Unit 12 Arsenic and Fluoride Pollution

Structure

12.1 Introduction

Water is the most essential component of life on earth as we can hardly live without water. Water for human consumption should be free from germs and toxic matters although should contain essential minerals. However, a clear and colourless water sample without a taste or odour does not guarantee the purity and safety of drinking. Chemical contamination of drinking water, either naturally or by anthropogenic sources, is a matter of serious concern as the toxic chemicals do not show acute health effects unless they enter the body in appreciable amounts, but they behave as cumulative poisons showing the adverse health effects after a long period of exposure (Plant et al., 2005). High rates of mortality and morbidity due to water-borne diseases are well known in India. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater (Kumar et al. 2005).

Safe drinking water is a fundamental need of every human being, despite any socioeconomic status. The health and happiness of the human race are closely tied up with the quality of the water used for consumption where the per capita consumption of water is an index of the quality of life of the people as well as their economic and social condition. There is a clear correlation between access to safe drinking water and GDP per capita (Kulshreshtha 1998). Groundwater is the most significant source of drinking water throughout the world though surface water plays a vital role in the supply of water for drinking. It was estimated that only 0.9% of the total water resources on earth is supplied from groundwater, though it is the major and the preferred source of drinking water in rural as well

as urban areas. It covers 80% of the total drinking water requirement and 50% of the agricultural requirement in rural India.

Arsenic contamination is a worldwide health problem due to its toxicity and the fact that it occurs at unhealthful levels in water supplies, particularly groundwater, in more than 70 countries on six continents (Ravenscroft et al., 2009). Arsenic contamination of drinking water is a worldwide problem due to its damaging effects on health (Kumar 2015). These effects range from skin ailments to serious and dangerous diseases such as cancer. Continuing exposure to arsenic can cause damage to the human cardiovascular, gastrointestinal, dermal, hepatic, pulmonary, renal, neurological (ATSDR, 2000), reproductive system and respiratory systems (ATSDR, 2000; Mandal and Suzuki, 2002; Kumar 2015).

Like Arsenic (As) contamination, Fluoride (F) as a groundwater contaminant is also a worldwide problem. The source of this contamination is natural, depending on climate, rock type and geochemical conditions that are favourable to the release of fluoride from aquifer rocks.

It is estimated that up to 60 million people are reported to be affected with dental, skeletal and/or non-skeletal fluorosis in India, the extent of fluoride contamination varying between 1.0 to 48.0 mg/l. Fluoride in groundwater is increasing in India at an alarming rate as groundwater is increasingly exploited. This unit emphasizes the sources, status, impacts and management of arsenic and fluoride pollution.

12.2 OBJECTIVES

After studying this unit, you should be able to:

- explain the sources of arsenic and fluoride pollution;
- discuss the status of arsenic and fluoride pollution;
- explain the impacts of arsenic and fluoride pollution and
- explain the management of arsenic and fluoride pollution.

12.3 ARSENIC POLLUTION

Arsenic is widely distributed in nature and principally occurs in the form of inorganic or organic compounds. In soils, arsine gases may be generated by fungi and other related micro-organisms. Different forms of arsenic have different toxicities, with arsine gas being the most toxic form of the inorganic oxyanions, arsenites being the most toxic form and arsenate, the less toxic form. The organic (methylated) arsenic forms are considered the least toxic (Kumar 2015). Exposure to inorganic compounds may occur in many ways through certain industrial effluents, pesticides, chemical alloys, combustion of fossil fuels, wood preservative agents, occupational hazards in mining and dissolution in drinking water. The most commonly found arsenic compounds in drinking water are arsenate or arsenite. However, groundwater is very prone to chemical

