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FLUORIDE CONTAMINATION IN FOODS AND DRINKING WATER: A REVIEW ON ITS TOXIC EFFECTS AND MITIGATION STRATEGIES

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ABSTRACT: One major element that can be found in abundance on Earth is fluorine. Even at very low concentrations, it has xenobiotic effects on the environment. It travels in water and the atmosphere after being released from minerals, and industrial processing. For oral health, it is advantageous at low concentrations. Fluoride exposure at high levels can result in a variety of toxicological issues. Fluoride poisoning affects the entire environment, including the soil, plants, surface water, marine life, and animals. The main sources of fluoride for humans are food and water consumption. Fluorosis will now be a global issue due to its toxicological issues. In conclusion, the accumulation of fluoride in soil has the potential to have long-term negative effects on plant development.

Keywords: Fluoride toxicity, Physio-biochemical activity, Phytoremediation, Dental fluorosis, Drinking water, Health risk.

INTRODUCTION

Water is basic to life on earth and crucial for all human dwelling places. It is the medium from which life evolved and all flora and animal existence relies on water. Water makes up the biggest constituent of living organisms comprising approximately 60% of human body and 80–90% of the body mass of most aquatic organisms. Water is an abundant substance; more than 70% of the planet's floor is blanketed by way of sea water, much of it several km deep. Approximately 2.5 % of water is clean and 96% of that is tied up in polar icecaps and glaciers or is underneath the earths surface. Just 0.3% of fresh water is held in wetlands, lakes, and rivers, and these are very unevenly disbursed [1]. Despite being common place, colourless, and odourless, water is an extraordinary substance with numerous residences, a lot of which derive from its uncommon molecular structure. Ground water is taken into consideration as an essential source of drinking water, which additionally functions as a water source for agricultural and industrial activities [1].

Our basic needs consist of air, containing sufficient oxygen, water that is potable, edible meals, and shelter. Food affords us a source of energy that is needed for work and for numerous chemical reactions. Meals include materials or chemical compounds needed for growth, for the restoration of injured cells, and for reproduction. Food consumption can be a gratifying and enjoyable, and a time for assembly with family and friends. Meals are vital for our existence and their ingredients have been extensively studied [2].

Because of its small size, high electronegativity, and position in the halogen group in the periodic table, fluoride is an important highly reactive element and does not usually exist in its free elemental state as fluorine but is found as the ion fluoride (F) in various compounds. It is universally found in soil, water, plant life and air.

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Fluoride is an ionic form of fluorine. Fluorine reacts violently with numerous elements [3]. It may additionally form various complexes with noble gases due to its reactiveness. It is the thirteenth most plentiful element in the earth crust. Human life and agriculture are both severely hampered by air pollution and fluoride is the most phytotoxic of all the common air contaminants. Hydrogen fluoride, in its protonated form, exists in acidic environments. Its pH value is 3.2. (HF). The protonated form of fluorine has an unexpected toxicity [4].

Fluoride is used to manipulate early dental caries in a variety of ways. Fluoride has been extensively employed in the handling of dental cavities due to its antibacterial and anti-carcinogenic properties. In addition to disrupting bacterial metabolism by blocking dynamic enzymes like proton-freeing ATP (adenosine triphosphate) and enolase, fluoride's antibacterial activity is produced by the formation of hydrogen ions and hydrogen fluoride in the cytoplasm of bacteria [5]. Fluoride is not an essential element for the development of healthy bones and teeth. fluoride is one of the essential microelements that must be present in small amounts. The fluorides can be divided into two groups: (a) those that are ionisable and (b) those that are not. Fluoride combats early dental cavities in a number of ways. The F has been extensively applied in the handling of dental cavities because of its anticarcinogenic and antibacterial properties [6]. The creation of hydrogen ions and hydrogen fluoride, as well as the inhibition of key bacterial enzymes like proton-freeing adenosine triphosphate (ATP) and enolase, cause the bacterial cytoplasm to become acidic, which has an antibiotic effect. One of the main environmental health issues results from an excessive F concentration in groundwater supplies, which may be the result of human interventions and population growth [7].

Fluoride is part of the minerals fluorospar (CaF_2 – calcium fluoride), the primary fluorine containing mineral, cryolite (Na_3AlF_6 – sodium aluminium fluoride) and fluorapatite (CaF_2. $3Ca_3$ $(PO_4)_3$. Different F containing minerals are include chiolite ($Na_5Al_3F_{14}$) matockite (PbFCl), sellaite (MgF_2), villaumite (NaF) and Wagnerite ($Mg_2(PO_4)$ [8].

High fluoride levels in drinking water is the cause of 65% of endemic fluorosis within the world and this is referred to as hydrofluorosis. Fluoride toxicity is endemic in 25 international locations round the arena, and affects 103 million humans all over the world.[9] The effect of F in water may be affected by the climate with the fluid intake being increased in some hot climates. Consequently the recommended level of F in drinking water cannot be generalized. The upper limit of F in drinking water recommended by the WHO is 1.5 mgL^{-1}. In the USA a level of 0.7 mg/L is recommended for community water fluoridation. In Senegal, a country standard has been set of 0.6 mg/L.

The fluoride belt reaches from Syria to Libya, Jordan, Egypt, Algeria, and Kenya, and from Turkey to Afghanistan, Iran, India, China, northern Thailand, and Pakistan [10]. Argentina, Tanzania, Pakistan, Mexico, Germany, India, Kenya, the United States of America, and China are the most afflicted countries. In Pakistan, excessive concentrations of F have been reported in many areas, including Tehsil Mailsi (>5.5), Kasur districts (2.47–21.1), Lahore, District Nagarparkar (18.5–35.4), District Tharparkar (13.8–49.3), and Khyber Pakhtunkhwa (13.53 ppm) [11].

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Fluoride may affect plant life. The F levels in vegetables by reach 40 mg kg^{-1} FW even though F is extraordinarily motionless and is not easily soluble or exchangeable. The range of fluoride intake may be 0.2–2.7 mg day^{-1}. The F content of plants and vegetable varies: e.g. for instance Mentha 5–102.3 ppm, Ridge gourd 12.8–20.6 ppm, banana 0.84–2.90 ppm, apple (Malus) [12] 05–5.7 ppm, Guava include 0.24–5.10 ppm, Mango 0.80–3.70, Bengal gramme 3.84–14.8, immature gramme 2.34–21.2, and Cucumber 2.57–4.1 ppm. Tea may contain 39.8–112 mg/kg (ppm). Plant life thriving in uncontaminated soils, on the other hand, often contains <10 mg /kg of F^-. The F^- reaches flowers through the air, water, and soil. Flora may store F^- at levels many times greater than those found in the environment, and this accumulation is influenced by a variety of parameters. Natural F in soil is 90 % higher either insoluble or bound to soil debris. The absorption of F^- within the plant body is also affected by changes in soil pH and the existence of various anions or cations [13].

