

## IMPACT OF FLUORIDE ON ENVIRONMENT & HUMAN HEALTH

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### ABSTRACT

**Fluoride is a threat to the environment and human health. Developed and developing countries are facing so many problems due to presence of fluoride in the drinking water. Human exposure to fluoride has mushroomed since World War II, due to not only fluoridated water and toothpaste but to the environmental pollution by major industries, from aluminum to pesticides, where fluoride is a critical industrial chemical as well as a waste-by product. The current paper deals with the amount of fluoride in the environment and its impact on human health, mainly on the Brain, Endocrine System, Thyroid, Pineal Gland, Immune System, Reproductive System and Organ Systems.**

**Keywords:** Fluoride, Environment, Drinking water, Health effect

### I. INTRODUCTION

Fluorides are organic and inorganic compounds containing the fluorine element, formed by halogen family (Fluorine F, chlorine Cl, bromine Br and iodine I). 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<sub>2</sub>), Sodium fluoride (NaF), sulfur hexafluoride (SF<sub>6</sub>) and Silico fluorides. Fluoride is a nontoxic compound for recommended dose but change to toxic if dose increases up to the standard level. Fluoride is associated with bones and teeth within 24 h of ingestion: that which is not retained is usually eliminated via the kidneys. Various factors affect the retention of fluoride in the body, such as diet and metabolism and age. Required levels of fluoride are estimated to be approximately 0.1 to 0.5 mg F/d for children less than 6 months old, while for adults the range is 4.5 to 4.0 mg F/d. However neither diet nor fluoride by themselves will eradicate dental disease; both proper diet and fluoridation are essential for optimum dental health. Too much fluoride during early childhood

can lead to dental fluorosis as a result of the enamel failing to crystallize properly [1].

### II. AMOUNT OF FLUORIDE IN ENVIRONMENT

Fluoride levels in surface waters vary according to location and proximity to emission sources. Surface water concentrations generally range from 0.01 to 0.3 mg/litre. Seawater contains more fluoride than fresh water, with concentrations ranging from 1.2 to 1.5 mg/litre. Higher levels of fluoride have been measured in areas where the natural rock is rich in fluoride, and elevated inorganic fluoride levels are often seen in regions where there is geothermal or volcanic activity (25–50 mg fluoride/litre in hot springs and geysers and as much as 2800 mg/litre in certain East African Rift Valley lakes). Anthropogenic discharges can also lead to increased levels of fluoride in the environment. Airborne fluoride exists in gaseous and particulate forms, which are emitted from both natural and anthropogenic sources. Fluoride released as gaseous and particulate matter is deposited in the general vicinity of an emission source, although some particulates may react with other atmospheric constituents. The distribution and deposition of airborne fluoride are dependent upon emission strength, meteorological conditions, particulate size and chemical reactivity. In areas not in the direct vicinity of emission sources, the mean concentrations of fluoride in ambient air are generally less than 0.1 µg/m<sup>3</sup>. Levels may be slightly higher in urban than in rural locations; however, even in the vicinity of emission sources, the levels of airborne fluoride usually do not exceed 2–3 µg/m<sup>3</sup>. In areas of China where fluoride-rich coal is used as a source of fuel, reported concentrations of fluoride in ambient air have reached 6 µg/m<sup>3</sup>. Fluoride is a component of most types of soil, with total fluoride concentrations ranging from 20 to 1000 µg/g in areas without natural phosphate or fluoride deposits and up to several thousand micrograms per gram in mineral soils with deposits of fluoride [2]. Airborne gaseous and particulate fluorides tend to accumulate within the surface layer of soils but may be displaced throughout the root zone, even in calcareous soils. The clay and organic carbon content as well as the pH of soil are

primarily responsible for the retention of fluoride in soils. Fluoride in soil is primarily associated with the soil colloid or clay fraction. For all soils, it is the soluble fluoride content that is biologically important to plants and animals [3].

### III. FLUORIDE RELEASED INTO THE ENVIRONMENT

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

**2. 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 aluminums. 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 [4].

