of caries because of its direct action on the enamel surface of teeth that have emerged from the gum.

8.2 What fluoridated products have been used to prevent cavities?

There is a variety of fluoridated products:

- **Fluoridated drinking water** is one of the most cost-effective means of delivering fluoride to large numbers of individuals. It requires a suitable community-wide drinking water delivery system along with a reasonable level of technological development. About 210 million individuals throughout the world consume such water.
- **Fluoridated toothpaste**, which usually contains approximately 1000 mg fluoride/kg, is considered to be one of the major factors responsible for the

gradual decline in the prevalence of dental caries in most industrialized countries. About 500 million individuals throughout the world use such toothpaste.

- **Fluoridated mouth rinse** is popular among public health care programmes for school aged children. Such rinses contain 0.05 or 0.2% of fluoride depending on whether they are recommended for daily or weekly use. It is not suitable for children below the age of six who might swallow significant amounts of the product.
- **Fluoridated solutions, gels or varnishes** , applied by dentists, may be effective for individuals with an elevated risk of dental caries. Because of the high level of fluoride contained (up to 22 300 mg/kg), and to avoid acute toxic effects in younger children who may swallow them, such materials are applied according to strict protocols.
- **Fluoridated salt** is considered to act against the appearance of caries in a way similar to fluoridated drinking water. According to the WHO, it should contain at least 200 mg fluoride/kg salt.
- **Fluoridated milk** was formerly considered to be a suitable means of increasing children's intake of fluoride; however, little information is available on the efficacy of this delivery method that requires close cooperation with the dairy industry as well as a widespread system of distribution.
- **Fluoride supplements** in the form of tablets, liquid drops or lozenges are intended to provide a source of fluoride when fluoridated drinking water is not available. There appears to be a growing consensus that fluoride supplements have a limited public health role in improving dental health.

The effectiveness of interventions other than drinking water fluoridation depends on the compliance by all sections of the population, particularly among socially and economically disadvantaged groups.

9. Does water fluoridation pose risks?

9.1 When can teeth be affected by dental fluorosis?

Dental fluorosis is a condition that results from the intake of excessive amounts of fluoride during the period of tooth development, usually from birth to approximately 6-8 years of age. It is linked to the excessive incorporation of fluoride into dental enamel and dentine which prevents the normal maturation of the enamel. The severity of this condition ranges from very mild to severe, depending on the extent of fluoride exposure during the period of tooth development. Mild dental fluorosis is usually characterized by the appearance of small white areas in the enamel; individuals with severe dental fluorosis have teeth that appear stained and pitted ("mottled").

Dental fluorosis occurs during the period of enamel formation. Exposure to excessive levels of fluoride after tooth development appears to have little influence on the extent of fluorosis.

Re-evaluation of past fluorosis data demonstrated a dose-response relationship and showed that even at low fluoride intake levels from water, a certain level of dental fluorosis will be found.

9.2 Is water fluoridation causing dental fluorosis?

Although there has been an increase in the prevalence of dental fluorosis over the past 30 to 40 years, it has generally been attributed to the widespread intake of fluoride from sources other than drinking water, such as toothpastes, mouth rinses, fluoride supplements fluoridated salt or milk, as well as locally applied dental gels, solutions and varnishes on top of the possible exposure from drinking water.

An elevated prevalence of dental fluorosis is observed in certain areas of the world, such as China, where the intake of fluoride may be extremely high, due in large part to the elevated fluoride content of the surrounding geological environment. The consumption of drinking water containing naturally elevated levels of fluoride, the indoor burning of coal rich in fluoride, the preparation of foodstuffs in water containing high fluoride levels and the consumption of specific foodstuffs naturally rich in fluoride, such as tea, all contribute to the elevated intake of fluoride, with the resultant development of dental fluorosis.

9.3 How can bones be affected by skeletal fluorosis?

Though the incorporation of fluoride into bone may increase the stability of the crystal lattice, it also delays or inhibits bone hardening (mineralization), causing the bones to become brittle or less able to withstand pressure. The greater the amount of fluoride incorporated into bone, the more severe are the effects associated with skeletal fluorosis.

In a **preclinical phase** of skeletal fluorosis, the patient may show no other symptoms than a slight increase in bone mass, detected radiographically.

During the **first and second clinical stages** of skeletal fluorosis, the symptoms are: sporadic pain and stiffness of the joints, chronic joint pain, osteosclerosis of cancellous bone and calcification of ligaments.

During the **clinical phase III**, associated with crippling skeletal fluorosis, symptoms are: limited movement of the joints, skeletal deformities, intense calcification of ligaments, muscle wasting and neurological deficits.

Other effects of skeletal fluorosis arise when high fluoride intakes overly stimulate bone formation which can result in calcium deficiency, osteomalacia, and secondary hyperparathyroidism.