Finland and other European countries have reported complete F in food assessments. Maximum concentrations were seen in fish, with fish bone F playing a role, particularly in canned fish (0.9–8.0 $mgkg^{-1}$ clean weight). Various foods prepared with fluorinated water may include a F concentration of 0.6–1.03 mg Kg^{-1}, when compared to the normal concentration of 0.2–0.3 mg kg^{-1}. Fluoride levels in tea range from 1–4 mg/cup. Fluoride in a variety of drinks may contribute to children's dental-fluorosis [14]. It reduces the stomatal conductance of all cells and tissues that are affected. At the same time, it works as a metabolic and reproductive inhibitor, causing photosynthesis and respiratory processes to be disrupted. Fluoride has been linked to plant death in the long run. Fluoride is one of the most dangerous contaminants in the atmosphere. Fluoride accumulation in the soil, around plant roots, and in the mesophyll, disrupts various morphological, physiological, and biochemical characteristics of flowers [15]. Fluoride poisoning has a negative influence on plant germination, growth, minerals and vitamins, photosynthesis, respiration, enzymes, plant duplicate, and yield. A direct threat to the entire food chain is posed by the accumulation of fluoride in the grains of staple crops like cereals and legumes as well as in the edible parts of plants like greens. It is also known that fluoride can disrupt cellular signalling and reduce the efficiency of antioxidative enzyme complexes like superoxide dismutase. Both of these effects can be attributed to fluoride exposure. The mineral calcium, which is necessary for the process of fertilisation, is thought to be disrupted by the presence of fluoride. It accumulates on the stigmatic floor, hence causing the calcium gradient within the stigma to become disorganised [16].

Once fluoride is released into the environment, it is able to enter the body via contaminated food, toothpaste, drinkable water, and other contaminated resources. Drinkable water is the major source of F for human consumption, with a few exceptions, and it contributes to health issues. United States Countrywide Studies Council reported that human exposure to airborne F is negligible [17]. Food goods, on average, contribute very little to F exposure. Fluoride is absorbed in part by human tissues after intake, and the final component is eliminated in urine. The increase in the concentration of F in the body of humans is caused by continuous exposure to diverse sources of F, each of which releases a little amount of F gradually. Several investigations have found that F contamination in groundwater is significantly linked to the bedrock mineral composition, which supplies greater F concentrations to subterranean water reservoirs [18].

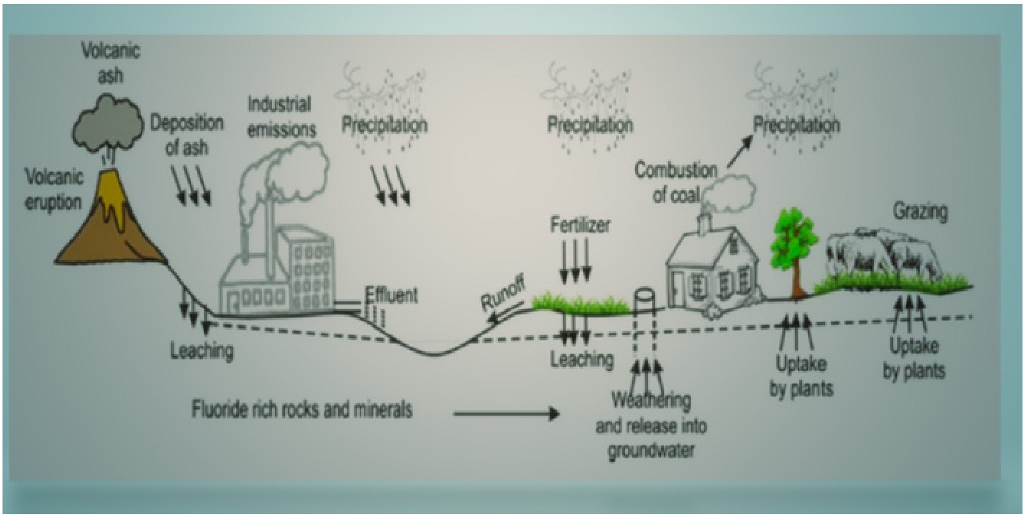

Figure 1: Fluoride sources in the environment [19].

Fluoride is released into groundwater sources because of bedrock leaching and weathering. The higher quantities of F in ground water are determined by natural factors and higher F values are directly associated to volcanic zones. Industry is a major source of F pollutants [19]. The amount of calcium and $NaHCO_3$ in the water, the water's pH, depth, and temperature, the recharge region's distance from the source, the way the water interacts with soil and rocks, and evapotranspiration are some of the factors that affect the solubility and dissolution of F in groundwater. In acidic liquids with a pH of 5, fluoride ions combine with metallic ions to create complexes. The F ion, on the other hand, thrives in water at high pH levels [20].

Fluorosis is caused by prolonged exposure to F in drinking water, and not only impacts humans but also animals kept as pets in the home. The most common symptoms of fluorosis in humans and animals are due to skeletal osteosclerosis (skeletal fluorosis), teeth mottling (dental fluorosis), and nonskeletal fluorosis, such as reproductive dysfunctions, neurological diseases, gastro-intestinal disturbances, and teratogenic consequences [21]. The level of F, exposure time, and intake frequency, affect the severity of fluorosis. Fluoridated water additionally impacts plant tissues by the way of coming into the plant via roots [21].

The excessive build-up of fluorides in plants causes visible leaf injury, culminating in harm, and changes in yield. Plants show fluoride pressure-related symptoms gradually and more strongly with prolonged exposure to F [22]. F bioaccumulation after human consumption of plants has been found in Asia, Africa, Australia, and South America. The accumulation of F following the consumption of high F plant elements may be a severe risk to the animals and people [23].

Hyperaccumulators and tolerant species may be screened for phytoremediation to control biohazards. These species may have strong antioxidant content and efficient F

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ion compartmentalization or export. Phytoremediation is a clean, cost-effective solution to remove F from soils and water [24]. It is time-consuming and sometimes green. In F^- contaminated fields, it would be costly to plant F hyperaccumulators and then grow crops or vegetables. It is important to genetically modify crop plants to produce F-tolerant genotypes with low F bioaccumulation [25].