### IV. IMPACT ON HUMAN HEALTH

#### A. Fluoride's effect on the brain

On the basis on information largely derived from histological, chemical and molecular studies, it is apparent that fluorides have the ability to interfere with the functions of the brain and the body by direct and indirect means. A few epidemiologic studies of Chinese populations have reported IQ deficits in children exposed to fluoride at 2.5 to 4 mg/L in drinking water. Although the studies lacked sufficient detail for the committee to fully assess their quality and relevance to U.S. populations, the consistency of the results appears significant enough to warrant additional research on the effects of fluoride on intelligence. Fluorides also increase the production of free radicals in the brain through several different biological pathways. These changes have a bearing on the possibility that fluorides act to increase the risk of developing Alzheimer's disease. Studies of populations exposed to different concentrations of fluoride should be undertaken to evaluate neurochemical changes that may be associated with dementia. Consideration should be given to assessing effects from chronic exposure, effects that might be delayed or occur late-in-life, and individual susceptibility [5].

#### B. Fluoride's effect on Endocrine System

In summary, evidence of several types indicates that fluoride affects normal endocrine function or response; the effects of the fluoride-

induced changes vary in degree and kind in different individuals. Fluoride is therefore an endocrine disruptor in the broad sense of altering normal endocrine function or response, although probably not in the sense of mimicking a normal hormone. The mechanisms of action remain to be worked out and appear to include both direct and indirect mechanisms, for example, direct stimulation or inhibition of hormone secretion by interference with second messenger function, indirect stimulation or inhibition of hormone secretion by effects on things such as calcium balance, and inhibition of peripheral enzymes that are necessary for activation of the normal hormone. Some of these [endocrine] effects are associated with fluoride intake that is achievable at fluoride concentrations in drinking water of 4 mg/L or less, especially for young children or for individuals with high water intake. Many of the effects could be considered subclinical effects, meaning that they are not adverse health effects. However, recent work on borderline hormonal imbalances and endocrine-disrupting chemicals indicated that adverse health effects, or increased risks for developing adverse effects, might be associated with seemingly mild imbalances or perturbations in hormone concentrations. Further research is needed to explore these possibilities [6].

#### C. Fluoride's effect on the Thyroid

Several lines of information indicate an effect of fluoride exposure on thyroid function. It is difficult to predict exactly what effects on thyroid function are likely at what concentration of fluoride exposure and under what circumstances. In humans, effects on thyroid function were associated with fluoride exposures of 0.05-0.13 mg/kg/day when iodine intake was adequate and 0.01-0.03 mg/kg/day when iodine intake was inadequate. Intake of nutrients such as calcium and iodine often is not reported in studies of fluoride effects. The effects of fluoride on thyroid function, for instance, might depend on whether iodine intake is low, adequate, or high, or whether dietary selenium is adequate.

#### D. Fluoride's effect on the Pineal Gland

The single animal study of pineal function indicates that fluoride exposure results in altered melatonin production and altered timing of sexual maturity. Whether fluoride affects pineal function in humans remains to be demonstrated. The two studies of menarcheal age in humans show the possibility of earlier menarche in some individuals exposed to fluoride, but no definitive statement can be made. Recent information on the role of the pineal organ in humans suggests that any agent

that affects pineal function could affect human health in a variety of ways, including effects on sexual maturation, calcium metabolism, parathyroid function, postmenopausal osteoporosis, cancer, and psychiatric disease.

#### **E. Fluoride's effect on Insulin Secretion/Diabetes**

The conclusion from the available studies is that sufficient fluoride exposure appears to bring about increases in blood glucose or impaired glucose tolerance in some individuals and to increase the severity of some types of diabetes. In general, impaired glucose metabolism appears to be associated with serum or plasma fluoride concentrations of about 0.1 mg/L or greater in both animals and humans. In addition, diabetic individuals will often have higher than normal water intake, and consequently, will have higher than normal fluoride intake for a given concentration of fluoride in drinking water. An estimated 16-20 million people in the U.S. have diabetes mellitus; therefore, any role of fluoride exposure in the development of impaired glucose metabolism or diabetes is potentially significant [7].

#### **F. Fluoride's effect on Immune System**

Nevertheless, patients who live in either an artificially fluoridated community or a community where the drinking water naturally contains fluoride at 4 mg/L have all accumulated fluoride in their skeletal systems and potentially have very high fluoride concentrations in their bones. The bone marrow is where immune cells develop and that could affect humoral immunity and the production of antibodies to foreign chemicals. There is no question that fluoride can affect the cells involved in providing immune responses. The question is what proportion, if any, of the population consuming drinking water containing fluoride at 4.0 mg/L on a regular basis will have their immune systems compromised? Not a single epidemiologic study has investigated whether fluoride in the drinking water at 4 mg/L is associated with changes in immune function [8]. Nor has any study examined whether a person with an immunodeficiency disease can tolerate fluoride ingestion from drinking water. It is paramount that careful biochemical studies be conducted to determine what fluoride concentrations occur in the bone and surrounding interstitial fluids from exposure to fluoride in drinking water at up to 4 mg/L, because bone marrow is the source of the progenitors that produce the immune system cells.

