# Chapter 6.5                                          Fluorides

## General description

Fluorine (F) is the most reactive nonmetal and the most electronegative element, and therefore almost never occurs in nature in its elemental state; it combines with all elements, except oxygen and the noble gases, to form fluorides. Sodium fluoride (CAS No. 7681-49-4) appears as an odourless white powder or colourless crystals, with a water solubility of 4% at 15°C and a pH (saturated solution) of 7.4 *(1)*. Hydrogen fluoride or hydrofluoric acid (CAS No. 7664-39-3) is a colourless gas or fuming liquid with strong irritating odour, highly corrosive, very soluble in water and with a vapour pressure of more than 1 atmosphere. Odour detectable limits are 0.033–0.1333 mg/m$^3$, while the irritating concentration is 4.17 mg/m$^3$ *(2)*.

## Sources

Inorganic and organic fluorides are present in all soils and water, as well as in the plants and animals consumed by humans for food *(3)*. Except for industrial emissions, the largest environmental source of fluorides is fluoridated water supplies; fluorine is added deliberately with the aim of preventing *dental* caries. In some parts of the world, deposits of rocks containing a high level of fluoride cause a large increase in the fluoride content of water or food and, consequently, the exposure to fluoride is sufficiently high (usually more than 6 mg/day) to cause endemic fluorosis *(3)*, which is characterized by stiff joints, weight loss, brittle bones, anaemia and weakness. Fluoride is found in insecticides, rodenticides, floor polishes, in the petroleum and aluminium industries, glass etching and timber preservation and in dietary supplementation and toothpastes (up to 1 mg/g of toothpaste), and it is added to water supplies *(4)*. Hydrogen fluoride/hydrofluoric acid is used in the semiconductor industry, the manufacture of chemicals, solvents and plastics, and in laundries.

Supplementation of drinking-water with fluoride has been carried out since 1945. As of 1984, more than 260 million individuals have received fluoridated water throughout the world. In addition, about as many people have been supplied with drinking-water with a natural fluoride content of 1 mg/litre or more. The latter group has had about 50% less dental caries than those with a supply of 0.1–0.3 mg/litre. Effluents from areas with fluoridation have limited influence on the final fluoride level in the fresh-water recipient because, in addition to removal by biological processes, large amounts are precipitated by aluminium, iron and calcium salts during chemical treatment of sewage *(5)*.

## Occurrence in air

Because of its extensive industrial use, hydrogen fluoride is probably the greatest single atmospheric fluoride contaminant *(3)*. The United States Environmental Protection Agency (EPA) has identified 1334 sites eligible for clean-up by the federal authorities *(6)*. Fluorine-containing compounds were found at 130 of these: fluorine at 28, hydrogen fluoride or hydrofluoric acid at 19. These and other sites that may be added in the future are potential or actual sources of human exposure to fluorine-containing compounds. The contribution of volcanic activity to the content of fluoride in the Earth's atmosphere is 1–7 × 10$^6$ tonnes per year *(7)*. Most airborne fluoride in urbanized areas comes from industrial sources: more than 155 000 tonnes were discharged into the atmosphere in 1968 and the

aluminium industry was responsible for about 10% of this emission. In industries such as steel production plants, superphosphate plants, coal-burning power plants, glassworks and oil refineries, occupational exposure to fluoride levels of about 1 mg/m$^3$ may occur. Various types of coal contain fluoride levels in the range 4–30 g/kg *(8,9)*. In a study conducted in the United States of America, the maximum concentration of fluoride in the air was 1.89 µg/m$^3$ *(10)* and similar results were reported from Europe *(11)*.

A high incidence of endemic fluorosis related to air pollution has been reported in China; the major source of air pollution was coal burned by residents in their homes. Another source of pollution is the small kilns used to make bricks and tiles. The fluorine content of the coal and mud used to make bricks and tiles exceeded 10 000 mg/kg, and this resulted in air pollution when the bricks or tiles were fired *(12)*. In the vicinity of a 1000-megawatt coal-fired power plant in the Netherlands, increased wet deposition of fluoride was observed *(13)*. The results of plume wash-out experiments were used to test a wash-out model for predicting the wet removal of major pollutants from a plume. In the immediate vicinity of factories producing fluorides, the amount of fluorides in the ambient air may be much higher for short periods, e.g. 5–20 times the values measured in background samples. However, recently reported values are usually lower owing to improved control technology.

