Chapter 1

Environmental trace elements and radioactivity

1.0.1 Introduction

The world we live is made up of different elements - from the lightest, H and He, up to U. About 92 different elements have been found on the earth. They exist in 272 stable and 25 naturally radioactive isotopes. Besides that, man has succeeded in creating several elements unknown in nature and plenty of isotopes of the elements that exist in nature[1].

The last two decades have an increase in the industrial development and production. These increase have led to an additional stress on the environment in the form of acid precipitation, heavy metals and radionuclides[2]. People can be exposed to trace elements and radionuclides in the environment in numerous ways. The trace elements or radionuclides can be inhaled, ingested or taken up. Effects of concern can take place at the initial epithelial barrier i.e., the respiratory track, the Gastro-Intestinal(GI) track, or the skin, or can occur in other organ of the system after penetration and translocation by diffusion or transport by blood, lymph, etc. The consumption of energy and other human activities mobilize large quantities of a number of elements in the environment. As a result the uptake of trace elements by living organism is
being modified and because of a narrow range of adequacy this can result in different abnormalities. The concentration of an element in the body is proportional to the intake of this element from the environment. This indicates the maintaining the concentrations of all elements at levels adequate for the living-species requirements [3]. Therefore it is necessary to study environmental trace element and radioactivity in order to understand the environmental impacts and control the same in the environment.

1.1 Environmental trace elements

The distribution of elements in nature, their concentrations and their movements can be seriously affected by the activities of man. Environmental pollution, results from man's introduction of different substances into the marine, atmospheric or soil environment. Sometimes this can result deleterious effects such as harm to living resources and hazards to human health [1].

All plants and all animals, including man, depend ultimately upon their environment for the supply of mineral nutrients. Many diseases are caused by the inability of the environment to supply these mineral needs in adequate, safe, or non-toxic. The relation between the environment and living beings is very complex. Industrial treatment of different materials, their transport, storage and processing, as well as other of man's activities, can influence this sensitive relationship.

The inventories for trace elements given by Nriagu et al. show that mankind has become the most important role in the global biochemical cycling of trace elements [4]. The man-induced mobilization of trace metals into the biosphere (median values in thousand tonnes yr\(^{-1}\) of the terrestrial plus aquatic inputs minus atmospheric emissions) comes to about 120 for As, 30 for Cd, 2150 for Cu, 11 for Hg, 110 for Mo, 470 for Ni, 1160 for Pb, 72 for Sb, 79 for Se, 71 for V, and 2340 for Zn. The annual total toxicity of all the metals mobilized, in fact, exceeds the combined total toxicity of all radioactive and organic wastes generated each year, as measured by the quantity of...
water needed to dilute such wastes to drinking water standard. Each year, millions of tonnes of new trace metals are produced from mines and subsequently redistributed in the biosphere. The greatly increased circulation of toxic metals through the soils, water and air their inevitable transfer to the human food chain remains an important environmental issue which entails some unknown health risks for future generations.

For the past two decades research interest has been focused on the environment. This is partly by the increasing pollution of air, water and soil partly by the development of several very powerful analytical techniques. This has helped us to isolate and to understand the role of many elements which are present in small quantities. However, the biological effects of many elements are not yet known fully. The biological systems need many chemical elements in appropriate proportion for their proper functioning and survival. Therefore careful attention, without dramatization, should be paid to the study of element movements in environment. The study of trace element in environment, especially the heavy metals, has received considerable attention during recent years.

1.1.1 Trace elements in the coal & fly ash

The global energy needs have enormously increased with rapid stress in technology and to a large extent these have been met from the fossil fuels. Coal is burned in furnaces operating at upto 1700 °C in order to produce the electric energy. In the combustion process, most of the mineral matter in the coal is fuzzed into an ash. A portion of the heavier ash, together with incompletely burned organic matter, drops to the bottom of the furnaces as bottom ash or slag. The lightest ash(fly ash), however, is carried away through boiler, together with hot flue gases and is separated from the hot gases and any volatalized mineral compounds, to the stack, where, depending on the efficiency of control devices, mostly is collected while the rest(escaping fly-ash) is released to the atmosphere. Owing mainly to the elimination of organic content of the coal, there is an enhancement of the concentration of trace elements from coal to ash[5].
Combustion of coal in the thermal power stations produces fly ash and particulate emissions and their production is related with the type of combustion system in which coal is fired. Fly ash is a finely powder which is carried away with flue gases and is mostly collected from the hot gases by mechanical collectors or electrostatic percipitators or a combination of both. In the combustion process, roughly about 20% (by weight) of ash is precipitated as bottom-ash or slag, and 80% as fly ash. The modern power plants are equipped with electrostatic precipitators allowing ash(fly ash) retention of about 98% and thus release of 2%(escaping fly-ash)[6].

Combustion of coal in the thermal power stations gives to gaseous and particulate pollution in the environment. It is estimated that a 1000 MW coal-fired power station consumes about 3 million tones of coal per year, produces 1.2 million tones of ash[7]. One of the largest users of of coal are thermal power plants. Coal is also used in several other industries like steel and other metallurgical plants and even in textile and other industries. During the coal burning fuel cycle a great number of elements is released in large amounts into the environment. Large coal-fired power plant using pulverised coal, discharges gaseous and particulate matter into the environment. The gaseous products-include large amounts of smoke and dust, a large number of polluting gases like $SO_2, NO_x, CO, CO_2$ etc.

Fly ash is the major solid waste product of the combustion of pulverised coal in power plants. Large quantities of coal ash(fly ash and bottom ash combined) are produced throughout the world. In United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 1988 Report committee estimated that about 280 metric tonnes of coal ash are produced annually in coal-fired power stations[5]. Increased collection efficiency coupled with increased demand for coal as a source of energy, will undoubtedly bring about the availability of large amounts of fly ash. Since fly ash is a world-wide problem and conditions vary, from country to country but also from location to location within country, the situation call for a multiple process to meet the local circumstances. The concentration of trace elements in fly ash is extremely variable and depends on the composition of the parent coal, conditions
During coal combustion, efficiency of emission control devices, etc. It is recognised that health hazards and environmental impact from thermal power plants result from the mobilization of trace elements from the fly ash.

However, given the large amount of coal ash that accumulate at thermal power plants, their possible reuse and dispersion and mobilization into the environment of the various elements depend on climate, soils, indigenous vegetation and agriculture practices, hence there is a need to characterise electrostatic precipitator ash generated and consists of very fine particles that are readily dispersed by wind[8]. There are around 75 thermal power plants in India which currently produce about 60 million tonnes of fly ash per annum. Very small percentage (3 to 5%) of fly ash, generated in India, is being used for gainful applications and corresponding figure for other countries vary from 30 to 80% [9].