#### **G. Fluoride's Interactive /Synergistic effect**

Intake of nutrients such as calcium and iodine often is not reported in studies of fluoride effects. The effects of fluoride on thyroid function, for instance, might depend on whether iodine intake is low, adequate, or high, or whether dietary selenium is adequate. Another possible explanation for increased blood lead concentrations which has not been examined is the effect of fluoride intake on calcium metabolism; indicates that higher blood and tissue concentrations of lead occur when the diet is low in calcium. Increased fluoride exposure appears to increase the dietary requirement for calcium in addition, the substitution of tap-water based beverages (e.g., soft drinks or reconstituted juices) for dairy products would result in both increased fluoride intake and decreased calcium intake. With the increasing prevalence of acid rain, metal ions such as aluminum become more soluble and enter our day-to-day environment; the opportunity for bioactive forms of AIF to exist has increased in the past 100 years. Human exposure to aluminofluorides can occur when a person ingests both a fluoride source (e.g., fluoride in drinking water) and an aluminum source; sources of human exposure to aluminum include drinking water, tea, food residues, infant formula, aluminum-containing antacids or medications, deodorants, cosmetics, and glassware [13].

#### **H. Fluoride's effect on the Reproductive System**

A few human studies suggested that high concentrations of fluoride exposure might be associated with alterations in reproductive hormones, effects on fertility, and developmental outcomes, but design limitations make those studies insufficient for risk evaluation.

#### **I. Fluoride's effect on the Gastrointestinal System**

The numerous fluoridation studies in the past failed to rigorously test for changes in GI symptoms and there are no studies on drinking water containing fluoride at 4 mg/L in which GI symptoms were carefully documented. GI effects appear to have been rarely evaluated in the fluoride supplement studies that followed the early ones in the 1950s and 1960s. There are a few case reports of GI upset in subjects exposed to drinking water fluoridated at 1 mg/L. Those effects were observed in only a small number of cases, which suggest hypersensitivity. However, the available data are not robust enough to determine whether that is the case.

#### **J. Fluoride's effect on the Kidney**

The kidneys play a vital role in preventing the build-up of excessive fluoride in the body. Among healthy individuals, the kidneys excrete approximately 50% of the daily fluoride intake. However, among individuals with kidney disease, the kidneys' ability to excrete becomes markedly impaired, resulting in a build-up of fluoride within the body. It is well recognized that individuals with kidney disease have a heightened susceptibility to the cumulative toxic effects of fluoride. Of particular concern is the potential for fluoride, when accumulated in the skeletal system, to cause, or exacerbate, renal osteodystrophy - a bone disease commonly found among people with advanced kidney disease. In addition, fluoride has been definitively shown to poison kidney function at high doses over short-term exposures in both animals and humans. The impact of low doses of fluoride, given over long periods of time, has been inadequately studied. A recent animal study, conducted by scientists at the US Environmental Protection Agency reported that exposure to just 1 ppm fluoride caused kidney damage in rats if they drank the water for an extended period of time, while a new study from China found an increased rate of kidney disease among humans consuming more than 2 ppm [9]. Hence, the adverse effects to kidney function that fluoride causes at high doses over short periods of time may also be replicated with small doses if consumed over long periods of time.

#### **K. Fluoride's effects on the Teeth**

According to the current consensus view of the dental research community, fluoride's primary - if not sole-benefit to teeth comes from TOPICAL application to the exterior surface of teeth, not from ingestion. Perhaps not surprisingly, therefore, tooth decay rates have declined at similar rates in all western countries in the latter half of the 20th century - irrespective of whether the country fluoridates its water or not. Today, tooth decay rates throughout continental Western Europe are as low as the tooth decay rates in the United States - despite a profound disparity in water fluoridation prevalence in the two regions. Within countries that fluoridate their water, recent large-scale surveys of dental health - utilizing modern scientific methods not employed in the early surveys from the 1930s-1950s - have found little difference in tooth decay, including "baby bottle tooth decay", between fluoridated and unfluoridated communities [10,12].