FLUORIDE CONTAMINATION IN DRINKING WATER

Ground Water Contamination: F poisoning of groundwater is a serious environmental hazard in the developing countries since it is very toxic and causes substantial problems even at very low levels. Fluoride-contaminated drinking water is present in more than 70 nations worldwide, with many of them located in Southeast Asia and South Asia [26]. An enhanced concentration of F has been documented in several nations, including Chile, Taiwan, India, Bangladesh, Mexico, and Hungary. In Pakistan, the situation is far worse, with several locations exceeding WHO F standards. Pakistan, like other developing countries, is suffering from a water shortage as well as F poisoning [27]. Over 5 million people pass away each year from diseases brought on by contaminated water, and 1.1 billion people lack access to safe drinking water and basic sanitation. It is believed that the water in Pakistan's lakes, aquifers, and rivers is unsafe for human consumption. Only 57% of Pakistan's population, according to several assessments, has access to clean drinking water. In Pakistan, on the other hand, according to international surveys, just 25.6% of the population has access to potable water [28].

Fluoride contamination of groundwater in sedimentary unconsolidated aquifers, such as those found in Cambodia, Argentina, Vietnam, America, India, and China, as well as arid and semi-arid areas such as Arizona, California and, China's Yuncheng Basin, and Pakistan, can all be classified as oxidising environments [29].

Fluoride Pollution in Pakistan: Drinking water seems heavily infected because of diverse anthropogenic and herbal sports in various cities of Pakistan cities, like Lahore, Karachi, Islamabad, Faisalabad Rawalpindi and Qasur. But, in Pakistan, the majority of the populace is laid low with water-associated health issues because of contamination by F of drinking water. The high fluoride concentrations include 35.4 ppm fluoride in Nagar Parkar, close to the Thar wilderness of Pakistan, a with 13.5 ppm in Khyber Pakhtunkhw, and 21.1 ppm in Khalan Wala, East Punjab [30].

Sources of Fluoride Contamination: The correlation matrix revealed that arsenic and fluoride had comparable levels of contamination in the research sites studied, which included agricultural area, sports, commercial activities, landfill, and family wastes. A CA dendrogram of ground fluids from each site similarly corroborated the co-dating between F and As and the physicochemical characteristics [31]. A team of researchers analysed the F concentrations and physicochemical features of groundwater in a fluorite mining site along the Swat River to determine the fate and dispersion of F and the hydro-geochemistry. To better understand the groundwater hydrochemical profile and F enrichment, groundwater samples (n = 53) were collected and analysed using an ion-selective electrode from shallow (24–40 m), mid-intensity (48–65 m), and deep (85–120 m) aquifers [32]. Deep aquifer groundwater had the lowest F concentration (0.7 mg/L), whereas shallow groundwater had the highest (6.4 mg/L). Maximum groundwater sample

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concentrations (62.2%) exceeded the WHO guideline (1.5 mg/L); for individual resources, 73% of shallow-groundwater samples (F concentrations up to 6.4 mg/L), 42% of mid-intensity-groundwater samples, and 17% of deep-groundwater samples exceeded this recommended upper limit. [33].

The general fineness of the groundwater was affected by ion change processes, silicate minerals, weathering of granite and gneisses rocks, and weathering of silicate minerals. The groundwater's hydro-geochemical analysis revealed that Na^+ is the most abundant cation and (bicarbonate) is the most abundant anion [34]. The sodium-bicarbonate water type has been linked to much higher F toxicity levels, and the chemical facies have been shown to switch from calcium-bicarbonate to (Na-bicarbonate) in calcium-deficient aquifers. Thermo-dynamic saturation indices showed that, in addition to fluorite minerals, other F minerals present in the area also raise F concentrations in the groundwater, indicating that fluorite minerals play a significant role in the development of fluorosis [35].

Fluoride-contaminated water: Fluoride can get into a person's body if they consume things that are contaminated with it, such as toothpaste, food, and air after it has been released into the environment. The United States National Research Council reported that human exposure to airborne F is minimal. Food items, overall, have a minor impact on F exposure. Human tissues absorb F in part after ingestion, with the remainder eliminated in urine [36]. Exposure to numerous F sources throughout the day, each of which releases a negligible amount of F slowly, causes an increase in the amount of F that is stored in the human body. Several studies show that the mineral composition of the bedrock is closely related to F contamination in groundwater sources, since it supplies higher quantities of F to underground water resources [37].

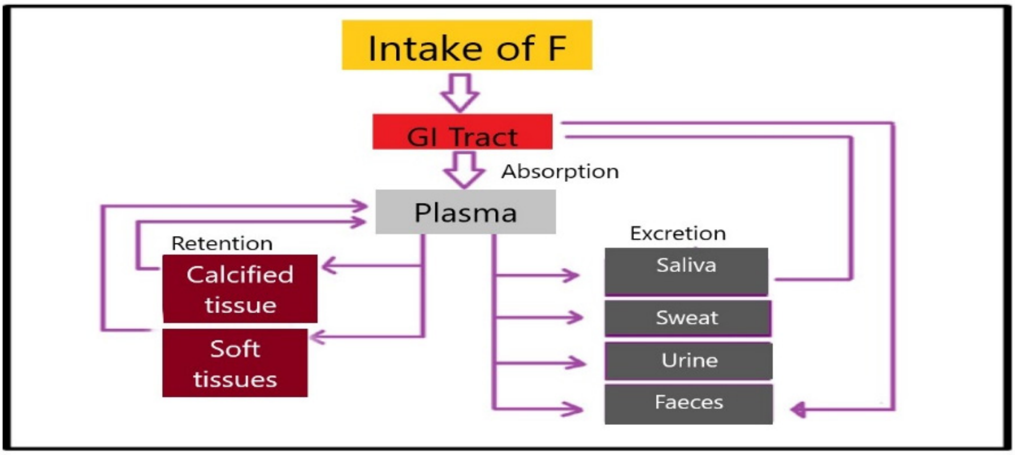

Figure 2: Fluoride in human body [37].

Fluoride is released through leaching and weathering of bedrocks, and it finds its way into groundwater sources. The greater concentrations of F in ground water are determined by natural features, and the presence of F is closely associated to volcanically active locations. Aside from natural reasons for higher F levels in groundwater, industry is another important source of F pollution [38]. Factors that

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affect F dissolution and solubility in groundwater include the Ca and Na-bicarbonate concentrations in groundwater, climate, and evapotranspiration. [24, 39].

Water may be contaminated with F as a result of the ongoing application of phosphate fertilisers and the presence of high F^- commercial waste. Researchers at the college of Wisconsin investigated the impact of super-phosphate and phosphate rock fertilisers on fluoride levels in water in 1943, and concluded that "while phosphate fertilisation is done for decades, very large portions of noticeably poisonous fluoride are delivered to the soil." They stated "Heavy quantities of fluorine are possible within the drainage water from fields due to high phosphate fertiliser use"[40].