1.1.2 Trace elements in the soil

In the natural systems (rock, soil-aqueous solutions-organisms) soils are an exceptionally important link. The soil is the product of climate and living organisms acting on rocks, and its nature is determined both by the parent rocks and by the forces acting on them. The content of trace elements in soils is different from the content of these elements in the parent rock; however, youth soils, especially in mountainous regions, resemble the parent rocks in their content of trace elements. The more or less uniform content of Trace Elements (TEs) in soils is result of their long geochemical history.

Water in the soil is the main route migration of chemical elements in the soils. Tracer experiments have shown that the soil is in equilibrium with the soil solution, and that the rate of ion exchange between the two phases is fast[1]. Geochemical components, particularly the soil which may significantly influence the elemental composition of the vegetation due to repletion or depletion of trace elements and initiate imbalances in soil-plant-animal-human food chain.
Inventory of trace metals by Nriagu et al. clearly suggests that soils are receiving a large quantity of trace elements from a variety of industrial wastes[4]. The principal sources of trace elements in soils, however, are the disposal of ash residues from coal combustion and the general wastages of commercial products on land. Nevertheless, each soil has a limited retention capacity for trace metals and there is a growing concern that many soils in Japan and central Europe either have become or will soon become overloaded with toxic metals at the current rate of anthropogenic input. The technology for decontaminating such soils has yet to be developed. High concentration of metals can be added to soils through anthropogenic sources such as application of sewage sludges and fertilizers or from the atmospheric releases. Natural occurrence of metals in bedrock can also contribute to high levels of metals in soil.

### 1.1.3 Trace elements in the plant

The species of plants collected and studied often differ as widely as kind of soil on which they are grown. The necessity for sampling specific parts to identify trace element(TE) deficiencies or toxicities affecting growth of agricultural crops is well recognized. The uptake of the elements from the environment depends upon many factors including the elemental abundance in lithosphere, the form of the elements, the pH of the soil, the physical conditions of the soil, and genetic constituents of the plant. The TE composition of plants is a modified selection of the trace minerals present in the geochemical environment in which the plants are grown. There are many plants that accumulate elements to an anomalous degree; these are often used as biological monitors of pollution. Examples are mosses, grasses, the needles, tree rings, etc[10].

The magnitude of absorption of trace elements by plants grown on fly ash amended soils depends on the content of trace elements in fly ash, the rate of application, the soil type and its pH, the type of plant etc[6]. The accumulations of some elements such as B, Mo, Se and S to toxic levels are responsible for reductions in the crop yields and consequently influence animal and human health[10]. Therefore selection
of proper variety, soil situations and some pretreatment of fly ash are some parameters to be assessed.

1.1.4 Trace elements in the sediment

Sediments in rivers have a considerable capacity to constitute and retain many toxic elements. The source of these elements may be natural or anthropogenic. Heavy metals, thus, may be natural constituents of the sediments as minerals or may be incorporated into the sediments as artificial pollutants. Characterisation of these inorganic pollutants is important to understand sediment transport mechanisms in terms of spatial and temporal variations. Sediments, as pollutant accumulators, can give important and valuable information on the quality of the river in the past[11].

1.1.5 Trace elements in the water

Water covers a significant part of our plant's surface in the form of oceans, seas, lakes and rivers. Almost all the elements can be found in the waters in various concentrations. While the composition of oceans and seas is similar in different parts of the earth, the composition of lakes, rivers and steams reflects the geological composition of the soils. Most natural waters at some stage make contact with and react with the minerals of the earth's crust, altering them and accompanying this interaction by changes in their own composition. Water is the primary agent in rock weathering, and the chemical composition of rocks determines the elemental composition of natural waters[1].

Several recent surveys showed that heavy metals(As, Cd, Cr, Co, Pb, Zn, Hg) are widely distributed in low concentrations in surface-water sources of public water supply. For some metals the data show a distinct regional pattern. Most trace element concentrations in the world's principal natural/river waters are around or below 0.01 ppm. Only Al, Fe, Mn, Ba and Sr range much over 0.01 ppm. Significant differences with respect to area in TE concentrations are found in the river waters of North America[1].
Industrial processes which consume water generally discharges waste-water into the river which pose considerable threat to the surface water\[12\]. The main sources of trace metal pollution in aquatic ecosystems including ocean are domestic wastewater effluents(especially As, Cu, Mn and Ni), coal-burning power plants(As, Hg and Se particular), non-ferrous metals smelters(Cd, Ni, Pb and Se), iron and steel plants(Cr, Mo, Sb and Zn) and the dumping sewage sludges. Deposition of excess of trace elements in soil causes damage to the crops, plants and the flora in this region. Consumption of water contaminated with excess of trace elements is injurious to health & perhaps for wide spread of diseases like gastro-intestinal disorders, mental retardation etc.

1.1.6 Trace elements in the atmosphere

The earth’s atmosphere is essentially a mixture of nitrogen(77%) and oxygen(21%) plus small amounts of $CO_2$, argon and other gases. The atmosphere also contains dust particles of various sizes. TEs in airborne dust comes from earth’s surface and also from sources beyond the atmosphere. Terrestrial aerosols are lifted from the surfaces of land and ocean by winds or injected by the eruption of volcanos and by industrial activities. Larger particles(> 10\(\upmu\)m) are promptly returned to the surface by sedimentation, but smaller particles may be raised to high altitudes. Particles reaching the stratosphere will eventually be distributed on a worldwide scale. Aerosols are transfered to the earth’s surface by wet deposition through precipitation and by dry deposition through sedimentation, impaction and diffusion\[1]\.

The grave pollution produced by modern technology and by world population growth is so serious that it may precipitate changes in concentration of the chief gases in the atmosphere which are essential for life and human welfare. Five sources of atmosphere pollutants are usually considered: transport, industry, power generation, space-heating, and refuse-burning. Pollutants could be further classified according to their physical and chemical composition as: inorganic gases(sulphur dioxide, hydrogen sulphide, nitrogen oxides, ozone, ...); organic gases(hydrocarbons, ...); inorganic
particulates (metal oxides, ...) and organic particulates (pollen, ash, ...)[1].

Affords have been made to establish a quantitative relationship between total mortality rates from all diseases and the level of air pollution and other socio-economic variables. It has been claimed that a 10% increase in air pollution would increase in the mortality rate by $1.2-1.9\%$ [13]. Different effects of pollution on plant and animal life have been reported. The geographical spread of airborne metals has been demonstrated by the analysis of vegetative uptake and accumulation of metallic elements. Because most metals can be extremely toxic to plants even in low concentration, airborne pollution may causing significant changes in the genetic structure of the plant population exposed to them.

Atmospheric pollution and climate: The meteorological variables which affect the severity of an air pollution problems at a given time and location are: (a) wind speed and direction; (b) insolation (amount of sunlight); (c) lapse rate (temperature variation with height); (d) mixing depth; and (e) precipitation. The non-meteorological factors of the type and quantity of pollutants, topography and individual susceptibility must also be considered.