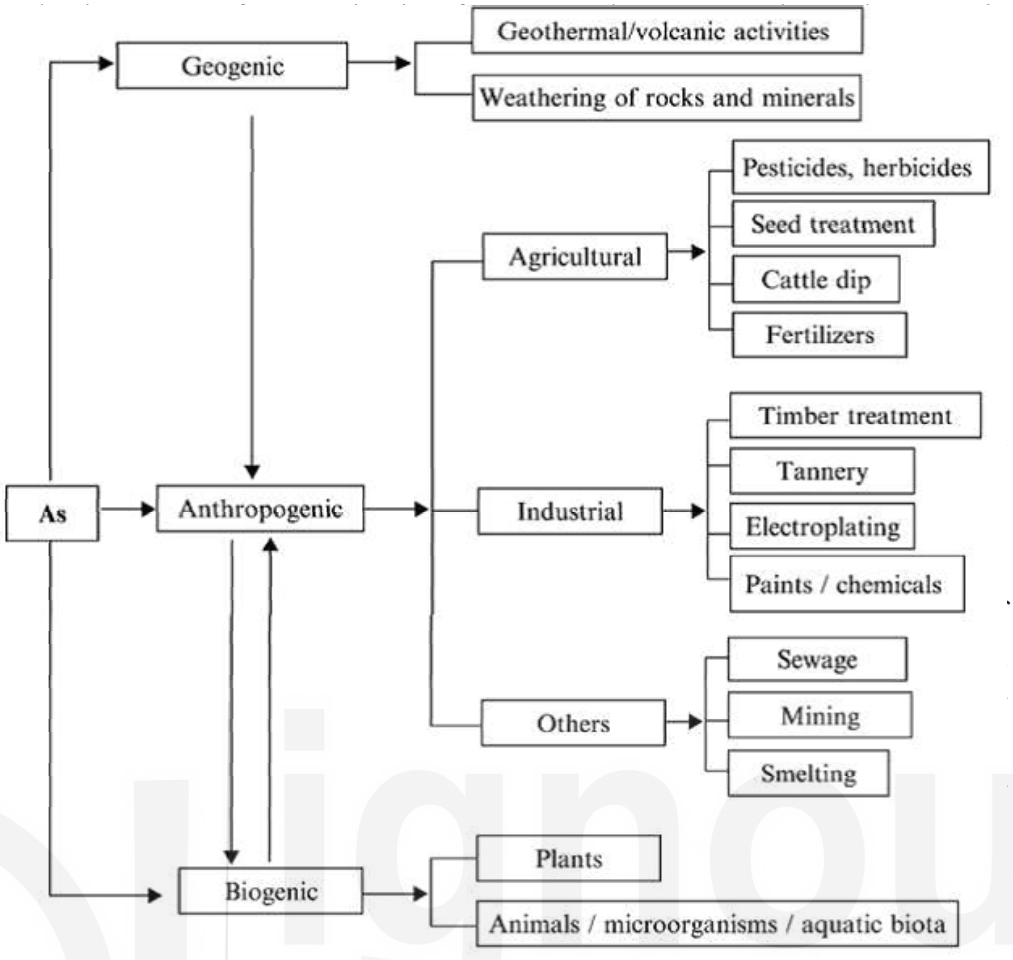

Fig. 12.1 Major Sources of Arsenic Pollution (Source: Kumar 2015).

1. Geogenic Sources

Arsenic is extensively distributed in geological materials, but with variable concentrations. Arsenic ranks 52nd in crustal abundance and is a major constituent in more than 245 minerals (O'Neill, 1995). Arsenic is introduced into soil and water during the weathering of rocks and minerals followed by subsequent leaching and runoff. Therefore, the primary source of arsenic in soil is the parent (or rock) materials from which it is derived (Yan-Chu, 1994; Kumar 2015)).

2. Anthropogenic Sources

Arsenic released from anthropogenic sources differs in chemical nature and bioavailability. The sources include commercial wastes (40%), coal ash (22%), the mining industry (16%), and the atmospheric fallout from the steel industry (13%) (Eisler, 2004). Arsenic trioxide (As_2O_3) is used extensively in the manufacturing of ceramic and glass, electronics, pigments and antifouling agents, cosmetics, fireworks, and Cu-based alloys (Leonard, 1991). Arsenic-containing pesticides and herbicides release arsenic-containing liquid and solid wastes that, upon disposal, are likely to contaminate water bodies and soil (Kumar 2015).