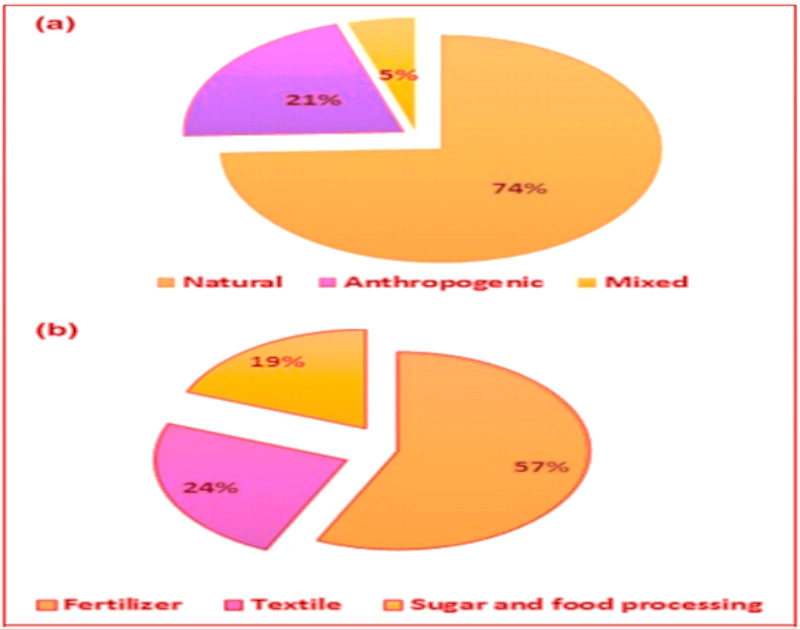

Figure 3: Contribution of natural and anthropogenic sources in Rahim Yar Khan using PCA-MLR [41].

Pakistan's unprotected population, especially youngsters, is at serious risk from the elevated F level in the country's groundwater supplies. Children are at a high danger of being poisoned by F. Urgent action is required to alleviate this risk. Extensive monitoring is generally necessary in order to determine the level of F contamination present in all of Pakistan's drinking water sources. Long-term plans should be implemented by the government to keep F levels in drinking water resources at safe levels and to educate the public on the dangers of F in groundwater [42]. Analyzing Freni's and his coworkers' efforts. [43].

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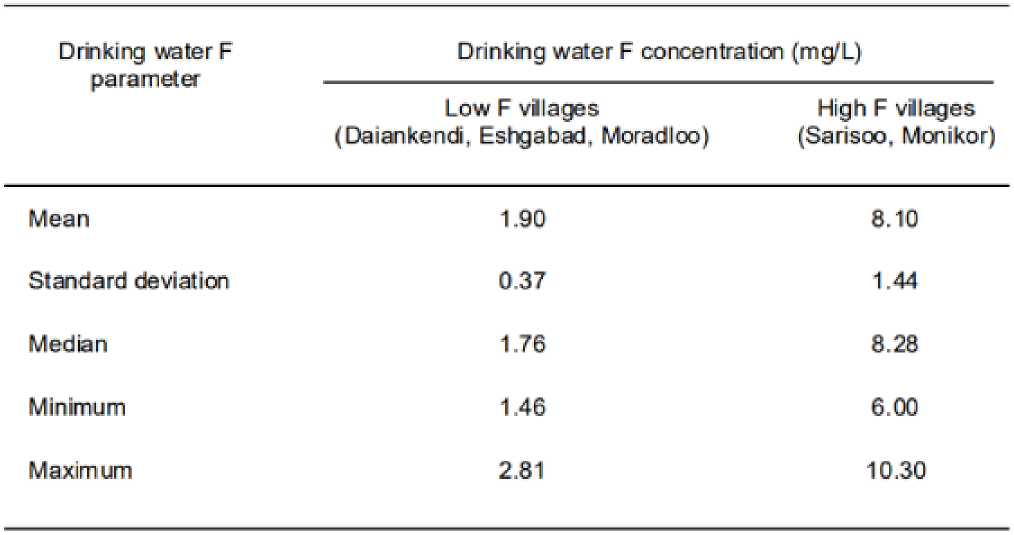
Table. 1: Drinking water fluoride concentration [43].



Drinking water F parameter	Drinking water F concentration (mg/L)	
	Low F villages (Daiankendi, Eshgabad, Moradloo)	High F villages (Sarisoo, Monikor)
Mean	1.90	8.10
Standard deviation	0.37	1.44
Median	1.76	8.28
Minimum	1.46	6.00
Maximum	2.81	10.30

In 2003, in Mexico, workers at a plant that produced aluminium fluoride and hydrofluoric acid were exposed to 3–27 mg/day of fluorine, whereas a control group was exposed to 2–13 mg/g per day. 33 A subclinical reproductive effect was seen, with an F-triggered toxic impact on both Sertoli cells and gonadotrophs, and an overall increase in FSH ($p \leq. 0.0001$) was observed [44].

Case-management research has been analysed. In Senegal, a fluorosis-endemic country with high water F levels, 108 mothers gave birth to newborns weighing less than 2500 g in 2012, and 216 mothers gave birth to infants weighing more than 2500 g. (controls). The proportion of mothers drinking well water with a elevated F content was 62 %, compared to 43.5 percent in the controls. Dean's Index score of 4 was found in 25.9% of the cases and 6.9% of the controls. Adjusted for gender, consanguinity, anaemia, and high blood pressure, the amount of water eaten and the modal rating on Dean's Index have been found to be strongly linked to the occurrence of low birth weight. The authors concluded that low birth weight is linked to pregnant women who live in endemic areas. In locations with endemic fluorosis, de-fluoridation initiatives and access to high fine water for pregnant females and children were required [45].

In addition, a recent study found that meals and their food content play a role in reducing F stress in goats and sheep [12]. Although the pattern size varied widely in this early study, the suggested water F level was between 1.5 ppm and 1.7 ppm. As a result, the focus of this study was on determining and connecting meal nutrients and F poisoning in the F endemic areas.[46].

Buffaloes had the highest frequency of dental fluorosis (55.9%), while the levels in other animals were goats: 10.7%, sheep: 7.3%, and camels: 5.3%. For immature animals, dental fluorosis rates were: buffalo calves: 62.2%; farm animals' calves:

51.1%. However, none of the mostly plant-eating juvenile ruminants studied—camels' calves, youngsters (goats), and lambs (sheep)—exhibited any specific dental fluorosis symptoms. Among recent years, the severity of dental fluorosis in grass eaters has increased in comparison to their plant eating counterparts.

Buffaloes (48.3%) had the highest prevalence of skeletal fluorosis, followed by goats (8.4%), camels (5.6%), cattle (39.8%), and sheep (5.6%) among adult animals (5.3%). Skeletal fluorosis did not appear to affect any of the juvenile plant eaters. However, skeletal fluorosis was found in grass-eating buffalo and cow calves: 21.6 % and 18.6 %, respectively [47].