Air pollution and mortar exhaust gases: Transportation sources account for over 60% by mass of the total pollution. Exhausts from automobile engines produce most of the atmospheric pollution. The exhaust include smoke (mainly from badly maintained or operated diesel engines), carbon monoxide, oxides of nitrogen, hydrocarbons, lead, and other things. These pollutants, once in the atmosphere, participate in different photochemical reactions. In the engine, organic lead (tetraethyl or tetramethyl lead) is broken down and lead is expelled mainly as a sub-micron particulate aerosol of oxides and halides altogether about 50% of the Pb in petrol is emitted to the atmosphere as a fine particulate. There is clear evidence of lead pollution is caused by mortar vehicles close to busy roads.

The quantitative relationship among trace elements over industrialized Indiana, USA, has been studied [1]. They showed that some elements show only minor variations.
over the area, while others show marked concentration increases near large industrial complexes-pollution sources. A close relationship between several elements likely to have common sources is demonstrated by linear correlation coefficients and mathematical cluster analysis. Pollution elements such as Fe, Mn, Zn, Sb, Cr, W, Co, Sc, La, Ce and Mg seem to be linked strongly to the local steel production and supporting industries. Cu, though also apparently of industrial origin, comes mainly from a different source.

Elements in the atmosphere aerosols may be due to natural process and/or to human activities. It is easy to identify the processes and therefore one cannot always distinguish between a pollutant and a natural component of atmosphere. In the study of the elemental concentrations in aerosols from the San Francisco Bay area it was concluded that the inorganic fraction of the particulate matter is largely soil-derived[1]. The remainder is mainly ocean aerosol.

Recent research on the health effect of air pollutants has highlighted the importance of aerosols. Thus evaluations in aerosol concentration have been associated with increases in mortality from all causes in series studies and as well as showing as association with respiratory disease.

### 1.1.7 Relevance of trace elements in health

In order to sustain life on the earth many elements are needed, some in bulk quantities, some only in trace amounts. The bulk of living matter is made up of eleven elements such as H, C, N, O, Na, Mg, P, S, Cl, K and Ca. Essential trace elements for warm-blooded animals are F, Si, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, As, Mo, Sn and I [3]. It is obvious that all essential elements may have toxic effects if present in more than the adequate concentration. In addition some elements exhibit toxic effects even in very small concentrations and are sometimes classified as toxic elements.
The mode of action of some of the trace elements highlighting their functions and deficiency aspects are summarized:

ALUMINUM: Al is the third most common element encountered in nature, accounting for about 7.5% of the lithosphere. Al compounds are widely used in all type of industries. Patients with renal distress often exhibit an accumulation of Al during dialysis[13]. Numerous studies have been shown that Al can inhibit cell division and produce chromosomal aberration in plants. Al has been found to cause cancer in a few experimental animal studies[14]. Neurotoxicity, especially of the Alzheimer, has been associated with Al accumulation, as has been a blood disorder, although the later condition is less frequently observed[15].

SULFUR: There are numerous studies of associations between sulfur oxide pollutants such as $SO_2$ and $SO_4$ and various health effect indices in polluted communities[16].

MANGANESE: Prolong chronic intake of Mn affects the Central Nervous System (CNS) which results in partial or total disability.

CHROMIUM: Chromium metal is biologically inert and has not been reported to produce toxic and other harmful effects in man or animal. Deficiency of chromium can induce the following signs: i) decreased glucose tolerance such as elevated blood glucose and an increased necessity of insulin, ii) body weight loss by decreased glucose availability, iii) peripheral neuropathy by decreased transmission velocity of peripheral nerves and iv) other signs such as metabolic encephalopathy by decreased glucose tolerance, and dystonia (weak muscle). Chromium deficiency can be caused by i) long-term parental nutrition with chromium insufficient or deficient fluid, ii) a low chromium diet of vegetables, fruit as a low-protein diet, iii) a low body weight and an insufficient maternal chromium supplement, iv) diabetes with increased urinary excretion of chromium and v) an increased demand for chromium due to pregnancy or multiparity[17].

Health effects of chromium are as follows: i) chromium ulcer (hardly curable), ii)
chromium-induced perforation of the nasal septum among chromium plating workers (chromium mist can induce an itch at the nasal septum, and chromium contamination with dirty fingers can cause perforation), iii) chromium lung cancer among chromium smelter workers, iv) chromium asthma, which is seen among cement workers, and v) health effects seen in residents using water polluted with chromium, causing dermatitis, stomach ache, diarrhea, vomiting as well as the perforation of the stomach. Cr compounds are also responsible for wide range of respiratory diseases.

NICKEL: Nickel is also an essential trace element. Excess intake of copper causes stomach ache, diarrhea, vomiting, liver dysfunction and hemolysis. Nickel alloys and Ni compounds are a major causes of dermatitis[18]. Asthma has been associated with inhalation of nickel containing mists released from industries. In addition to inhalation-related cancers, malignant neoplasms could be induced by Ni compounds at the site of exposures.

COPPER: Copper is also an essential trace element. It is a constituent of enzymes necessary for life such as cytochrome oxidase, superoxide dimutase, ascorbate oxidase or ceruloplasmin. It is essential for cross-linking of elastin. Signs of copper deficiency are anemia, blood vessel necrosis, dyspigmentation, neuropathy, emphysema and diarrhea.

ZINC: It is considered essential trace element because it is i) a constituent of over 100 enzymes, necessary for nucleic acid and protein synthesis, RNA/DNA polymerase and ii) necessary for hormone synthesis and secretion such as gonadotrophin in the pituitary glands, and insulin and glucagon in pancreas and iii) needed in other processes such as the metabolism of amino acids and collagen[19].

Signs of Zn deficiency are i) depressed growth, ii) depressed sex hormone production, iii) depressed immunity, iv) zinc deficiency of the skin such as dermatitis, hair loss, and delayed healing of wounds and v) depressed metal activity induced by low zinc in the hippocampus.
ARSENIC: Epidemiological studies have demonstrated that inorganic As is carcinogenic[20]. Arsenic is released into environment as a pollutant during the several industrial process & symptom associated with arsenic toxicity include epithelioma, liver dysfunction and several cancers[13]. Different compounds of arsenic may be inhaled and absorbed by human body resulting in lung tumors and mild bronchitis[21]. Increased incidence of respiratory cancer have been documented for occupationally exposed individuals in smelting and chemical industries. Skin ailments marked by the emergence of dark brown spots on the body, thickening of palm and feet tissues, growth of warts on hands and legs, asthmatic and bronchial problems, cirrhosis of the liver, kidney failures and skin cancers attributable to arsenic poisoning are being reported.