Fluoride ion in air can be determined by collection on a membrane filter followed by treatment with an ion-specific electrode *(14)*.

## Routes of exposure

### Air
Fluorides are emitted into the air in both gaseous and particulate forms. Particulate fluorides in the air around aluminium smelters vary in diameter from 0.1 µm to around 10 µm *(15)*. This means that penetration into the lung alveoli is possible, with resultant health effects.

### Drinking-water
In temperate areas, the optimal level of fluoride was established at 1 mg/litre and this level was connected with a low prevalence of dental caries *(3,16)*. Some mineral waters contain fluoride at a concentration of 8.5 mg/litre and have been associated with skeletal fluorosis *(17)*.

### Food
Comprehensive determinations of fluoride in foods were reported from Finland *(18)* and other European countries *(19)*. Highest values were reported in fish; fish bone fluoride contributed to these, especially in canned fish (0.9–8.0 mg/kg fresh weight) *(18)*.

Various foodstuffs prepared with fluoridated water may contain a fluoride concentration of 0.6–1 mg/kg as compared to the usual concentration of 0.2–0.3 mg/kg *(7)*. One cup of tea contains 1–4 mg of fluoride *(20)*. Fluoride in various beverages may contribute to dental fluorosis in children *(21)*.

Exposure of plants to airborne fluorides leads to deposition on the outer surface and uptake into plant tissues. Fluoride in vegetation contributes to human and animal dietary fluoride. Long-term exposure to concentrations of more than 0.2 µg/m$^3$ may cause injury to plants *(3)*.

**Relative significance of different routes of exposure**

Owing to considerable fluctuations in fluoride levels, there is significant variability in human fluoride intake. In heavily industrialized English cities, the maximum amount of fluoride inhaled daily ranges between 0.01 and 0.04 mg *(22)*. In the Netherlands, it was estimated that children living near industrial sources of fluoride inhaled 0.06 mg of fluoride on a day of maximum pollution *(23)* and similar values were reported from Sweden.

Regarding occupational exposure, the daily amount of fluoride inhaled, assuming a total respiratory rate of 10 $m^3$ during a working day, could be 10–25 mg when the air concentration is at the most frequent exposure limits of 1–2.5 $mg/m^3$ *(24)*. For monitoring of workers, fluoride levels in urine should be checked periodically and skeletal X-ray examinations, particularly of the pelvis, should be performed *(24)*.

The intake of drinking-water by direct consumption and by addition to food was estimated at 0.5– 1.1 mg/day for children aged 1–2 years *(16)*. The mean daily intake of bottle-fed infants in Sweden during the first 6 months of life in areas with optimum fluoride content was estimated at 0.13–0.20 mg/kg body weight *(3)*. In areas where drinking-water contains less than 0.4 mg/litre, the fluoride intake of adults from food and drinking-water does not exceed 1 mg/day. The total diet in areas where water supplies are fluoridated may contain a mean of 2.7 mg/day compared with 0.9 mg/day in non-fluoridated areas *(25)*.

In summary, except under occupational exposure conditions, respirable intake of fluorides is almost negligible. Total fluoride intake depends on fluoride levels in food and beverages, while fluoride in water adds considerably to fluoride levels in prepared food. Additional intentional fluoride intake may occur through the ingestion of fluoride tablets and the use of fluoride-containing therapeutic agents and topical fluoride preparations.

# Toxicokinetics

Soluble fluorides are readily and completely absorbed from the gastrointestinal tract. Bioavailability from dentifrices is 84–100% *(26)*. Following single oral fluoride doses of 1.5–10 mg, plasma fluoride levels reached 0.06–0.4 mg/litre within 30 minutes *(27)*. Pharmacokinetic data showed a multiexponential elimination of plasma fluoride; the initial rapid phase was followed by a slower phase with a half-life of 2–9 hours *(28)*. With normal renal function, fluoride is excreted in hours to days; in the presence of end-stage renal disease, the elimination phase was prolonged up to 2 years *(29)*. Fluoride is not protein-bound and occurs as free ion in the plasma *(28)*. The volume of distribution is 0.5–0.7 litre/kg *(4)*.

Bone deposition of fluoride occurs to the extent of 50% in growing children but only 10% in adults *(30)*. The renal excretion of fluoride is slow; 50% is excreted unchanged daily in the urine *(28)*. Fluoride is also excreted in the faeces and in sweat, and the balance is deposited in bone. Mobilization from calcified tissues is dependent on the fluoride content of bone which reflects previous fluoride intake, mainly in drinking-water.