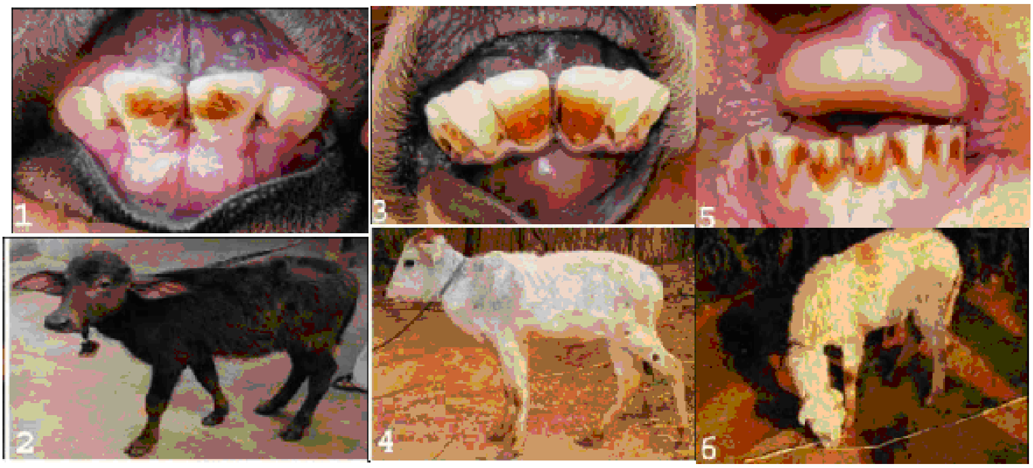


Figure 4: Severe dental fluorosis in calves of : 1 and 2: buffalo, 3 and 4: cattle and 5 and 6: sheep [48].

RESULTS FOR FLUORINE LEVELS

In all of the samples tested, high amounts of F were discovered, 5.2 to 20.4 mg/L, with a mean of 8 mg/L, which is more above the WHO's recommended upper limit of 1.5 mg/L. However, the WHO allows countries to also set individual country levels and Senegal set a level of 0.6 mg/L. The F concentration was substantially greater than in prior studies in Pakistan, namely D. G. Khan and Sialkot as well as globally, namely Africa and Korea. Sheikhupura, Kasur Multan, Bahawalpur, Gujranwala, and Lahore have been deemed the worst impacted areas of Punjab for F levels by the "Pakistan Council of Research in Water Resources" and the present study area is bordered by Bahawalpur and Multan districts in Southern Punjab [49]. As the research area is known for agriculture and industrial activity, with fertiliser usage on various cash crops like cotton, wheat, rice, and sugar cane being widespread, increased F concentrations in shallow groundwater in this site may be anthropogenic. The average amount of soluble F in Pakistani fertilisers is 175 mg/kg, although usage of fertiliser in Punjab province has increased from 156.7 kg/ha in 2005–2006 to 185.5 kg/ha in 2009–2010. While there are several smelting enterprises in the research region, and dust, industrial wastes, and coal combustion all contribute to F pollution [50].

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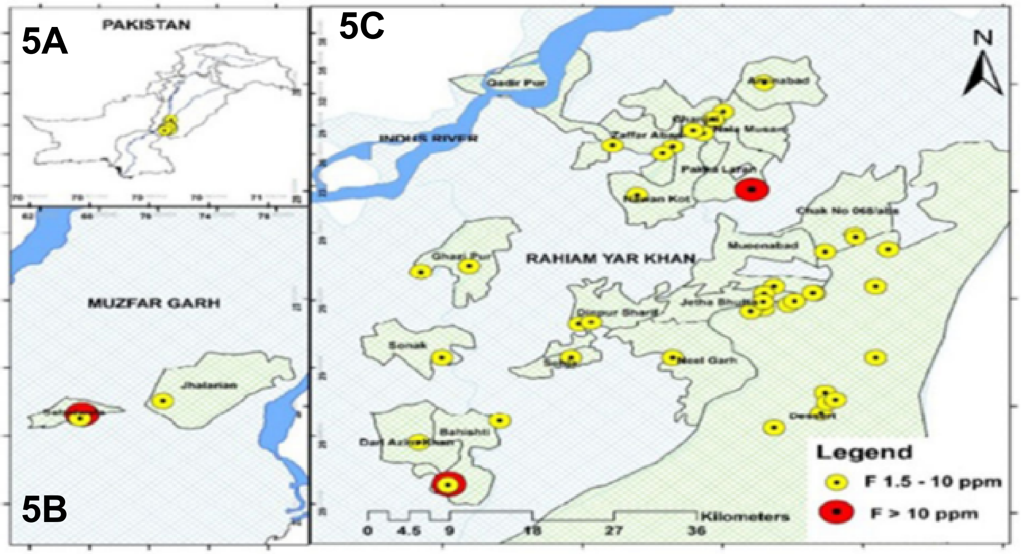

Figure 5: Results of fluoride levels in 5A: Pakistan at several sampling locations around the 5B: Muzfar Garh and 5C: Rahim Yar Khan areas [51].

Influence of fluoride on human health

Because F is a strongly electronegative element, it has a strong attraction towards positively charged ions like calcium ions. As a result, mineralized tissues like teeth and bone which have the highest quantity of Ca ions have a great attraction for F which is deposited in the form of 'calcium–fluorapatite' crystals. The effect of F^- is clinically significant. F displaces OH^- from hydroxyapatite, to generate fluorapatite, which is harder and tougher. Dental fluorosis [52] is a disorder in which excess F causes mottling and brittleness of the teeth. Fluoride use is frequently viewed as a two-edged sword. Although the Scientific Committee on Health and Environmental Risks (SCHER) gave an opinion of critical review of any new evidence on the hazard profile, health effects, and human exposure to fluoride and the fluoridating agents of drinking water (Brussels, Belgium: Directorate General for Health and Consumers, European Commission; 2011 May 16. pp. 2-4) that F is not an essential trace element for human growth and development and is accordingly not necessary for the development of healthy teeth and bones, many consider that a lack of fluoride in sufficient amounts (less than 0.5 ppm in drinking water), especially in youngsters, may causes health concerns like dental cavities, inadequacy of bone mineralization and a lack of production of dental enamel. The counter argument is that systemic fluoride exposure slightly reduces dental decay by impairing thyroid function resulted in delayed tooth eruption, by up to one year, and thus reducing the exposure time for the teeth in the decay producing oral environment. Thus children exposed to high water fluoride levels may have less decay at a given age due to delayed tooth eruption. However the impaired thyroid metabolism also produces other development delays such as neurotoxicity and reduced IQ. When fluoride is taken or utilized in excess (more than 1.0 ppm), it can cause health concerns in children, the elderly, and in pregnant women [53]. The condition of dental fluorosis is characterized by tooth enamel mottling. It was the catalyst for the identification of a link between F

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intake and human health. The loss of matrix proteins is accompanied by an increase in mineralization within the growing tooth as enamel forms. Fluoride disturbs enamel mineralization in a dose-dependent way during this phase, producing unusually large gaps in the structure, increased porosity, and excessive enamel protein retention. Higher density and bone mass characterize skeletal fluorosis, with adults and children both being affected. These symptoms do not appear till the disease has progressed to the advanced stage. F^- is deposited mostly in neck joints, pelvis, shoulder and knee bones, making for difficulty in walking and movement. Skeletal fluorosis symptoms are similar to the symptoms of arthritis or spondylitis [54].