CADMIUM: Chronic inhalation of Cd produces a variety of effects such as emphysema, liver damage, anemia and renal tubular damage. The carcinogenity of Cd has been demonstrated in experimental animals[13]. It was found that a significant depression in growth and the occurrence of rough fur in rats fed food containing only scarce amount of cadmium[22].

It was also found an elevated rate of abortion in female goats fed food containing scarce amount of cadmium, and severe amyosthenia, aphagia or hypophagia(difficulty to take food) resulting in death occurred in infant goats fed food containing scarce amount of cadmium. These findings suggest that cadmium is not only a harmful element but also an essential element. Some cadmium workers suffered from lung dysfunction and renal proximal tubular dysfunction such as 2-microglobulinuria, proteinuria, glycosuria, and aminoaciduria.

LEAD: Lead is very useful, but very harmful as well. It has multiple serious health effects[17]. Lead is a potent negative neurological and hematopoietic effects on workers, such as extensor paralysis(drop hand), sensorineural paralysis(anesthesia of hands and feet), anemis, an increase in stippling erythrocytes, increased urine coproporphyrin, decreased dehydratase(-aminolaevulinate), increased urine(-aminolaevulinic acid) and
lead face (anemic face of lead workers). Pb has been recognised to be acutely toxic at high-dose exposures. Recent researches, with respect to understanding that toxicity of Pb indicate the Pb is capable of producing toxic effects to adults and children far lower than those producing gross clinical symptoms. Prolong chronic intake of lead causes neurological & mental retardation.

Lead is especially toxic to children. It also induces negative psycho-neurological effects on children. Increased blood lead results in a decrease in learning. Soil pollution with lead has been discussed in relation to depressed intelligence among children living in the US slums. For lead, frequent values for several countries are within the range of 90 to 150 \( \mu g \ l^{-1} \). Relatively high values, 170 to 240 \( \mu g \ l^{-1} \), are seen for several cities in Italy, Los Angeles, and Halifax (Canada). China and Japan show intermediate values of 50 to 80 \( \mu g \ l^{-1} \), while distinctly lower levels, ranging between 8 and 30 \( \mu g \ l^{-1} \), have been reported from Nepal and some remote parts of Venezuela[23]. The differences in concentrations reflect the various environmental conditions which are major contributions to the total daily intake of lead. This picture may change as more countries initiate regulatory measures to limit lead emission to the environment.

MERCURY: It is a toxic trace element. Its presence at all levels is considered poisonous to the body. Intestinal absorption of metallic mercury is quite low and thus ingested mercury rarely induces intoxication. However use of inorganic laxatives may increase the intestinal absorption of mercury resulting in intoxication. Exposure to mercury results in abdominal pains, diarrhea and nephropathy. Prolong exposure to Hg at higher levels also produces major effects on central nervous system[24]. The teratogenic effects of Hg, in particularly the organomercurials, have been documented in humans.

1.1.8 Need for studies of trace elements in environment

Elemental analysis of environmental systems is undertaken

(i) to study the long-term changes in the distributions of environmental trace elements
(ii) to assess the state of health related to environmental exposure problems including nutrition
(iii) to elucidate the fundamental biochemical links between chemical elements and living things.

In environmental sciences the increase in pollution level due to the metals which are not biodegradable has caused serious concern. These metals may be important contributing factor to the chronic diseases warranting continuous monitoring and surveillance and monitoring activities. A significant amount of research is currently in progress in identifying the plant species which have the ability to accumulate selected elements as part of environmental monitoring process[1].

The relationship between health and exposure to elements through food, air, and water is a major area of analytical endeavor that is bound to attract ever-increasing attention.

The nuclear and related analytical techniques for trace element analysis

Atomic Absorption Spectrometry (AAS):

AAS allows measurement of the concentration of a species in an atomic vapor which absorbs radiation at characteristic wavelengths[25]. To provide the energy for vaporization and atomization, either a premixed flame or electro thermal atomizer is used. Various combinations of the flame techniques are in practice, including direct nebulisation after pre concentration by solvent extraction for separation of bulk components (e.g., calcium, sodium, and phosphate ions), flameless techniques (especially for aluminum, cadmium, and mercury), and gaseous hydride formation commonly used for arsenic and selenium. Detection limits go down to picograms range for several elements. With the introduction of electrothermal or flameless atomization, application of AAS has achieved a tremendous impact on trace element analysis.

AAS has been extensively used in the determination of a number of elements such as copper, zinc, cadmium, lead, iron, and nickel. Although until today mainly single
elements can only be determined sequentially, this disadvantage is compensated by high sensitivity. The sensitivity is high due to the introduction of the electrothermal atomization in furnaces (ETAAS) or furnace-AAS, preferably with graphite tube furnaces (GFAAS) and of the background compensation by Zeeman effect. The power of detection of GFAAS is by 2-3 orders of magnitude higher compared to that of Flame-AAS (FAAS).

Advantages: For single element determinations or sequential analysis of a number of elements, both flame and flameless varieties have considerable merit. Further, the equipment is only moderately expensive, can be employed for many applications, and is very simple to handle.

Disadvantages: At present, AAS is not commonly used for simultaneous multielement determination but for occasional exceptions which although very promising, are still on a test scale. Flameless methods are subject to matrix effects which may be troublesome if not adequately corrected for. Moreover, solid samples require ashing which may lead to the problem of loss and contamination. This requires stringent precautions.

**Atomic Emission Spectrometry (AES) and Inductively Coupled Plasma**

**Atomic Emission Spectrometry (ICP-AES):**

AES is the classical technique which has long been used for simultaneous multielement determinations. The principle of the technique is to apply a high-voltage electric arc or high-temperature flame to excite the atoms to very high energy states. The atoms eventually return to lower energy levels, thereby emitting radiation of characteristic energies and wavelengths, forming the emission spectra which are specific to particular atomic species[26].

AES is the oldest multielement atomic spectrometric methods and originally involved the use of flame, electric arc or spark excitation. However, immense new activities took place after the introduction of various new plasma excitation sources like Inductively Coupled Plasma (ICP), Direct Current Plasma (DCP), Capacity coupled
Microwave Plasma (CMP) and Microwave Induced Plasma (MIP). Most experience for
the analysis of biotic matrices has been gathered with ICP. With pneumatic nebuliza-
tion, the power of detection lies somewhere between that of flame and furnace AAS
techniques. Especially for elements with thermally stable oxides (e.g. lanthanides),
the limits of detection are low. This is in contrast to elements with high ionization
and most sensitive analytical lines with high excitation potential. Accordingly, Cd,
Tl and Pb can be determined by AAS with significantly higher power of detection.
The powers of detection of ICP-AES and of DCP-AES methods are almost identical
and are similar to those of spark-AES.