3. Biogenic Sources

Though the biogenic sources contribute small amounts of arsenic into soil and water ecosystems, plants and micro-and macro-organisms affect the

redistribution of arsenic through their bioaccumulation (e.g., biosorption), biotransformation (e.g., bio-methylation), and transfer (e.g., volatilization) (Kumar 2015).

12.3.2 Status of Arsenic Pollution

The presence of arsenic in groundwater in India is the most serious health hazard. Arsenic pollution is observed in West Bengal, Bihar and the North-eastern region. Many areas within the north-eastern states with an arsenic concentration greater than 0.05 mg/l imply that millions of people are at serious risk of arsenic poisoning. It was reported that the concentration of arsenic generally varies from 0.02 to 0.9 mg/l (exceeding the WHO standard of 0.01 mg/l and Bureau of Indian Standard (BIS) of 0.05 mg/l) (Kumar 2015). The North Eastern Regional Institute of Water and Land Management (NERIWALM) report (Chakraborty, 2007) indicated that arsenic levels in Assam, Manipur, Tripura and Arunachal Pradesh were above 300 parts per billion (ppb). World Health Organisation (WHO) reported that the consumption of water contaminated with arsenic levels of over 50 ppb can cause skin lesions and even cancer (Kumar 2015).

12.3.3 Impacts of Arsenic Pollution

Arsenic contamination is a worldwide health problem due to its toxicity and the fact that it occurs at unhealthful levels in water supplies, particularly groundwater, in more than 70 countries on six continents (Ravenscroft et al., 2009). Arsenic contamination of drinking water is a worldwide problem due to its damaging effects on health (Kumar 2015). These effects range from skin ailments to serious and dangerous diseases such as cancer. Continuing exposure to arsenic can cause damage to the human cardiovascular, gastrointestinal, dermal, hepatic, pulmonary, renal, neurological (ATSDR, 2000), reproductive system and respiratory systems (ATSDR, 2000; Mandal and Suzuki, 2002; Kumar 2015).

Clinical symptoms occurring in the early stage of human arsenic poisoning were unspecific. The clinical manifestations of arsenic poisoning are myriad, and the correct diagnosis depends largely on awareness of the problem. Among the people who were taking high-arsenic water, early symptoms include palpitations, fatigue, headache, dizziness, insomnia, weakness, nightmare and numbness in the extremities and anaemia.

Long term intake of drinking water having arsenic concentration beyond the permissible limit of 0.05 mg/lit has deleterious effects on human health namely respiratory effects, cardiovascular effects, gastrointestinal effects, haematological effects, hepatic effects, renal effects, dermal effects, neurological effects, developmental effects, reproductive effects, genotoxicity effects, mutagenic effects, immunologic effects, carcinogenic effects and biochemical effects.

The above effects are mainly producing the following diseases:

i) Tumor in lungs, skin, kidney and urinary bladder

ii) Cancer and skin problems

iii) Cardiovascular diseases, diabetes and reproductive disorders

iv) Hypertension, erectile dysfunction, diabetes, depression, obesity and other conditions leading to alteration of intercellular potassium volume

v) Mining workers often accumulate a high level of arsenic in their respiratory systems leading to liver cancer and lung cancer.

In many countries, arsenic in drinking water has been observed at concentrations greater than the WHO guideline value i.e., 10 μg/l (0.01 mg/l) or the prevailing national standards. The major issue of arsenic-contaminated water is to find out the level of contamination and it is not so easy because of no colour, no odour and no taste even in the highly contaminated water. Arsenite is more toxic (approximately ten times) than the arsenate due to the former's ability to react with sulfhydryl groups thereby increasing the residence time (Nagarnaik et al., 2002). Although there is no widely accepted mechanism for the release of arsenic in groundwater, it has been accepted that the majority including the North-Eastern states of India is of natural, geological origin. Arsenic is considered to be closely linked with the oxidation-reduction process of pyrite and iron oxide (Kumar 2015).