Toxicologists have recently expressed worry about the combined toxicity of As and F. There have been a few investigations of co-exposure on several species utilizing low and high doses. The liver, kidneys, blood, bone, brain, ovary, IQ, learning, chromosomes and behavior all showed abnormal alterations on exposure to this contamination. Vitamins E and C, calcium phosphate and curcumin may help to reduce or eliminate the harmful effects of As and F. Several successful As and F removal solutions have been developed for contaminated water. Arsenic pollution has been found in ground water in Pakistan and other nations, and it has also been found in rice and other staple foods. Exposure to fluoride is comparable to that of exposure to arsenic (As) because both can enter the food chain via contaminated ground water [55].

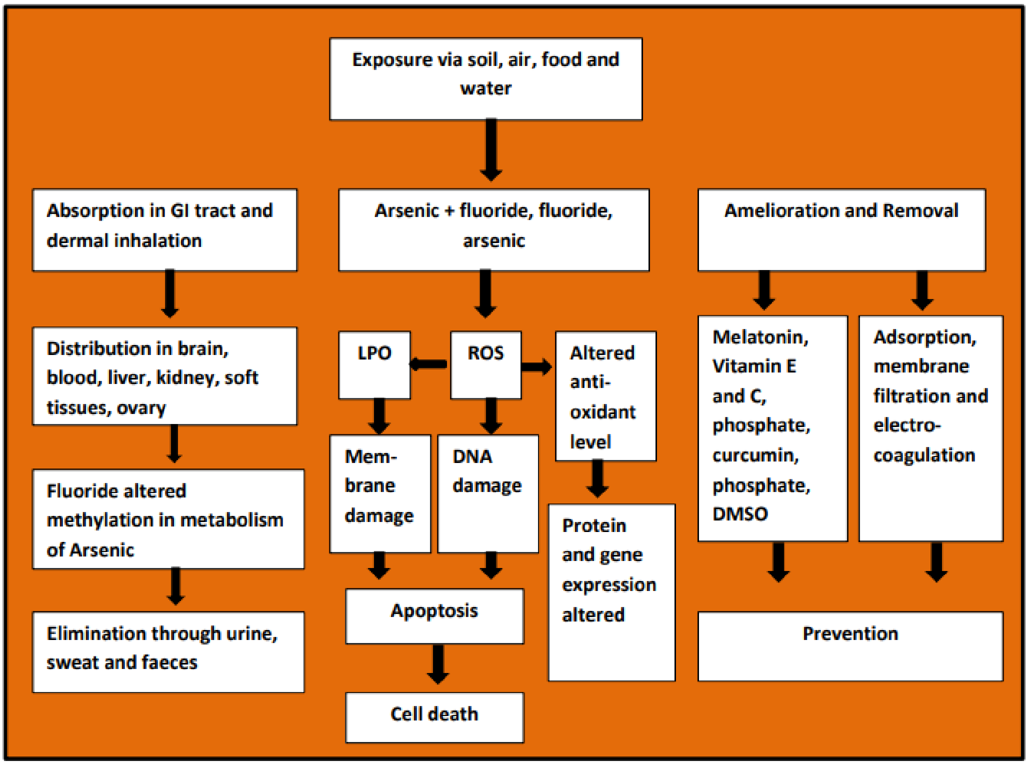

Figure 6: Exposure route, impacts of As and F, and removal and mitigation techniques [56].

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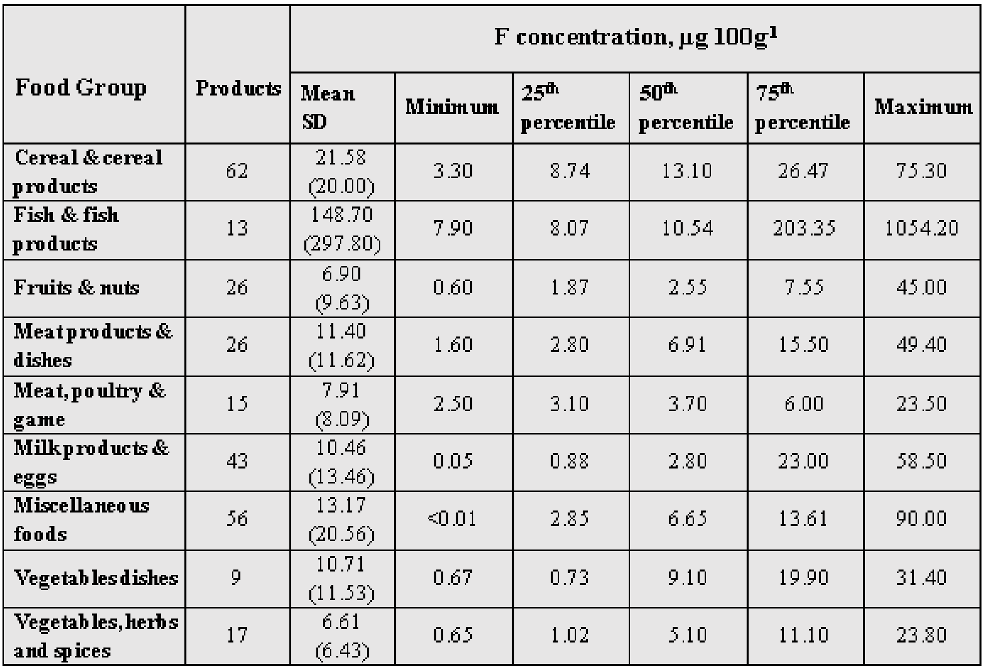
Parents of infants and young children were provided with dietary information via a validated 3-day food diary, which was used to select the foods and beverages for F analysis. The food diaries were gathered between 2003 and 2014 as part of research to determine the most frequently consumed foods and beverages, as well as the main providers to dietary F consumption in this age range. All major supermarket chains, convenience stores, grocery stores in the northeast of England were used to acquire the indicated food and drink products. To account for any potential within-product variability, 30 samples were acquired for each item. The brands were chosen consist on the entries in the food diaries for each item [57]. The total mean standard deviation recovery of F added to 10% of screened samples was 98.5 %, indicating that the F analysis approach was valid. The 10% of randomly selected samples had a good correlation between analysis and reanalysis, showing great repeatability (R = 97%). There were 518 food and drink products examined in all, with 251 of them being baby beverages and food. Because of the constraints of a brief message, the whole list of the 518 individual items, along with their F contents, is published elsewhere. The assembled information reveals a significant variety of F content both within and within food and beverage classes [58].