# Health effects

## Effects on experimental animals and *in vitro* test systems

*Toxicological effects*

The oral $LD_{50}$ in mice is in the range 44.3–46 mg/kg, while in rats it is 51.6 mg/kg. Toxic effects reported in animals were mild fluorosis in cattle when their diet contained sodium fluoride at a concentration of 40 mg/kg, decreased wool production and changes in the teeth of sheep with an average daily fluoride intake of 14 mg over a 7-year period; in fish, weight loss, violent movements, tetany and death were reported after exposure to poisonous amounts of fluoride (3).

*Mutagenic effects*

When tested for mutagenicity, positive results were obtained in the mouse lymphoma test for sodium fluoride. The latter induced unscheduled DNA synthesis in cultured human cells and was not mutagenic in the *Salmonella*/microsome assay at concentrations of up to 4421 µg/plate (4).

## Effects on humans

Fluoride has been classified by the United States National Academy of Sciences (31) as an essential nutrient. Its beneficial as well as its toxic effects in humans have important public health implications. While daily intake of 1–3 mg of fluoride prevents dental caries, long-term exposure to higher amounts may have deleterious effects on tooth enamel and bone; single doses of 5–10 mg/kg body weight cause acute toxic effects, and death was reported following ingestion of 16 mg/kg (3,4). The usual lethal concentration range is 70–140 mg/kg (4).

The toxicity of fluorides is due to the toxicity of the fluoride ion, a direct cellular poison that binds calcium and interferes with the activity of proteolytic and glycolytic enzymes. Fluoride inhibits oxygen consumption and blood clotting and diminishes erythrocyte glycolysis. It also induces efflux of potassium from red blood cells; the resulting hyperkalaemia and hypocalcaemia have been implicated as contributing factors in fluoride-induced arrhythmias (29,32).

The acute effects of hydrogen fluoride inhalation are extreme irritation of the respiratory tract with coughing and choking; upon contact with skin and eyes, the liquid or vapour causes severe irritation that may result in severe burns and prolonged or permanent visual defects.

Following ingestion, fluorides react with gastric acid to produce highly corrosive hydrofluoric acid which causes nausea, vomiting, diarrhoea, abdominal pains and haemorrhagic gastroenteritis, cardiac arrhythmias, hyperactive reflexes and tetanic contractures due to hypocalcaemia. Respiration is first stimulated, then depressed. Death is usually caused by respiratory paralysis (4).

Chronic effects from inhalation or ingestion are fluorosis, weight loss, malaise, anaemia, discoloration of teeth and osteosclerosis (brittle bones, calcified ligaments) (3). Fifty cases of mild skeletal fluorosis and periosteal thickening were described in a German study of people residing for 20 years within 2 km of industrial fluoride pollution (33).

Dust pollution from a phosphate mine was identified as the cause of extensive dental fluorosis in several hundred children living within 1–1.5 km of a mine that used old emission control technology

*(34)*. Increasing prevalence of dental fluorosis with increasing water fluoride level was found by Myers *(35)*. Dental fluorosis, osteoporosis and osteosclerosis were more frequent than in controls in a study performed in children living in areas polluted by aluminium plant waste *(36)*. Adverse effects have been attributed to daily ingestion of large amounts of fluoride for the treatment of osteoporosis *(37,38)*.

The health effects of fluoride intake in drinking-water are summarized in Table 1 *(39)*.

### Table 1. Fluoride intake in drinking-water and health effects

| Drinking-water fluoride concentration (mg/litre) | Health effect | Population affected (%) |
| --- | --- | --- |
| 1 | Dental fluorosis | 1–2 |
| 2 | Dental fluorosis | 10 |
| 2.4–4.1 | Dental fluorosis | 33 |
| 8 | Osteosclerosis (on X-ray) | -- |

*Source*: Kaminsky *(39)*.

Transplacental passage of fluoride was studied in 25 randomly selected neonates in India. Average fluoride concentration in cord blood was 60% of that in the mother's blood *(40)*. Some functional changes in the testicles and increase in fetal death rate were observed after exposure to lead fluoride dust at a concentration of 50 mg/m$^3$ in a Russian study *(41)*.

No evidence has been found of an association between fluoride and mortality from cancer in humans *(42)*.