12.3.4 Management of Arsenic Pollution

Conventional Arsenic Removal Technologies and Remedial Options

Many technologies have been developed for the removal of high concentrations of arsenic from drinking water. The most common arsenic removal technologies use oxidation, coagulation, precipitation, adsorption and ion exchange and membrane techniques. Other potential approaches would include phytoremediation or the use of bacteria, which can play an important role in catalyzing biological arsenic removal processes. All the arsenic treatment technologies ultimately concentrate arsenic in the sorption media, the residual sludge or in a liquid media. To avoid indiscriminate disposal and environmental pollution, these wastes need to be treated or disposed of properly.

1. **Oxidation and Filtration**: Oxidation of As (III) to As (V) by adding a suitable oxidizing agent followed by coagulation, sedimentation and filtration. Oxidation and filtration normally refer to the processes that are designed to remove naturally occurring iron and manganese from water. If arsenic is present in the water, it is removed via two primary mechanisms: adsorption and co-precipitation. First, soluble iron and As (III) are oxidized. The As (V) then adsorbs onto the iron hydroxide precipitation that is ultimately filtered from the solution. In general, the Fe: As mass ratio should be at least 20:1. These conditions customarily result in an arsenic removal efficiency of 80-95% (Haldar and Ray 2014).

2. **Coagulation/Filtration:** It removes arsenic by co-precipitation and adsorption using iron coagulants. Coagulation/filtration using alum is already used by some utilities to remove suspended solids and may be adjusted to remove arsenic. But the problem with this type of filtration system is that it gets clogged very easily, mostly within two to three months. The toxic arsenic sludge is disposed of by concrete stabilization, but there is no guarantee that it won't leach out in future.

3. **Co-precipitation**: The effectiveness of arsenic co-precipitation, with iron, is relatively independent of source water pH, in the range of 5.5 to 8.5. This technology can typically reduce arsenic concentrations to less than 50 µg/L and in some cases below 10 µg/L. To remove arsenic by co-precipitation, a coagulant is to be added. Water treatment with coagulants, such as alum, ferric chloride and ferric sulfate is effective in removing arsenic from water. Ferric salts are more effective in removing arsenic than alum on a weight basis and affect a wider range of pH. In both cases, pentavalent arsenic can be more effectively removed than trivalent arsenic (Haldar and Ray 2014).

4. **Iron oxide adsorption** filters the water through a granular medium containing ferric oxide. Ferric oxide has a high affinity for adsorbing dissolved metals such as arsenic. The iron oxide medium eventually becomes saturated and must be replaced. Sludge disposal is a problem here too.

5. **Adsorption:** Activated alumina is an adsorbent that effectively removes arsenic. The technology can reduce arsenic concentrations to less than 50 µg/L in general and in some cases even below 10 µg/L. Its effectiveness is sensitive to a variety of untreated water contaminants and characteristics. Activated alumina columns connected to shallow tube wells in India and Bangladesh have removed both As(III) and As(V) from groundwater for decades. Long-term column performance has been possible through the efforts of community-elected water committees that collect a local water tax for funding operations and maintenance. It has also been used to remove undesirably high concentrations of fluoride.

6. **Ion Exchange** has long been used as a water-softening process, although usually on a single-home basis. Traditional anion exchange resins are effective in removing As(V), but not As(III), or arsenic trioxide, which doesn't have a net charge. Effective long-term ion exchange removal of arsenic requires a trained operator to maintain the column.

Both **Reverse osmosis** and **electrodialysis** (also called *electrodialysis reversal*) can remove arsenic with a net ionic charge. (Note that arsenic oxide, As_2O_3, is a common form of arsenic in groundwater that is soluble, but has no net charge.) Some utilities presently use one of these methods to reduce total dissolved solids and therefore improve the taste. A problem with both methods is the production of high-salinity wastewater called brine, or concentrate, which then must be disposed of.

In some places, all the water supplied to residences by utilities must meet primary (health-based) drinking water standards. Regulations may necessitate large-scale treatment systems to remove arsenic from the water supply. The effectiveness of any method depends on the chemical makeup of a particular water supply. The aqueous chemistry of arsenic is complex and may affect the removal rate that can be achieved by a particular process.