Advantages: The method posses a wide dynamic range in addition to having the
unusual feature of being relatively free from inter element matrix effects, barring a
few exceptions. Since no electrodes are used there is no contamination from them
with other type plasma.

Disadvantages: The sample material should be in solution which means that, for
solid environmental samples, dissolution or ashing will be potential source of con-
tamination or loss of analyte. However, for fluids such as water, a preconcentration
step is necessary to be able to determine several trace elements. There are consider-
able difficulties in using ICP-AES due to stray light, background recombination, and
nebulization-transport effects that warrant improvement.

Mass Spectrometry (MS):
Mass spectrometry operates on the principle of producing gaseous ions from a sample,
sorting out the resulting mixture of ions according to their mass-to-charge ratios, and
providing output signals which are measures of the relative abundance of each ionic
species. MS techniques include spark source MS, isotope dilution MS, and secondary
ion MS. Of these, only spark source MS is of major importance for simultaneous
multielement analysis [27].

Advantages: MS is a versatile multielement instrumental method with excellent sen-
sitivity.
Disadvantages: Only a few elements can be determined in environmental samples because of their generally low trace element concentration profiles. MS needs elaborate preparation of conducting electrodes, and ashing of the sample may be necessary to exploit full capabilities. Moreover, extreme care should be taken to ensure homogeneity of the sample material since only a fraction of the total sample is utilised during sparking. Unresolved spectral interferences due to molecular lines and multi charged species constitute other sources of trouble. Finally cost of the equipment is high.

Nuclear Activation Techniques:
The principle of activation analysis involves the production of radioactive nuclides from stable isotopes, followed by the measurement of the radiations emitted by the radioisotopes. When this technique is used, a number of steps can be combined efficiently to achieve very high sensitivity and accuracy[28].

In general, these steps include choice of an appropriate nuclear reaction, availability of a suitable irradiation facility, optimal conditions for irradiation (post-irradiation and pre irradiation treatment), if any, and suitable radiation detection system. There are various radioactive analysis, such as those using neutrons, charged particle and energetic photons. Among the varieties of these techniques, thermal neutron activation is most commonly used for environmental samples because of the generally high activation cross-sections for a number of elements.

Neutron Activation Analysis(NAA), which is the most common mode of these techniques, is used for analysis of environmental and biological matrices. The physical phenomena upon which NAA based are the properties of the nucleus, radioactivity, and the interaction of neutron with matter. When a neutron interacts with a target nucleus by a non-elastic collision, a compound nucleus is formed in a highly excited state. The lifetime of compound nucleus is typically 10^{-16} to 10^{-14} s. This is long enough that no traces remain to identify the particular process of formation, but short enough that the nucleus can undergo a rapid de-excitation to a more stable configuration, in a number of different ways which usually involve emission of nuclear
particles or prompt gamma rays. In most cases, the new nucleus is radioactive and will further de-excite by emitting decay gamma rays. The NAA method relies on the measurement of either these characteristic prompt or decay gamma rays for identifying elements and determining their amounts present in samples. About 70% of the elements have nuclides possessing suitable for NAA.

Advantages: Unusual freedom from contamination following irradiation and high sensitivity constitute the major advantages of this technique. Matrix problems are virtually non existent, with occasional exceptions. This method is based inherently on nuclear properties as opposed to electronic properties.

Disadvantages: In general, nuclear activation techniques involve high equipment costs. Neutron Activation Analysis (NAA) requires a neutron source such as nuclear reactor. Non destructive analysis, in particular, requires very complex and expensive instrumentation. Moreover some elements of environmental interest can not be determined. Further more successful application of nuclear activation technique requires a high level of expertise.

**X-Ray Fluorescence (XRF) & Total reflection X-Ray Fluorescence (TXRF):**

The emission of characteristic X-rays following atomic excitation has long been used for elemental analysis. Electrons, X-rays and gamma rays have been used for the excitation. The essential components of an X-ray spectrometer are an excitation source; specimen chamber; detection system capable of separating X-rays by either wavelength, energy or both; and the electronics necessary to process signals and accumulate spectra. A computer based electronic system with appropriate data-reduction software is an essential component of an XRF system. The XRF technique is applicable in principle to all the elements from sodium to uranium. When a wavelength dispersion grating is used to separate the secondary X-ray signal from the sample into a spectrum it is known as Wavelength Dispersive XRF (WDXRF), and when a solid state Si(Li) detector is used it is known as Energy Dispersive XRF (EDXRF). The detection limits of XRF are in most cases incompatible with requirements for
certain environmental samples. In general detection limits are tens to hundreds of micrograms per gram and even with sample pretreatment, the detection capability is usually limited to a range between 0.01 to 10 \( \mu g/g \). The power of detection is optimal for elements around atomic number 30. The main limiting factor for the power of detection is the Compton and Rayleigh scattering of the primary beam. Furthermore, inter element effects necessitate it to calibrate with standards that must be very similar in composition to the sample\[29\]. Better power of detection and accuracy can only be achieved by decreasing the signal-to noise ratio and the matrix effects. This can be done in the following ways.

(a) By application of Total Reflection X-Ray Fluorescence (TXRF) technique\[30, 31\]. Here, a very small angle of incidence of exciting X-ray beam is chosen so that it is totally reflected at the target surface. When the target surface is optically flat (as is possible with quartz, glassy carbon or polyacryl) and even when it is homogeneously coated with a very thin film of sample material, the power of detection of TXRF is a factor of up to 1000 (pg-region) better than conventional energy dispersive techniques. The main problem lies in sample preparation on the micro-scale. This starts with cleaning the sample carrier and distributing the elements to be determined as an homogeneous thin layer of less than \( \mu m \) thickness. Solution evaporation, cathodic sputtering or electrolytic deposition techniques can be used for this purpose.

(b) The other alternative is to use Particle Induced X-ray Emission (PIXE) method\[32\]. With respect to the power of detection, TXRF is more superior to PIXE. However PIXE has higher absolute power of detection in comparison to conventional XRF. The PIXE is an optimal tool for multielemental analysis of environmental samples. The absolute detection limits can go down to pico gram level. The above techniques clearly describe that there is no single technique which is complete in itself to provide data for all the elements at all concentrations. Further the limitations like cost, availability and user friendliness of each technique needs to be considered before choosing a technique. Keeping this point in mind, the nuclear techniques such as PIXE and PIGE were used in the present work for trace element analysis of environmental samples.
1.2 Environmental radioactivity

Environmental radionuclides can be divided into three groups according to origin [33]:
(a) those of primordial origin, together with radioactive daughters; (b) those continuously produced by natural processes other than the decay of primordial radionuclides; (c) those generated by man's activities.