As regards industrial exposure, establishment of dose–response relationships has been difficult. The parameters used were air concentrations and urinary fluoride. There was good correlation between the concentrations of fluoride in post-shift serum and urine, and a linear relationship was observed between mean serum and urinary fluoride concentrations and hydrogen fluoride concentration in the workplace: 82.3 µg/litre in serum and 4 mg/litre in urine corresponded to an atmospheric hydrogen fluoride concentration of 2.5 mg/m$^3$, which was the threshold limit value (TLV) in Japan, where the study was carried out *(43)*. The current TLV in the United States is 2.3 mg/m$^3$.

Bronchial hyper-reactivity was the main health effect at a mean hydrogen fluoride concentration of 0.56 mg/m$^3$ and a mean particulate fluoride concentration of 0.15 mg/m$^3$ *(44)*. The risk for developing asthmatic symptoms, i.e. dyspnoea and wheezing was 3.4 and 5.2 times higher in the medium- and high-exposure groups, respectively, as shown in Table 2 *(45)*. The data in Table 2 show that total fluoride exposure, together with smoking was the major risk factor for the development of dyspnoea and wheezing in aluminium potroom workers; the incidence of symptoms

decreased after the first year of employment. No allergenic, carcinogenic or teratogenic hazards have been attributed to fluoride *(3,4)*.

**Table 2. Risk estimate for the development of dyspnoea
and wheezing in aluminium potroom workers**

| Fluoride exposure (mg/m$^3$) | Risk estimate | 95% confidence interval |
|---|---|---|
| 0–0.4 | 1.00 | - |
| 0.41–0.8 | 3.35 | 1.51–7.41 |
| >0.8 | 5.20 | 2.02–13.34 |

*Source*: Kongerud & Samuelsen *(45)*.

## Evaluation of human health risks

### Exposure evaluation

Exposure of the general European population to fluoride in its various chemical forms is highly variable. In heavily industrialized urban areas, typical daily inhalation intakes are in the range 10–40 µg/day (0.5–2 µg/m$^3$), and in some cases are as high as 60 µg/day (3 µg/m$^3$). Fluorides are emitted to the atmosphere in both gaseous and particulate forms, but studies typically only report total fluoride content.

The main sources of fluoride intake by humans are food and water. Except for occupational exposure, exposure to fluoride by inhalation is negligible.

Regarding occupational exposure, the daily amount of fluoride inhaled assuming a total respiratory rate of 10 m$^3$ during a working day could be 10–25 mg when the air concentration is at the most frequent exposure limits of 1–2.5 mg/m$^3$.

### Health risk evaluation

The most important long-term adverse effect of fluorides on human populations is endemic skeletal fluorosis. The beneficial effect is prevention of caries, as a result of both fluoride incorporation into developing teeth and post-eruptive exposure of enamel to adequate levels of fluoride. It is therefore of crucial importance to gather information on fluoride sources in the diet, especially water, the etiology of early skeletal fluorosis as related to bone mineralization, and dose–response relationships *(3)*.

The earliest reports of skeletal fluorosis appeared from industries where exposure of workers to 100–500 µg/m$^3$ per 8-hour day for more than 4 years led to severe skeletal changes. Skeletal fluorosis has also been diagnosed in persons living in areas with excessive fluoride in soil, water, dust or plants *(3)*.

In one study, bronchial hyper-reactivity was the main health effect at a mean fluoride concentration of 0.56 mg/m$^3$ and a mean particulate fluoride concentration of 0.15 mg/m$^3$. In a longitudinal study performed on 523 aluminium potroom workers, total fluoride was the most important risk factor among the exposure variables. In this study, the risk for developing asthmatic symptoms, i.e. dyspnoea and wheezing, was 3.4 and 5.2 times higher in the medium- and high-exposure groups, respectively, than in the low exposure group. Exposure to other pollutants was limited and did not appear to confound the results.

Children living in the vicinity of a phosphate processing facility who were exposed to concentrations ranging from about 100 to 500 µg/m$^3$ exhibited an impairment of respiratory function. It is not known, however, whether the concentrations were gaseous or total fluoride. In another study, no effects on respiratory function were observed at gaseous fluoride levels of up to 16 µg/m$^3$.

There is no evidence that atmospheric deposition of fluorides results in significant exposure through other routes (e.g. through contamination of soil and consequently groundwater).

**Guidelines**

For exposure of the general population to fluoride, reference exposure levels have been derived by applying a "benchmark dose" approach to a variety of animal and human exposure studies. The 1-hour reference exposure level to protect against any respiratory irritation is about 0.6 mg/m$^3$, and the level to protect against severe irritation from a once in a lifetime release is about 1.6 mg/m$^3$ *(46)*.