Some utilities with multiple water supply wells could shut down those wells with high arsenic concentrations, and produce only from wells or surface water sources that meet the arsenic standard. Other utilities, however, especially small

utilities with only a few wells, may have no available water supply that meets the arsenic standard (Haldar and Ray 2014). Thus, the remedial options are as follows:

i. Use of surface water sources

ii. Exploring and harnessing alternate arsenic-free aquifer

iii. Removal of arsenic from groundwater using arsenic treatment plants/ filters

iv. Adopting rainwater harvesting/watershed management practices.

Surface water sources and deep aquifers are practised in places wherever they are found feasible in terms of technical and financial aspects, and as such schemes are few. Different types of arsenic removal schemes have been devised. These devices vary in size, filtering mechanisms, and mechanisms of operation. Based on the size, the schemes can be categorized as 'Arsenic Removal Unit (ARU)' and 'Arsenic Removal Plant (ARP)'. ARUs are those, whose inlets are directly connected to a hand pump or tube well. They are complete units. The "Arsenic Removal Unit" is normally a small assembly which can meet the requirement of water for a smaller section of people. ARPs, on the other hand, are those units, which can treat a large quantity of water and can cover a large section of the populace. Nearly, 77 ARUs, each having coverage of 15000 populations, have been installed with the existing piped water supply scheme. And 2396 ARUs, each having coverage of 600-800 population, have been fitted with the existing hand pumps. Nearly 1900 ARPs have been put in operation in many places.

Mitigation Measures

Elevated arsenic content in groundwater is one of the most serious concerns as it affects large unconsolidated aquifers along many alluvial and deltaic plains of the world, particularly in southern, south-eastern and eastern parts of Asia. The problem is compounded because the drinking water supply of these thickly populated regions is dependent on shallow aquifers which are found to be contaminated. In India, approximately 40 million people are residing within the risk zone of arsenic contamination (Acharyya, 2005; Saha 2009; Kumar 2015). A major source of arsenic in groundwater is of geogenic origin and is intricately linked to the aquifer geometry and groundwater flow regime. Its effective mitigation warrants understanding of physicochemical processes in groundwater and aquifer framework, lithology and groundwater flow regime of the area. The mitigation measures include a variety of options, ranging from removing arsenic from groundwater after it is extracted, searching for alternative aquifers, reducing the level within the aquifer itself, diluting the contaminants by artificial recharge, and blending it with potable water etc. (Kumar 2015).

EMERGING METHODS

Besides the conventional methods mentioned above, several new methods have been studied recently. The methods are listed below (Haldar and Ray 2014):

1. Fe-Mn Oxidation

2. Greensand Filtration

3. Coagulation assisted Microfiltration
4. In situ (sub-surface) Arsenic Immobilization
5. Enhanced Coagulation
6. Biological Arsenic Removal
7. Phytoremediation

Ex-Situ Arsenic Removal

This method primarily targets lowering the concentration of arsenic after the water is extracted from aquifers. The following processes are adopted for arsenic removal.

1. Precipitation Processes
2. Adsorptive Processes
3. Ion-exchange Processes
4. Membrane Processes

In-Situ (Sub-surface) Arsenic Treatment

In-situ remediation refers to all such techniques that make arsenic immobilization possible within the aquifer itself. As arsenic is mobilized in groundwater under reducing conditions, it is also possible to immobilize the arsenic by creating oxidized conditions in the subsurface (Kumar 2015).

1. Use of Atmospheric O_2 for Iron and Arsenic Rich Water
2. Use of Atmospheric O_2 and Ferrous Chloride for Low Iron and Arsenic Rich Water

a. Sub-Terranean Arsenic Removal (SAR)

In this technique, the aerated water is stored in feed water tanks and released back into the aquifers through the tube well by opening a valve in a pipe connecting the water tank to the tubewell pipe under the pump head. Many different physical, chemical and biological processes are intensified in the surrounding area of the well screen section, the so-called oxidation zone. Because of the input of oxygen, the redox potential of the water is increased. The dissolved oxygen in aerated water oxidizes arsenite to less-mobile arsenate, the ferrous iron to ferric iron and Manganese (II) to Manganese (III), followed by adsorption of arsenate on iron (III) and Manganese (III) resulting in a reduction of the arsenic content in tube well water (Kumar 2015).