All form of life on earth are unavoidably exposed to the ionizing radiations from the natural sources present in the terrestrial matter as well as in the extraterrestrial matter. Population exposures arising from the natural radiation sources are fairly constant at any place. However, certain human activities have enhanced the radiation dose to the population at large. Such activities are mainly the nuclear weapon testing during yesteryears, nuclear facilities for electrical power production, coal based thermal power plants and wastes dispersion from the industries. The ionising radiations arising from the natural sources and from the aforementioned human activities irradiate the population externally from the radionuclides which have been taken into the human body through normal physiological pathways.

The relative dose from specific radionuclides may not be in proportion to their concentration in air, water, food, or other material that are in the pathways for introduction of the radionuclides into the body. Thus, a particular radionuclide in a mixture may be the most important one. The dosimetric importance of radionuclides depends on their differential metabolism by man, the quantity consumed, and physical and chemical properties that determine their movement in the environment and eventual uptake, deposition, and retention by man. As a result, the measurements should be specific for given radionuclides and in some cases should identify their chemical and physical form. The study on internal exposure due to some radionuclides like $^{210}$Pb, $^{210}$Po & $^{226}$Ra(natural origin) and $^{137}$Cs & $^{90}$Sr(fallout origin) further assumes significance because of their long-lived radioactive and biological half-lives[33].
Human beings can be exposed to environmental radioactivity in a number of ways. When a gamma-emitting substance is deposited on the surrounding surfaces, the ambient radiation background will be increased. If the contaminant is initially airborne, the radioactive particles may be inhaled or may deposit on the skin. Particles deposited on the surfaces can be resuspended by wind action or human activity and can then be inhaled. The most complex mechanisms are those that involve contamination of food chains. The pathways are often more complex, and fine details of some of the transport mechanisms are not always understood. The environment is crisscrossed with physical, and biological pathways that link the biophysical and biochemical processes on which all organisms depend for their existence. There are subtleties that may increase the opportunities for human exposure, but there also natural protective barriers.

Measurements of radionuclides in man's environment are required for assessment of exposure to both natural and manmade radiation sources and studies of the movement and retention of manmade radionuclides in environmental media and of the composition of the natural radiation environment. Measurements aid in the determination of changes in the concentrations of certain radionuclides and identification of long-term trends due to the nuclear fuel cycle, to man's use of radioactive materials. Experimental studies of natural radionuclides in the environment contribute to our knowledge of geological processes and atmospheric phenomena.

Natural radioactivity
Natural radioactivity ordinates from extraterrestrial sources as well as from radioactive elements in the earth's crust. About 340 radionuclides have been found in nature, of which about 70 are radioactive and are found mainly among the heavy elements. All elements having an atomic number greater than 80 possess radioactive isotopes, and all isotopes of elements heavier than number 83 are radioactive. The radioactivity of the earth now includes the primordial radionuclides, whose half-lives are sufficiently long that have survived the interval since their creation, and the secondary radionuclides which are derived by their radioactive decay. The naturally
occuring radionuclides can be divided into those that occur singly and those that are components of three chains of radioactive elements\(^{238}\text{U}, \ 232\text{Th}, \ 235\text{U series}\). Natural radiation dose to the population arises from the cosmic rays, cosmogenic radionuclides as well as U and Th series radionuclides and \(^{40}\text{K}\) present in the earth's crust. This is the highest contributor of population dose at any place and it is fairly constant in absence of any above mentioned human activity[34]. The internal dose estimation can be divided into two components namely, ingestion and inhalation.

**Radionuclides in Nuclear fallout**

During the fifth and sixth decades of this century, the major source of the manmade radiations was the atmospheric nuclear explosions carried out by the nuclear weapon countries namely USA, USSR, Great Britain, France and China. 423 atmospheric tests totaled about 545 MT, consisting of 217 MT yield from the A-bombs and 328 MT from H-bombs[35]. The atmospheric testing of nuclear weapons has resulted an increase in external and internal dose to the population at large. Later on, due to atmospheric nuclear test ban treaty of 1963 by major nuclear powers, the dose contribution from the nuclear explosions to the population is diminishing every year. However, the above ground nuclear explosions were carried out by France and China till 1980 and have contributed to some extent in enhancement of environmental radioactivity. About 400 radionuclides with the half lives varying from a fraction of a second to the several years are produced during the nuclear explosions and nuclear power generation. The total radioactivity of the fission and activation products in a nuclear explosion at the initial stage is extremely large, but reduces at a fairly rapid rate as the result of radioactive decay. The production of these radionuclides depend on the type of explosion, fissile material use, and the yield of the device. The average estimated production of \(^{137}\text{Cs}\) and \(^{90}\text{Sr}\) is 5.9 and 3.9 PBq/MT where it is estimated that one atom of \(^{239}\text{Pu}\) is produced per fission. Radionuclides with shorter half lives quickly decay to the stable daughter products and the long-lived ones circulate globally and finally settle down on the earth's surface and enter the human body. The total deposition of \(^{137}\text{Cs}, \ 90\text{Sr}\) and \(^{239-240}\text{Pu}\) from the nuclear explosions
through 1980, is estimated to be approximately, 960, 600 and 13 PBq respectively.

**Technologically modified exposures from the primordial radionuclides**

There are circumstances where a section of population finds themself in a natural radiation environment to which they would not exposed if some kind of technology had not developed. Examples are living in the neighbourhood of a coal-fired power plant, production and usage of phosphates fertilizers etc[36]. Fossil-fuel fired power plants can release the trace amounts of natural radionuclides present in these sources. Amount released from coal-fired plants without particle control are in the range of Curies per GW-year; amounts from oil-fired plants are somewhat less. Phosphate fertilizers are used in huge amounts everywhere in the world. The natural resource from which agricultural phosphorus is obtained is phosphate rock, found in sedimentary formations, usually interbedded with marine shales or limestones. The application of phosphates fertilizer for agricultural production results in increase of primordial radionuclide’s activity in the soil. Exposures to practices in every-day life that cause an increase in the level of dose resulting from the technologically enhanced background radiation such as the use of the certain materials in the construction of buildings, consumption of water and foodstuffs in which the concentration of radionuclides is unusually high because of their origin, or has been enhanced, for example use of fertilizers and fly ash[37].

Two important by-products from the processing of phosphate rock are gypsum and calcium silicate slag, both of which are used in the building industry. Use of these products may increase the gamma radiation exposure.