Food Group	Products	F concentration, µg 100g^{1}					
		Mean SD	Minimum	25th percentile	50th percentile	75th percentile	Maximum
Cereal & cereal products	62	21.58 (20.00)	3.30	8.74	13.10	26.47	75.30
Fish & fish products	13	148.70 (297.80)	7.90	8.07	10.54	203.35	1054.20
Fruits & nuts	26	6.90 (9.63)	0.60	1.87	2.55	7.55	45.00
Meat products & dishes	26	11.40 (11.62)	1.60	2.80	6.91	15.50	49.40
Meat, poultry & game	15	7.91 (8.09)	2.50	3.10	3.70	6.00	23.50
Milk products & eggs	43	10.46 (13.46)	0.05	0.88	2.80	23.00	58.50
Miscellaneous foods	56	13.17 (20.56)	<0.01	2.85	6.65	13.61	90.00
Vegetables dishes	9	10.71 (11.53)	0.67	0.73	9.10	19.90	31.40
Vegetables, herbs and spices	17	6.61 (6.43)	0.65	1.02	5.10	11.10	23.80

Table 2: Fluoride content of 267 drink and food products consumed by children [58].

The conventional wisdom up until the 1980s was that for fluoride to have the greatest cariostatic effect, it had to be absorbed into dental enamel throughout tooth formation by forming hydroxy fluorapatite, that is more resistant to ingested acids [37]. A new paradigm that was created in 1981 slowly but progressively altered research on fluoride caries [59]. Therefore, topical fluoride is suggested as opposed to systemic fluoride. By blocking cellular enzymes (directly or in association with metals) or increasing the proton permeability of cell membranes, fluoride also alters the metabolism of oral microbial cells (in the form of hydrogen fluoride) [38,39].

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FLUORIDE SOURCES IN THE ORAL ENVIRONMENT

Total fluoride content contributing to oral fluoride exposure, such as water and drinks, various foods, dental goods, and fluoride supplements and alternatives to fluoridated water, including fluoridated salt or milk, can be used to estimate total daily fluoride exposure and intake. The level of fluoride in drinking water in natural waters intended for human consumption ranges from trace quantities to many mg/L, and potentially hazardous levels. Fluoride-rich water is typically found near the base of steep mountains and in locations with marine-derived geological formations. There are significant differences in the natural fluoride absorption of drinking water between and within nations. Based on preceding texts, the WHO determined the recommendation for the upper threshold for fluoride in drinking water at 1.5 mg/L in 2010 but also allows countries to set their own country standards[59].

The custom of consuming bottled water is increasing. In the EU, naturally occurring fluoride has a maximum limit of 5 mg/L and bottled water having a fluoride content over 1.5 mgL^{-1} must bear the warning "contains more than 1.5 mg/l of F: not suited for frequent ingestion by newborns and children under 7 years of age." However, naturally occurring F or added F, as well as the yearly average of the highest daily air temperatures at the retail site, affect the concentration of fluoride in bottled water in the United States. Fluoride levels in imported and domestically packaged bottled water must not be more than 2.4 to 1.4 mg/L [60].

Drinks and tea foliage is sources of fluoride

According to some sources, the tea plant accumulates fluoride in its leaves after absorbing it from the soil. Between 50 to 900 mg/kg of total fluorine are present in the leaves. Due to the fact that about 25–100% of the fluorine is released at some point during the infusion, the infusions' fluorine content can range from 0.3 to 8.8 depending on the quantity of dry tea used, how it was ground, how much fluorine was in the water used to deliver it, whether milk was present, and other variables. The range of fluoride levels in ready-to-drink tea has been determined to be between 0.01 and four.1 mg/L, with a single study reporting a very high average of 24.7–25.7 mg/L. Fluoride concentrations in various liquids, such as juices, nectars, and juice drinks, varied from 0.10 to 2.0 mg/L in Portugal, 0.02–2.80 in the United States, and 0.07–1.42 in Mexico. Fluoride concentrations in juices and juice-flavoured drinks for newborns and children varied from 0.01 to 0.25 mg/L in Poland and 0.11 to 1.81 in the United States. Fluoride levels in carbonated smooth drinks tested in Europe ranged from 0.10 to 0.38. Inside the United States and Mexico, values varied from 0.02 to 1.28 mg/L and 0.07 to at least one of62 mg/L, respectively [61].

The fluoride concentration in beer ranged from 0.067–1.12 mg/L in Europe. High fluoride values, 1.77 and 1.66, have been detected in beer from Ireland and the United States, respectively. The large variances in F concentrations identified in this study may be classified as low herbal F presence or high F presence due to naturally occurring or intentionally inserted F in the water utilised in the manufacturing process. Fluoride concentrations in bottled wines from the Canary Islands varied from 0.03 to 0.70 mg/L, while those from Turkey ranged from 0.02 to 0.38 mg/L. Fluoride concentrations in nineteen California wines ranged from 0.23 to 2.80 mg/L, allegedly because of the use of cryolite as a pesticide [61].

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Fluoride contents in commercially accessible milk were usually modest, not exceeding 0.1 mg/L, according to a study. However, increased concentrations of F in pasture or livestock drinking water may add to F levels in milk from various animals. Fluoride amounts in soya milk ranged from 0.01 to 0.964 mg/L, resulting in noticeable F concentrations. Even when lactating mothers consume a lot of F, the fluoride amounts in breast milk are frequently low. Fluoride contents in breast milk range from 0.002 to 0.073 mg/L. In one study conducted at a high altitude (>2000 m), very high fluoride concentrations were discovered [62]. The outcomes showed that the fluoride level of breast milk from mothers with dental fluorosis and children with dental fluorosis was measured at an excessive altitude of 0.13–0.99 mg/L (average 0.55 mg/L), compared to 0.001–0.10 mg/l (average 0.006 mg/L) in breast milk from women without dental fluorosis. These findings proposed that there is still more to learn about the factors that influence the amount of fluoride in breast milk, such as the effect of altitude. In a study on F concentration in small one components product reconstituted with fluoride-free water according to the manufacturer's instructions, F concentrations ranging from 0.01 to 0.75 mg/l were noted. Fluoride awareness was discovered to be a simple linear characteristic of water F concentration when equations were generated using water of various fluoride concentrations [62].