The development of skeletal fluorosis depends on a number of factors, such as age, nutritional status, renal function and calcium intake, in addition to the extent and duration of exposure to fluoride. Skeletal fluorosis may be reversible to some degree.

9.4 At what intake levels does fluoride cause skeletal fluorosis?

The occurrence of endemic skeletal fluorosis in certain areas of the world where the intake of fluoride may be extremely high (e.g., India, China) has been well documented in case reports and surveys. An increased intake of fluoride from foodstuffs and drinking water with high levels of fluoride of geological origin plays a major role. Yet it is difficult to characterize the exposure-response relationship because many other factors may be important such as nutrition and climate, which influence fluid intake, or the indoor burning of coal rich in fluoride (in China).

Indeed, the many studies on human skeletal fluorosis carried out around the world sometimes show significantly different results from one area to another. In most of these studies, only fluoride intake from drinking water seems to have been taken into account. In the USA for instance, only five cases of crippling skeletal fluorosis were reported over the past 40 years. Their total intake of fluoride over a 20-year period was estimated to be approximately 15–20 mg/day.

Studies in India, Senegal and China on populations exposed to drinking water naturally high in fluoride show diverging results. In most studies, fluoride concentrations in drinking water ranging from 1 to 9.7 mg/litre were associated with a varying prevalence of skeletal fluorosis within the range of 0 to 71%.

In India, a study on the dependence of skeletal fluorosis on duration of exposure and age showed that skeletal fluorosis among individuals consuming water with an average fluoride concentration of 9.0 mg/litre started to appear after 10 years of residence in the village and affected all individuals after 20 years.

Studies using bone-fracture as an indicator of increased bone brittleness due to skeletal fluorosis have shown an increased risk of bone fractures at total fluoride intakes of 14 mg/day and evidence suggestive of an increased risk of bone effects at total fluoride intakes above about 6 mg/day.

10. Conclusion

All organisms are exposed to fluoride released from natural sources and/or by human activities.

Fluoride can help prevent cavities, but at high intakes it can harm teeth development (dental fluorosis) and at higher intakes still, weaken and deform bones (skeletal fluorosis). There is a narrow range between intakes which are beneficial and those which begin to be detrimental.

When drinking water is artificially fluoridated, the "optimum" level of fluoride, associated with the maximum level of dental caries protection and minimum level of dental fluorosis, is considered to be approximately 1 mg/litre. Although there has been an increase in the prevalence of dental fluorosis over the past 30 to 40 years, it has generally been attributed to the widespread increased intake of fluoride from sources other than drinking water, such as toothpastes, mouth rinses, fluoride supplements, fluoridated salt or milk, as well as locally applied dental gels, solutions and varnishes.

Effects on the bone, such as skeletal fluorosis and fracture, are considered to be the most relevant outcomes in assessing the adverse effects of long-term exposure of humans to fluoride.

In areas of the world with high levels of fluoride naturally present in minerals and water, intake of fluoride from drinking water and foodstuffs is the primary cause for endemic skeletal fluorosis, a crippling disability that affects millions of people in various parts of Africa, China and India. In some regions, the indoor burning of fluoride-rich coal also serves as an important source of fluoride.

At total fluoride intakes of 14 mg/day, there is clear evidence of skeletal fluorosis and an increased risk of bone fractures; at total intake levels above about 6 mg fluoride/day the evidence is suggestive of an increased risk of effects on bone.

There is inadequate information for estimating total exposure to fluoride and the uptake into the body from different sources which limits the conclusions on dose response that can be drawn from studies on adverse effects. Excess exposure to fluoride in a form that can be absorbed by organisms poses a risk to aquatic and terrestrial environments.

There is a need to improve the knowledge available on the accumulation of fluoride in organisms and how this can be monitored and controlled.

The biological effects associated with different levels of fluoride exposure should be better characterised.

Annex

Annex 1:

Footnote on the "safe fluoride concentration" figure for the caddisfly species

The figure "1.79 mg/litre" does not come from Level 3 but is directly sourced from the full IPCS source document.

It says:

"Camargo & La Point (1995) calculated "safe concentrations" (8760-h EC0.01s) for the last-instar larvae of several net-spinning caddisfly species. "Safe concentrations" ranged from 0.39 mg fluoride/litre (Hydropsyche pellucidula) to 1.18 (Hydropsyche lobata) and **1.79 mg fluoride/litre** (Chimarra marginata). Further "safe concentrations" were calculated for the caddisfly species Hydropsyche bronta, at 0.2 mg fluoride/litre, and H. occidentalis and Cheumatopsyche pettiti, at 0.7 mg fluoride/litre (Camargo, 1996b)."

Source & © IPCS "Environmental Health Criteria for Fluorides", (EHC 227), Chapter 9 [see http://www.inchem.org/documents/ehc/ehc/ehc227.htm#9.1.2.2]: Effects on other organisms in the laboratory and field