#### **L. Fluoride's causes Cancer**

Fluoride appears to have the potential to initiate or promote cancers, particularly of the bone, but the evidence to date is tentative and mixed. As noted above, osteosarcoma is of particular concern as a potential effect of fluoride because of (1) fluoride deposition in bone, (2) the mitogenic effect of fluoride on bone cells, (3) animal results described above, and (4) pre-1993 publication of some positive, as well as negative, epidemiologic reports on associations of fluoride exposure with osteosarcoma risk. Osteosarcoma presents the greatest a priori plausibility as a potential cancer target site because of fluoride's deposition in bone, the NTP animal study findings of borderline increased osteosarcomas in male rats, and the known mitogenic effect of fluoride on bone cells in culture [11]. Principles of cell biology indicate that stimuli for rapid cell division increase the risks for some of the dividing cells to become malignant, either by inducing random transforming events or by unmasking malignant cells that previously were in nondividing states. Fluoride exposure has also been linked to bladder cancer - particularly among workers exposed to excess fluoride in the workplace. According to the US National Research Council, "further research on a possible effect of fluoride on bladder cancer risk should be conducted.

#### **M. Effects on Other Organ Systems**

The committee also considered effects on the gastrointestinal system, kidneys, liver, and immune system. There were no human studies on drinking water containing fluoride at 4 mg/L in which gastrointestinal, renal, hepatic, or immune effects were carefully documented. Case reports and in vitro and animal studies indicated that exposure to fluoride at concentrations greater than 4 mg/L can be irritating to the gastrointestinal system, affect renal tissues and function, and alter hepatic and immunologic parameters. Such effects are unlikely to be a risk for the average individual exposed to fluoride at 4 mg/L in drinking water. However, a potentially susceptible subpopulation comprises individuals with renal impairments who retain more fluoride than healthy people do.

#### **V. A CASE STUDY**

Fluoride occurs in almost all waters from trace to high concentrations and both, lower (0.6 mg/l) and upper (1.2 mg/l) limits of concentration in drinking water, is responsible for health effect and benefits for human beings. Very low doses of fluoride (<0.6 mg/l) in water promote tooth decay. However, when consumed in higher doses (>1.5 mg/l), it leads to dental fluorosis or mottled enamel

and excessively high concentration (>3.0 mg/l) of fluoride may lead to skeletal fluorosis.

In India, an estimated 62 million people, including 6 million children suffer from fluorosis because of consuming fluoride-contaminated water. Although fluorosis was identified as early as 1937, a programme for controlling the disease through networking between State Rural Drinking Water Supply Implementing Agencies and Health Departments was launched during 1986–87.

Generally, high fluoride contamination in hard-rock terrain is common due to water quality variation and changes in shallow and deep aquifers zones. But, in alluvial plain groundwater, the variation and changes in fluoride levels are usually rare. A number of cases of fluorosis have been reported mostly from the granite and gneissic complex of different states such as Andhra Pradesh, Delhi, Madhya Pradesh and Rajasthan (Table 1).

**Table 1: Fluoride concentration in the groundwater in different states of India**

S No.	Location	Fluoride (mg/l)
1	Guntur, Andhra Pradesh	0.6–2.5
2	Anantapur, Andhra Pradesh	0.56–5.8
3	Hyderabad, Andhra Pradesh	0.38–4.0
4	Ranga Reddy, Andhra Pradesh	0.4–4.8
5	Delhi	0.2–32.5
6	Chandidongri, Madhya Pradesh	1.5–4
7	Shivpuri, Madhya Pradesh	0.2–6.4
8	Churu, Rajasthan	0.1–14
9	Dungarpur, Rajasthan	0.1–10
10	Varanasi, Uttar Pradesh	0.2–2.1
11	Agra, Uttar Pradesh	0.1–17.5
12	Mathura, Uttar Pradesh	0.6–2.5
13	Sonbhadra District, Uttar Pradesh	0.483–6.7

In the Ganga alluvial plain of Uttar Pradesh (UP), fluoride content has been reported by various researchers, and State and Central Governments in the districts of Varanasi, Unnao, Kanpur, Agra and Mathura (Table 1). Fluoride contamination in many parts of UP (Unnao, 2 mg/l; Debraspur, 2.1 mg/l; Janghai, 3.2 mg/l; Kulpahar, 3 mg/l; Babera, 3.3 mg/l; Karchhana, 2.8 mg/l; Jhansi, 2.8 mg/l, and Etah, 3 mg/l) has been reported mainly in the Quarternary–Upper Tertiary deposits.