Content of fluoride in food

The average level of F in all meals produced by businesses in the United States Department of Agriculture Database is 2.7-fold greater than in the United Kingdom Database, at 47g/100g against 17 g/100g. Even when tea is separated, the average level of F in the United States Compared to the United Kingdom Database, the Department of Agriculture Database continues to be 1.9 times larger. Food typically contains fewer than 50 g/100g of fluorine. Exceptions consist of: (1) manufactured goods (breakfast cereals, desserts, snacks, and sauces) and drinks that may contain substantial levels of fluoride if fluoridated water is used during manufacturing or for their practise; (2) tea, which may release excessive concentration of fluoride accumulated within the limit at some point during infusion; and (3) Fish and shellfish bones and exoskeleton remains, in which fluoride is taken from the ocean, Due to mechanical deboning, samples that are examined might contain a high fluorine level. Finally, it is important to remember that several studies have confirmed the presence of total and/or free fluoride in particular foods in addition to these databases. The results of research are challenging to evaluate due to the amount of fluorine in food being affected by a number of variables, including: (1) the areas where food is grown; (2) variations in the concentration of fertiliser and pesticides used or variations in feeding habits; (3) the method of processing the food receives; (4) the quantity of water and F content of the water used during synthesis; and (5) various sample pre-treatment men [63].

Fluoride supplements and fluoridated milk or salt

Salt fluoridation is a method of water fluoridation that began in 1956 in Switzerland. Fluoridated salt is used by an estimated 40 million to 280 million people globally, mostly in the European Union, South America, and Central America, as well as a few Asian countries such as Cambodia and Laos, and Madagascar in Africa. Sodium fluoride and potassium fluoride at concentrations of 250–300 mg/kg of F are commonly employed in salt fluoridation. In the 1950s, milk was first promoted as a

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practical means of providing F in the fight against tooth decay. According to systematic reviews, fluoride supplements administered as chewing gum, drops, lozenges, or capsules can successfully protect caries in primary teeth. Nevertheless, there is compelling reports that dietary additions with F can help shield permanent teeth from cavities. A rise in mild-to-moderate fluorosis incidence has been attributed to the usage of F supplements. The American Academy of Paediatric-Dentistry advises considering F nutritional supplements for children at high risk of caries who consume fluoride-deficient (< 0.6 mg/l) water [8], whereas the European Academy of Paediatric Dentistry recommends F drugs and F drops be measured on an individual basis for children at high risk of caries [64].

Dental products which contain fluoride

Although toothpaste, gels, and rinses that contain fluoride are no longer regarded as dietary sources, they can nevertheless considerably increase oral fluoride consumption when used improperly. Fluoride consumption by young children should be carefully regulated throughout the first six years of life due to poor control of the swallowing reflex, and the careful balancing of risk and effectiveness is probably accomplished by using low quantity of high F tooth paste under careful parental supervision. Fluoridated toothpastes for children typically have 250 to 500 g/g of F while fluoridated toothpaste for adults often contains 1000–1500 g/g of F [65].

FLUORIDE REMEDIATION TECHNIQUES

There are various ways for removing fluoride from water and soil that can help lessen fluoride toxicity.

Nalgonda technique: Chemicals such as lime and alum are brought in and combined with fluoride-contaminated water in the Nalgonda procedure. Following gentle stirring, flakes (aluminium hydroxides) form and are easily sedimented away. The principal ingredient of the fluoride is eliminated together with the flocs by sorption and the fluoride ion combining with several of the hydroxide groups to create safe drinking water [66].

Bone Char: Animal bones are simply crushed and burned to destroy all organic material to create bone char. Tricalcium phosphate and carbon make up a large part of it.

Synthetic tri-calcium phosphate: Phosphoric acid and lime are used to make artificial tri-calcium phosphate, which was less costly than bone. The medium is renewed by using a 1 percent NaOH solution and then a moderate acid washing. It is possible to eliminate 700 mg of F / L.

Florex: Florex, a commercially available blend of tri-calcium phosphate and Hydroxy-apatite, has the capacity to remove fluoride from 600 mg/L and was regenerated using a 1.5% solution of sodium hydroxide.

Activated carbon and lime: Certain types of activated carbon have been shown to be particularly effective at removing fluoride. According to the results of a standard analysis of both raw and processed municipal waste, it was discovered that the effluents from lime softening contained significantly less fluoride than the raw water.

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Limestone, special soils and clay: Limestone, rare soils, and clay, to name a few examples. Fluoride removal has previously been attempted using limestone and heat-treated soil. Limestone utilised to decreased fluoride levels in wastewater to below the maximum contamination level (MCL) of 4 mg/L. A F absorption process by clay minerals is postulated based on experimental evidence.

Natural minerals and fly ash: The removal of F was replaced by the use of natural substance such as red soil, charcoal, brick, and fly ash. Purple soil, followed by brick, fly ash, and charcoal, has the best F-removal capacity, according to the study.

Electrokinetic (EK) decontamination: Electrokinetic (EK) decontamination is a method for treating organic and inorganic pollutants polluted soils, sludges, and sediments. The EK method is entirely dependent on the application of an immediate electric capacity to polluted soil via a network of electrodes. A ramification of reactions and transportation procedures in polluted soil leads to the mobilisation of pollutants to the electrodes in the direct present-day electrical region. The migration of impurities toward the electrode is aided by an electric subject in this production. Other natural substances in the soil, however, can be mobilised as well [67].

CONCLUSIONS

Water is the most treasured of all-natural sources as it is fundamental to existence on the earth. Contamination of surface water by F is an extreme environmental concern world wide and their is growing global concern about the toxic effects of fluoride on plant, animal and human health. The levels of F in field-grown vegetables can be as high as 40 mg kg^{-1} fresh weight despite the fact that F is not particularly soluble or exchangeable.

FUTURE PERSPECTIVES

Combating skeletal fluorosis, dental fluorosis, and nonskeletal fluorosis on a large scale is a cause for source of concern due to lack of knowledge and expensive treatment. Research should be focused on creating simple, cost-effective methods for treating fluorosis or purifying water so that it is free of this element. In addition to government and nongovernmental organisations, public awareness is a key component in the management of this serious problem. In an effort to raise awareness among young people, the Rajasthan government in India has included fluorosis mitigation techniques in the curriculum for pupils. Through their regular surveys, public health professionals ought to be informed about the impacted patients. The public must be educated about the risks of fluorosis and the importance of drinking clean water, and this requires the organisation of camps and programmes. Health insurance and the medical community should be trained to tackle the issue and minimise the harm in areas where water seems to be the main cause of fluorosis and there is no other source of water. The national rural health insurance programme is one such insurance programme (under NRHM). Along with the steps listed above, medical staff members need to receive thorough training in the proper diagnosis of fluorosis and prevention measures.

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