b. Permeable Reactive Barriers (PRB) Technology

In this in-situ technique, walls containing reactive media are installed across the path of a contaminated groundwater plume to intercept the plume. The barrier allows water to pass through the media which removes the components by precipitation, degradation, adsorption, or ion exchange. Four types of materials have been used in the construction of permeable reactive barriers (PRB) used in the treatment of arsenic-contaminated groundwater - zero-valent iron (ZVI), furnace slag, and sorbents and composite materials (organic + ZVI or a sorbent). It has been observed that iron-based sorbents (IBS) can remove efficiently both the As (III),

As(V) and their mixtures. Iron oxide bearing minerals (iron-oxide coated sand) have long been recognized as an effective reactive media for arsenic-contaminated groundwater remediation (Kumar 2015).

c. Electrokinetic Treatment

Electrokinetic treatment is an emerging in-situ remediation method designed to remove heavy metal contaminants from soil and groundwater. The method is most applicable to soils with small particle sizes, such as clay. However, its applications for treating arsenic-contaminated groundwater are not of practical interest as treatment is limited by the depth to which the electrodes can be placed (Kumar 2015).

Of the various in-situ remediation techniques, in India, only the SAR technology (as described above) has been demonstrated successfully in parts of West Bengal.

12.4 FLUORIDE POLLUTION

Fluoride is the 13th most common element in the earth's crust as a component of the rocks and minerals. Fluoride is the lightest member of the halogen group of elements. In some respects, its behaviour is quite different from other halogens and it is reflected in natural water also. It is considered one of the minor constituents of natural waters, but it is an important parameter in ascertaining the suitability of water for potable purposes. Intake of 1mg/l per day is very much essential for the healthy growth of teeth, but a level higher than the permissible limit of 1.5mg/l is dangerous to health (ISI, 1991). Fluoride contamination of groundwater has now become a major geo-environmental issue in many parts of the world due to its toxic effects even if consumed in trace quantities. Fluoride in groundwater poses a great problem in most the states of India. Fluoride concentration in the groundwater of India varies widely ranging from 0.01ppm to 48 ppm (Gupta et. al., 2006). High fluoride content in drinking water sources has been observed in 15 states of India (Susheela 2001) and its manifestation in the form of fluorosis has been reported. The deficiency of fluoride leads to dental caries and a higher concentration leads to dental and skeletal fluorosis. Fluoride also circulates in the blood and affects the foetus, nerves and heart. Fluoride reduces the secretion of the thyroid gland by affecting iodine in the body which may lead to mongolism. Apart from these, excess fluoride intake will also cause gastro-intestinal problems like loss of appetite, nausea, vomiting, pain in the abdomen, intermittent diarrhoea, muscular weakness, excessive thirst, etc. (Nemade et.al., 1996). High fluoride intake over a period of time can cripple one for life (Dinesh Chand 1998).

12.4.1 Sources of Fluoride Pollution

Fluoride contamination in groundwater is mainly geogenic, wherein, during weathering and circulation of water in rocks and soils, fluoride is leached out and dissolved in groundwater and thermal gases. The fluoride content of groundwater varies greatly depending on the geological settings and types of rocks. Agricultural (use of phosphate fertilizers) and industrial activities

(clays used in ceramic industries or burning of coals) also contribute to fluoride concentration in groundwater.

The occurrence of fluoride in groundwater is mainly a natural phenomenon which is dependent on local and regional geological settings, particularly concerning the lithology of the aquifer and hydrological conditions. The parameters that tend to concentrate fluoride in groundwater resources tend to be related to soil characteristics with respect to their capacity for retention and leaching of fluoride. Because of the likelihood of excess fluoride in groundwater, WHO reduced the permissible limit in drinking water of fluoride in India from 1.5 to 1.0 ppm in the year 1998 (UNICEF, 1999).

A. Natural Sources

Fluoride enters the human body through a variety of sources viz. water, food, air, medicaments and cosmetics. The chief natural source of fluoride in the soil is the parent rock itself. Fluorite, the only principal mineral of fluorine in nature, occurs mostly as an accessory mineral in granitic rocks. The granite rocks contain fluoride concentrations of 20–3600 ppm. Apatite, amphiboles, pegmatite, hornblende, muscovite, biotite, micas, certain types of clays and villiaumite also contain fluorine.