**1.2.1 Radioactivity in the coal and fly ash**

The world production of coal, expressed in coal equivalent for energy purposes, was $3.1 \times 10^{12}$ kg in 1985 [34]. A large fraction of coal extracted from the earth is burnt in thermal power stations. Coal contains naturally occurring radionuclides arising from the U and Th series and also $^{40}\text{K}$. Therefore coal burning is one of the sources
of technologically enhanced man from natural radioactivity [38]. Large coal-fired power plants using pulverised coal, discharges gaseous and particulate matter into the environment along with fly ash, which is enriched in radionuclides such as $^{226}$Ra, $^{40}$K etc [39]. In the light of the possible radiological significance in the environment, studies have been carried out by many investigators in different parts of the world to assess the nature and quantity of radioactivity release from the coal-fired thermal power stations. Some of these studies have shown that the radiation hazard in the environment of the coal-fired stations is comparable and sometimes even higher than that of Nuclear Power Stations [40]. Therefore it is necessary for study of radioactivity in fly ash and its products.

To define a source term for assessing the ecological and human exposures and doses resulting from the releases of radionuclides from the thermal power plants, it is necessary to estimate the radionuclide contents in the environment. External exposures result primarily from more penetrating gamma rays although energetic beta particles from those nuclides closer to the body will also contribute to the external dose. Internal exposures from the inhalation and/or ingestion of radionuclides, which then proceed to administer a radiological dose resulting from their radioactive decay, leading to energy absorption with specific tissues.

Radiation exposures occur through the fuel cycle, which consists of coal mining, the use of coal and the use of fly ash. The concentrations of the radionuclides are usually low in coal, when coal is burnt in power stations, the fly ash that is emitted through the stack gets enriched in some of the radionuclides and hence combustion of coal on a large scale for power generation assumes importance from the environmental point of view [40]. Fly ash is used in building construction as backfill, bricks, foundation and in concrete mixes. Since fly ash containing significant concentrations of $^{226}$Ra and its decay products, in addition to higher than normal external gamma ray exposures to the residents, the elevated airborne concentrations of $^{222}$Rn and $^{220}$Rn, and their daughters may create, significant risk of bronchial carcinoma from the inhalation of the Rn daughters. There are conflicting views in the impact of the use fly ash on the
dose from inhalation of radon decay products. With respect to external irradiation, the committee estimated in the UNSCEAR 1988 report, on the basis of measurement made by Stranden, that the use of concrete containing fly ash constructing dwellings would result in additional effective doses of 70 μSv and 30 μSv in concrete and wooden houses, respectively[5].

1.2.2 Radioactivity in the soil

The radionuclides which contribute most to environmental radiation are the members of the natural radioactive series and 40K. These are present in rocks and minerals in concentrations that can vary by order of magnitude, depending on the geochemical process to which the materials they come from have been subjected[41-42]. The soil has a concentration of natural radionuclides that is determined by the concentrations in the parent rock and by the physiochemical phenomena associated with its weathering.

Contamination of land and water can occur either from the deposition of radioactive material originally introduced into the atmosphere, or from the waste products discharged directly into the surface waters or placed in or on the ground, from which they are eventually mobilized by ground water or erosion. A consequence of the nuclear tests carried out since 1945 has been the injection of man-made radioactive elements into the atmosphere. Their harmfulness on being deposited in the soil depends upon their migration rate, affecting man by direct radiation, by inhalation or by ingestion of superficially contaminated vegetables/food.

It is useful to analyse gamma-ray emitting radionuclides in soil as an aid to evaluating direct radiation exposure. Soil sample analysis is a common method of environmental monitoring, but the interference of dose from measured radionuclide concentrations is complex due to wide range variations in resuspension or uptake by vegetation. Because soil accumulates long-lived radionuclides, information from soil sample analyses is not very useful for estimating short-term trends in radionuclide concentrations, but
can, in some circumstances, be used for retrospective evaluation of environmental contamination.

1.2.3 Radioactivity in the plant

The primary reason for concerned about radioactive contaminants of the environment is that it results in exposure of humans. The dose to plants and lower animals is not an important consideration because they are orders of magnitude more resistant to the effects of radiation than humans[43]. Numerous radioactive elements are distributed widely in plants and soils. Radioactive elements present in the natural environment enter the human body through agricultural products. There is increasing interest in documenting the levels of natural radionuclides in agricultural samples. Most of the food consumed by human beings is grown on land and except for elements like C and O, which may be obtained from the atmosphere, it is the soil that nourishes the terrestrial ecosystem that supplies human food. Radionuclides such as $^{210}$Po and $^{226}$Ra that occur naturally in soil are incorporated metabolically into plants and ultimately find their way into food and water.

In addition to root uptake, direct deposition on foliar surfaces can occur, in which case contaminants can be absorbed metabolically or, more likely, can be transferred directly to animals that consume the contaminated foliage. Foliage deposition is potentially a major source of food chain contamination by both radioactive and non-radioactive substances[44]. Uptake of a long-lived radionuclide by plants depends to a considerable degree on whether it remains in the root zone and on the extent to which it is chemically available for transport to root endings and the metabolic requirements of the plant. Radioisotopes of elements that are ordinarily present in soil and that are utilized in plant metabolism are absorbed in a manner independent of the radioactive properties of the element.
1.2.4 Radioactivity in the sediment

The sediment play a predominant role in aquatic radioecology by serving either as a sink or as a temporary respiratory for radiative substances, which can then pass by way of the bottom-feeding biota or by resuspension or dissolution to the higher tropic levels[45]. Radionuclides introduced into the body of the water reach the bottom sediment primarily by sorption solids that later deposit on the bottom. The deposited remains of biota that have absorbed or adsorbed pollutants may also be an important source.

In sediments of the Clich River below Oak Ridge, Tennessee, the amounts of radioactivity contained by the sediments were found to be variable, which is not surprising considering that the load and composition[46]. The tendency of the sediments to remove pollutants depends on the sorption and ion exchange as well as the salinity of the overlying water.

1.2.5 Radioactivity in the water

Surface waters are coupled to surface aquifers, soils, and atmosphere. Trace contaminants that show that somehow find their way into deep underground aquifers may in time reach surface waters and become incorporation into the biosphere. Atmospheric pollutants eventually deposit on soils or surface waters, and the main mechanisms for removal of contaminants from soil runoff and leaching into soil water that eventually seeps to streams.

Radionuclides can occur in freshwater systems either from atmosphere deposition, run off/soil erosion or release of liquid effluents. Regardless of the source, two forms of radiation exposure can occur -external and internal. External exposure can occur from the surface of the water and sediment, and from the immersion in the water. Internal exposure can occur from the ingestion of radionuclides, either directly as from drinking water, or as a result of transfer through aquatic food webs and consumption of aquatic biota.
The concentration of naturally-occurring radionuclides in water are several orders of magnitude less than those found in rocks and soils and mostly due to $^{40}\text{K}$ [47]. In many natural waters, there is a significant shift away from the equilibrium between parent and daughter nuclides in the U and Th series. The radionuclide content of sea water exhibits a fairly narrow range, unlike those for bodies of fresh water and urban water supplies, which are more dependent on local conditions of rock and soil radionuclide content and geochemistry. In the sea, the radioactive isotope $^{40}\text{K}$ occurs as 0.0118% in natural potassium. Taking the concentration of K in sea-water as 0.31 g l$^{-1}$ the activity due to $^{40}\text{K}$ is 324 pCi l$^{-1}$, i.e. more than 90% of the total radioactivity of sea water[48].