The study area located in the Chopan block, experiences semi-arid and arid climate, with an average annual minimum and maximum temperatures 10°C and 47°C respectively. Since fluorite, apatite, mica and various other minerals take part during rock–water interaction and liberate fluoride into the groundwater, it is imperative to know the presence of minerals in the rock specimen microscopically. Normally biotite in granite rocks may contain as high as 0.91% fluorine, hornblende contains 0.17% fluorine and fluorapatite has fluorine concentration as high as 3.72%. The data shows 20–30% quartz, 40–45% feldspar, 5–10% apatite, 20–25% biotite with minor chlorite and sphene. Feldspar is occasionally sericitized. Apatite grains are euhedral to subhedral with variable grain size (elongated grains are

sometimes as long as 200 μm) and are closely associated with the hydrous minerals at the boundary of the coarse grained feldspar and quartz. As far as immediate association is concerned, apatite grains are closely related to biotite and at places chlorite and myrmekites. The close association of apatite grains with the hydrous phases and myrmekites at the grain boundary of feldspar megacrysts is probably caused by the late fluid activity from crystallization of the granite body [12,14].

The present study of groundwater quality with reference to fluoride concentration in the Kachnarwa region indicated that the ground water are alkaline in nature. Fluoride concentration in the ground water of the study area varied from 0.483 to 6.7 mg/l. High fluoride concentration was found in the villages covered with granitic gneissic complexes than the other rock formations. The highest fluoride concentration was found to corroborate with low calcium values and high sodium content in the ground water. Weathering and leaching of fluorine-bearing minerals in rock formations under alkaline environment lead to the enrichment of fluoride in the ground water. Among the 13 groundwater samples analysed in the study area, 47% of samples had high fluoride content

than the maximum permissible limit (1.5 mg/l). A high rate of evapo-transpiration, comparatively low rainfall, intensive irrigation and heavy use of fertilizers, alkaline environment, longer residence time of water in the weathered aquifer zone and low rate of dilution are favourable factors for the dissolution of fluorine-bearing minerals and thereby increase of fluoride concentration in the groundwater [14].

## VI. CONCLUSION

The present study was confined to a small area in the Kachnarwa region. A more detailed study is necessary for better understanding of the source and effects of fluoride problems in other parts of the Sonbhadra District. Local people ingesting the groundwater have not received medical attention in the study area till date. Since these people are dependent on the groundwater for domestic use, remedial measures such as importing of drinking water and rainwater harvesting are needed. Nutritional diet such as calcium and phosphorus-rich food should be recommended to those affected with fluorosis, as it decreases rate of accumulation of fluoride in the human body. Environmental awareness programme for the health implications of fluoride should be emphasized through education of the public and community participation [12,14].

Public Health Service recommendations for fluoride use include an optimally adjusted concentration of fluoride in community drinking water to maximize caries prevention and limit enamel fluorosis. This concentration ranges from 0.7 ppm to 1.2 ppm depending on the average maximum daily air temperature of the area [1, 2]. In 1991, PHS also issued policy and research recommendations for fluoride use. The U.S. Environmental Protection Agency (EPA), which is responsible for the safety and quality of drinking water in the United States, sets a maximum allowable limit for fluoride in community drinking water at 4 ppm and a secondary limit (nonenforceable guideline) at 2 ppm [3,4]. The U.S. Food and Drug Administration (FDA) is responsible for approving prescription and over-the-counter fluoride products marketed in the United States and for setting standards for labeling bottled water and over-the-counter fluoride products [5]. A dosage schedule for fluoride supplements for infants and children aged  $\leq 16$  years, which is scaled to the fluoride concentration in the community drinking water, has been jointly recommended by ADA, the American Academy of Pediatric Dentistry (AAPD), and the American

Academy of Pediatrics (AAP). In 1997, the Institute of Medicine published age-specific recommendations for total dietary intake of fluoride. These recommendations list adequate intake to prevent dental caries and tolerable upper intake, defined as a level unlikely to pose risk for adverse effects in almost all persons [6,7].

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