Data from various sources indicate that prolonged exposure of humans (workers and children) to fluoride concentrations of between 0.1 and 0.5 mg/m$^3$ leads to impairment of pulmonary function and skeletal fluorosis. No effects have been found at levels of up to 16 µg/m$^3$ gaseous fluoride. However, the available information does not permit the derivation of an air quality guideline value for fluoride(s).

Skeletal fluorosis is associated with a systemic uptake exceeding 5 mg/day in a relatively sensitive section of the general population. Systemic uptake from food and fluoridated water is about 3 mg/day. It is highly unlikely that ambient air concentrations of fluorides could pose any material risk of fluorosis.

It has been recognized that fluoride levels in ambient air should be less than 1 µg/m$^3$ to prevent effects on livestock and plants. These concentrations will also sufficiently protect human health.

# References

1.   BUDVARI, S. *The Merck index*, 11th ed. Rahway, NJ, Merck, 1989.
2.   RUTH, J.H. Odor thresholds and irritation levels of several chemical substances: a review. *American Industrial Hygiene Association journal,* **47:** 142–151 (1986).
3.   *Fluorine and fluorides*. Geneva, World Health Organization, 1984 (Environmental Health Criteria, No. 36).
4.   *CCIS (R): Computerized Clinical Information System*. Denver, CO, Micromedex Inc., 1994.
5.   SINGER, L. & ARMSTRONG, W.D. Fluoride in treated sewage and in rain and snow. *Archives of environmental health,* **32:** 21–33 (1977).

6.    CANADY, R. ET AL. Toxicological profile for fluorides, hydrogen fluoride and fluorine. *Government reports, announcements and index,* Vol. 24 (1993).

7.    *Reviews of the environmental effects of pollutants: IX Fluoride*. Cincinnati, OH, US Environmental Protection Agency, 1980 (EPA-600/1-78-050).

8.    MCDONALD, H.E. & BERKELEY, P.D.  Fluoride as air pollutant. *Fluoride: quarterly reports,* **2:** 4–12 (1969).

9.    ROBINSON, J.M. ET AL. *Engineering and cost effectiveness study of fluoride emissions control, Vol. 1 (Final report).* Springfield, VA, US Environmental Protection Agency, 1972.

10.   THOMPSON, R.J. ET AL. Fluoride concentrations in the ambient air. *Journal of the Air Pollution Control Association,* **21:** 484–487 (1971).

11.   LEE, R.E. ET AL. The distribution and transport of airborne particulate matter and inorganic components in Great Britain. *Atmospheric environment,* **8:** 1095–1109 (1974).

12.   CHEN, Y. ET AL. Air pollution-type fluorosis in the region of Pingxyang, Jiangxi, People's Republic of China. *Archives of environmental health,* **48:** 246–249 (1993).

13.   TEN BRINK, H.M. ET AL. Plume wash-out near a coal-fired power plant: measurements and model calculations. *Atmospheric environment,* **22:** 177–188 (1988).

14.   *NIOSH manual of analytical methods,* 3rd ed., Vol. 1. Washington, DC, US Government Printing Office, 1984.

15.   LESS, L.N. ET AL. Fluorine uptake by grass from aluminum smelter fume. *International journal of environmental studies,* **7:** 153–160 (1975).

16.   MCCLURE, F.J. Ingestion of fluoride and dental caries. Quantitative relations based on food and water requirements of children one to twelve years old. *American journal for diseases of children,* **66:** 362–369 (1953).

17.   LANZ, O. ET AL. Fluoride-induced chronic renal failure. *American journal of kidney disease,* **10:** 136–139 (1987).

18.   KOIVISTOINEN, P. Mineral element composition of Finnish foods. I. General description of the study. *Acta agricola scandinavica,* **22**(Suppl.)**:** 7–13 (1980).

19.   TOTH, K.I. & SUGAR, E. Fluorine content of foods and estimated daily intake from foods. *Acta physiologica hungarica,* **51:** 361–369 (1978).

20.   RICHMOND, V. Thirty years of fluoridation: a review. *American journal of clinical nutrition,* **41:** 129–138 (1985).

21.   LEVI, S.M. & ZAREI M.Z. Evaluation of fluoride exposures in children. *Journal of dentistry for children,* **58:** 467–472 (1991).

22.   MARTIN, A.E. & JONES, C.M. Some medical considerations regarding atmospheric fluorides. *HSMA health reports,* **86:** 752–758 (1971).