The studies of mixing radioactive fallout in the Pacific indicated a persistent holdup of radioactivity near surface for as long as 5 years after cessation of atmospheric tests of nuclear weapons. $^{90}\text{Sr}$ and $^{137}\text{Cs}$ have been the nuclides most thoroughly studied. Knowledge of the behavior of radionuclides in rivers, estuaries, and coastal waters is important because of these aquatic systems are major receptors of effluents from industrial plants and municipalities.

### 1.2.6 Radioactivity in the atmosphere

The atmosphere contains natural and man-made aerosols that originate from many sources. In addition to the air pollutants introduced as the result of human activities, meteoritics, volcanic activity, dust storms, forest fires, and ocean spray contribute great quantities of gases and suspended solids. After deposited on the ground, the particulates may become resuspended as the result of wind action.

One dominant and almost inevitable source of environmental airborne activity is natural radioactivity. The natural radiation sources are Radon and radon decay daughters and gamma rays originating from the earth crust/building materials. The major process by which natural radioactivity is released into the atmosphere is the emanation from the ground of the noble gases Radon($^{222}\text{Rn}$) and Thoron($^{220}\text{Rn}$),
which are produced as a result of decay of uranium and thorium decay in the earth crust. Inhalation of these decay products causes damage to the respiratory track and therefore they need special attention as compared to other radioactive noble gases. More than 50 percent of the population dose is received due to indoor radon alone[49]. In many countries, there are some individuals who receive doses from this natural source which are substantially higher than that would be permitted in occupational exposure.

1.2.7 Biological effects of radiation

Similar to the variations in the chemical toxicity of materials encountered in daily life, there is a gradation in the toxicity of radioactive elements. Radiotoxicity is defined as the ability of a radioactive material to produce injury by virtue of its emitted radiation once it reaches susceptible site in or on the body. The radiotoxicity of a given material is obtained giving weightage to the following factors:
(a) radioactive half life; (b) amount of radionuclide; (c) type of emitted radiation and its energy; (d) degree of selective localisation in the body; (e) rate of elimination from the body.

In chemical toxicity evaluation, attention is mainly focused on acute effects while in radiotoxicity evaluation long term effects are also considered. For this reason, radiotoxicity is encountered, in general, at levels which are orders of magnitude lower than those encountered in chemical toxicity.

In case of external irradiation with beta particles of very low energy(less than 0.225 MeV), there may be about 80% reduction in the dose across the epidermis, leading to significantly higher doses to the cells in the upper viable layer than to the basal layer. With alpha particles, the variation in dose will be much more pronounced, with no appreciable dose to the basal layers[50].

Bone Cancer: It is probable that little inhaled Pu and Th reaches the blood stream and skeleton, but cuts and abrasions may result in absorption from the site of injury.
Pu concentrates mainly on endosteal surfaces adjacent to bone marrow cavities.

Strontium and Radium are associated with mineral bone and behave similarly in their distribution pattern. Experience with radium patient shows that osseosarcoma and carcinoma, but not leukaemia, are a hazard from the bone-seeking alpha emitters. With continuous admistration of a long range beta emitters such as $^{90}$Sr, there is a suggestion that leukaemia rather than osseosarcoma may be the important hazard[51].

Increase incidence of bone cancer & of head sinus carcinoma has been observed in persons exposed radium, particularly in painters of luminous dials, but also in radium chemists or persons treated with Ra salts for a supposedly therapeutic effect. The bone sarcomas appear to have been induced by alpha particles from either the $^{226}$Ra or $^{228}$Ra decay series, where the head sinus carcinomas are thought to be caused mainly by accumulation of Radon gas in the frontal sinus and mastoid cells.

Lung cancer: The deposition and retention of radionuclides in the respiratory tract constitute a unique problem. Of insoluble particles deposited, a large proportion may remain in the lungs for long periods. High concentrations of radionuclides in lung may cause death by destroying functional tissue, whereas lower concentrations may cause progressive fibrosis. Eventually, some radionuclides deposited in the respiratory tract is accumulated in other tissues, such as liver, skeleton and thyroid. When the radionuclides were inhaled in the soluble from a dose-related depression of circulating lymphocytes was seen as soon after inhalation.

The high incidence of lung cancer among miners in Eastern Europe has been attributed to the diffusion of Rn into the mine atmosphere[52]. Lung cancers has been also reported among miners in non-uranium mines in which elevated concentrations of radon are present. This has been true among in Newfoundland flourspar mines, where Rn enters the mines via ground water, and among miners in Swedish iron, zinc, and lead mines. These experience as well as experimental evidence that radioactive substances can cause lung cancer in laboratory animals have resulted in considerable
attention being given to the methods of protecting employees and general public from the effects of radon and its daughters.

Leukaemia: Leukaemia is a relatively rare disease which has been observed to occur in increased frequency among Japanese survivors at Hiroshima and Nagasaki, among children irradiated in infancy for thymic enlargement and among patients irradiated for ankylosing spondylitis and possibly among children who were irradiated in utero in the course of pelvic examination during pregnancy. There have been several studies of the incidence of leukaemia in children who are exposed in utero, with conflicting evidence that the fetus may be more sensitive to the leukemogenic effects of radiation. From all epidemiological evidence, it can be concluded that for the purpose of estimating the upper limit of risk to an exposed population, a risk coefficient of 20 cases of leukaemia per rad per million can be assumed[53]. These cases would occur during a period of about 15 years[54].

Genetic effects: The genes are large molecules which may undergo structural changes (mutations) as the result of action by a number of agents including heat, ionizing radiation, and mutagenic chemicals[55]. It is possible for a mutation to be passed directly to progeny, in whom the mutant characteristic may ultimately manifest itself. It is estimated that about 4% of all individuals inherit characteristics that result from recessive mutations due to natural factors in the environment.

The process of the ionization changes atoms, at least transiently, and may thus alter the structure of the molecules containing them. If the affected molecules are in a living cell, the cell itself may be damaged either directly or indirectly. The most important form of damage is to the DNA; this damage may prevent survival and reproduction of the cell, but frequently the damage is repaired. If that repair is not perfect, it may result in a viable but modified cells. A modified cell may give rise to a clone of modified cells that may eventually result in cancer. A modified cell in the gonads, with the function of transmitting genetic information to descendants, may transmit incorrect hereditary information and may cause severe harm to some
of those descendants. These somatic and hereditary effects are called as stochastic effects. The genetically induced effects due to ionizing radiation exposed are generally of the same kind as those that occur spontaneously in the populations.
Bibliography