It was observed in India that granites, minerals like sepiolite and palygorskite, acid volcanic and basic dykes of Rajasthan, the dark mineral fraction of gneisses of Tamil Nadu, fluoride-rich rocks in Karnataka and hard rock terrains south of Ganges valley in the arid north-western part are identified as rock sources. The varieties of soil sources include canal irrigated black cotton soils of Karnataka, soils and clays of Gujarat, and sodic soils in irrigated areas of Haryana and Andhra Pradesh.

1. Fluoride in Soil

The fluoride content in soil normally ranges from 200 to 300 ppm. Since fluorides are retained by the soil through strong associations with soil components, fluoride is not readily leached from soils. The fluoride content in soil increases with depth, and only 5 to 10% of the total fluoride in the soil is water-soluble. The fate of inorganic fluorides released into the soil also depends on the chemical form, rate of deposition, soil chemistry and climate. In acidic soils with pH below 6, most of the fluorides are in complexes with either aluminium or iron. Fluoride binds to clay by displacing hydroxide from the surface of the clay. The adsorption is strongly dependent upon pH and fluoride concentration. It is most significant at pH 3 to 4 and decreases above pH 6.5.

2. Fluoride in Food and Beverages

Virtually all foodstuffs contain at least trace amounts of fluoride as it is ubiquitous in the environment. Fluoride is entering the human food-and-beverage chain in increasing amounts through the consumption of tea, wheat, spinach, cabbage, carrots and other Indian foods. The fluoride in these items presumably results from the use of soil or fertilizer-borne fluoridated water for food and beverage processing. It has been observed that many agricultural products from Andhra Pradesh in India were containing fluoride ranging from 0.20–11.0

mg/kg. The tea plant is a hyperaccumulator of fluoride. Tea plants accumulate and store fluoride by absorbing it from the air and soil. Tea plants are found to have high fluoride uptake and 97% of it gets accumulated in leaves. The fluoride content of tea leaves is about 1,000 times the soluble fluoride content of soil and 2 to 7 times the total fluoride content in the soil.

B. Other Sources

The sources of fluoride also include aluminium smelters, industrial plants manufacturing hydrofluoric acid, phosphate fertilizer plants, enamel, glass, brick and tile works, textile dyeing, plastics factories and industries consuming high sulphur non-coking coal-like thermal power plants.

Presently, large amounts of an industrial effluent containing fluoride are generated from high-tech industries manufacturing semiconductors and integrated circuits. Teflon-lined cookware may also contribute to fluoride uptake by humans. The concentration of fluoride was found to increase to nearly 3 ppm in Teflon-coated cookware but in aluminium ware, it was decreasing. In stainless steel and Pyrex ware also fluoride concentration was found to increase but to a lesser degree. Fluoride in water may initiate leaching of aluminium from cooking utensils and copper from pipe works at normal and high concentrations respectively

C. Fluoride in Human Body

Fluoride as hydrofluoric acid is absorbed through the skin in humans and animals. The absorbed fluoride is rapidly distributed throughout the body via the blood, of which around 99% gets deposited in bones and teeth. The absorption of fluoride from the stomach is by a passive diffusion process inversely proportional to pH but is a rapid diffusion from the small intestine after gastric emptying. The presence of a diet rich in calcium, or co-exposure to calcium carbonate, reduces the fluoride absorption. Fluoride does not accumulate in most soft tissue but may enter the intracellular fluid of soft tissues as hydrogen fluoride.

The concentration of fluoride in soft tissues is reflected by that in blood. Fluoride is concentrated in high levels within kidney tubules and has a higher concentration than plasma. So, the kidney could be a potential site and target of chronic fluoride toxicity because of its exposure to relatively high fluoride concentrations. In humans, the placenta can regulate the transfer of fluoride from maternal blood to fetal blood, but fluoride is only poorly transported from plasma to milk.