23.   BIERSTEKER, K. ET AL. Fluoride excretion in urine of school children living close to an aluminum refinery in the Netherlands. *Environmental research,* **13:** 129–134 (1977).

24.   *Occupational exposure limits for airborne toxic substances,* 2nd ed. Geneva, International Labour Office, 1980 (Occupational Safety and Health Series, No. 37).

25.   KUMPULAINEN, J. & KOIVISTOINEN, P. Fluorine in foods. *Residue reviews,* **68:** 37–57 (1977).

26.   DRUMMOND, B.K. ET AL. Estimation of fluoride absorption from swallowed fluoride tooth pastes. *Caries research,* **24:** 211–215 (1990).

27.   TRAUTNER, K. & EINWAG, J. Human plasma fluoride levels following intake of dentifrices containing aminefluoride or monofluorophosphate. *Archives of oral biology,* **33:** 543–546 (1988).

28.  EKSTRAND, J. ET AL. Pharmacokinetics of fluoride in man after single and multiple oral doses. *European journal of clinical pharmacology,* **12:** 311–317 (1977).

29.  MCIVOR, M.E. Acute fluoride toxicity: pathophysiology and management. *Drug safety,* **5:** 79–85 (1990).

30.  HEIFETZ, S.B. & HOROWITZ, H.S. The amounts of fluoride in self-administered dental products: safety considerations for children. *Pediatrics*, **77:** P876–P882 (1986).

31.  NATIONAL RESEARCH COUNCIL, FOOD AND NUTRITION BOARD. *Recommended daily allowances*, 9th ed. Washington, DC, National Academy of Sciences, 1980, pp. 156–159.

32.  MCIVOR, M.E. Sudden cardiac death from fluoride intoxication: the role of potassium. *Annals of emergency medicine*, **16:** 777–781 (1987).

33.  SCHMIDT, C.W. [Neighborhood fluorosis.] *Deutsches Gesundheitswesen*, **31:** 1700–1703 (1976) [in German].

34.  MOLLER, I.J. & POULSE, S. A study of dental mottling in children in Khouribga, Morocco. *Archives of oral biology,* **20:** 601–607 (1975).

35.  MYERS, H.M. Dose–response relationship between water fluoride levels and the category of questionable dental fluorosis. *Community dental and oral epidemiology,* **11:** 109–112 (1983).

36.  ZHUMATOV, U.ZH. [The status of the teeth and periodontal tissues of children living in an area polluted by the wastes from an aluminum plant.] *Stomatologiia (Moskva)*, **72:** 61–64 (1993).

37.  GRENNAN, D.M. ET AL. Iatrogenic fluorosis. *Australian and New Zealand journal of medicine,* **8:** 528–531 (1978).

38.  KANIS, J.A. Treatment of symptomatic osteoporosis with fluoride (review). *American journal of medicine,* **95** (Suppl.): 53S–61S (1993).

39.  KAMINSKY, L.S. ET AL. Fluoride: benefits and risks of exposure (review). *Critical review in oral biology and medicine*, **1:** 261–281 (1990).

40.  GUPTA, S. ET AL. Transplacental passage of fluorides. *Journal of pediatrics,* **123:** 139–141 (1993).

41.  FILIN, A.S. ET AL. The late effects of exposure to lead fluoride. *Gigiena I Sanitariia,* **3:** 28–29 (1992) [in Russian].

42.  *Some aromatic amines, anthraquinones and nitroso compounds and inorganic fluorides used in drinking water and dental preparations.* Lyon, International Agency for Research on Cancer, 1982 (IARC Monographs on the Carcinogenic Risk of Chemicals to Humans, Vol. 27).

43.  KONO, K. ET AL. Urine, serum and hair monitoring of hydrofluoric acid workers. *International archives of occupational environment and health,* **65:** S95–S98 (1993).

44.  SARIC, M. ET AL. The role of atopy in potroom workers' asthma. *American journal of industrial medicine,* **9:** 239–242 (1986).

45.  KONGERUD, J. & SAMUELSEN, S.O. A longitudinal study of respiratory symptoms in aluminum potroom workers. *American review of respiratory diseases,* **144:** 10–16 (1991).

46.  ALEXEEF, G.V. ET AL. Estimation of potential health effects from acute exposure to hydrogen fluoride using a "benchmark dose" approach. *Risk analysis*, **13:** 63–69 (1993).