It is reported that the average dietary intake of fluoride ranges between 0.02–0.048 mg/kg/day for adults living in areas with 1.0 ppm fluoride in water and areas with less than 0.3 ppm fluoride in water, the adult dietary intake ranges from 0.004–0.014 mg/kg/day. In children, the dietary intake ranges from 0.03–0.06 mg/kg/day in areas with fluoridated water and is 0.01–0.04 mg/kg/day in areas without fluoridated water.

12.4.2 Status of Fluoride Pollution

The technological advances made in the irrigation and drinking water sector developed almost simultaneously in India. While the technology has allowed

drinking water to be pumped from the ground through bore wells and hand pumps, it also provided the irrigation sector with the means for unfettered pumping of groundwater through millions of irrigation bore wells (nearly 3.7 million
in 2004), leading to an imbalance in the natural ecological system resulting in scarcity and pollution of groundwater. This unregulated groundwater tapping intensified the failure of drinking water sources and mainly paved the way for geogenic pollutants like fluoride in groundwater. In addition, geological processes, and weathering of fluoride bearing minerals in soil under different hydro-geological settings also contributed to higher groundwater fluoride levels in endemic areas. Thus, the scarcity of groundwater and the presence of excess fluoride can be treated as the two most crucial, critical and core issues in the Indian system of sustainable drinking water supply. Fluorosis is reported in 20 states of India, indicating that endemic fluorosis has emerged as one of the most alarming public health problems in the country. Among the affected states, Rajasthan, Andhra Pradesh and Gujarat are the most endemic. People in several districts of Rajasthan and Assam are forced to consume water with fluoride concentrations up to 44 ppm and 23 ppm, respectively. The Mega-City of Delhi is endemic to fluorosis with a natural maximum fluoride concentration of 32 ppm.

12.4.3 Impacts of Fluoride Pollution

Health and Environmental Impacts

Fluorosis is a crippling disorder due to the entry of fluoride into the body, which affects every organ, tissue, and cell in the body, and results in health complaints having overlapping manifestations with several other diseases like gouts and osteoporosis. In short, it causes dental fluorosis and musculoskeletal fluorosis. Fluoride damages the pineal gland, which secretes melatonin hormone in the brain. It also affects the reproductive systems and intelligence (Susheela, 2001). The acuteness of symptoms depends on the individual metabolism, nutrition, income, education, weather and socio-economic conditions of a locale.

12.4.4 Management of Fluoride Pollution

Defluoridation of drinking water is the only practicable solution to overcome excessive fluoride, where an alternative source is not available. While several technologies, based on industrial level processes such as adsorption and ion exchange in filter systems, coagulation and precipitation and membrane filtration have been developed and tested, sustainable implementation has rarely been achieved in rural communities. There are few technologies available for fluoride removal. The list of the technologies is as follows (Haldar and Ray 2014):

1. Nalgonda Technique
2. Precipitation Methods
3. Activated alumina
4. Electrocoagulation

5. Bone Char
6. Contact Precipitation
7. Degreased and alkali-treated bones
8. Activated Carbon and Lime
9. Ion Exchange Resins

CHECK YOUR PROGRESS 1

Note: i) Use the space given below for your answers.
ii) Check your answers with those given at the end of the unit.

1. Explain the sources of arsenic pollution.

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2. Explain the impacts of arsenic pollution.

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3. Explain the sources of fluoride pollution.

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4. Explain the impacts of fluoride pollution.

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12.5 LET US SUM UP

Arsenic is widely distributed in nature and principally occurs in the form of inorganic or organic compounds. Different forms of arsenic have different toxicities, with arsine gas being the most toxic form of the inorganic oxyanions, arsenites being the most toxic form and arsenate, the less toxic form. The organic (methylated) arsenic forms are considered the least toxic. Arsenic and fluoride contamination problems in groundwater are a major concern. In this unit, we have discussed the sources, status, impacts and management of arsenic and fluoride pollution.

12.6 KEY WORDS

Heavy Metals: It refers to a group of toxic metals including arsenic, chromium, copper, lead, mercury, silver, and zinc.

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ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Please refer to section 12.3.1
2. Please refer to section 12.3.3
3. Please refer to section 12.4.1
4. Please refer to section 12.4.3