

## VITAL ROLE OF HEAVY METALS IN THE DEGRADATION OF THE ENVIRONMENT

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### ABSTRACT

Large material productivity results in the addition of unwanted substances into the environment, which are potentially harmful to living things. The chemical industry's contribution to human welfare is evident in the wide range of chemicals used in drugs, cosmetics, plastics, synthetic fibres, paints, cleansing agents and many other kinds of consumer products. Major effluents such as antibiotics, radioactive substances, drugs, and heavy metals which are carcinogenic, mutagenic, and teratogenic, finish up in the environment. Heavy metals are accumulated with time in the soils and plants. These heavy metals could turn up with a negative impact on the physiological activities of the plants. Contaminants sourced from the air, soil, water etc. result in the accumulation of heavy metals in the environment. The effect of heavy metals on the environment is reviewed in this paper.

**KEYWORDS:** Environment, Bioaccumulation, Contaminants, Heavy Metals and Source.

### INTRODUCTION

Initially, it was believed that there is alimitless abundance of land and resources, but today, the resources in the world are lesser due to our carelessness and negligence of their consumption. Increased material productivity results in the addition of a lesser or greater amount of some substances into the environment, that are potentially dangerous for living things. The chemical industry's contribution to human welfare is evident in the extensive range of chemicals used in drugs, cosmetics, plastics, synthetic fibres, paints, cleansing agents and many other kinds of consumer products. Major effluents such as antibiotics, radioactive substances, heavy metals, and medical drugs are carcinogenic, mutagenic, and teratogenic (Guvan *et al.*, 2003). Unfortunately, all these chemicals end up in the environment.

Metals are elements which can conduct electricity, possess metallic lustre, are malleable and are ductile. They tend to form cations and have abasic oxide. Usually, the terms 'metal' and 'heavy metal' are used to refer not only to the pure element but also to all possible chemical species in which the element

may exist (Duffus, 2002). The metals are supposed to be heavy metals if the standard state-specific gravity is more than 5 g/cm<sup>3</sup>. Hence, many are recognized as heavy metals.

Heavy metals accumulate with time in the soils and plants. These heavy metals could turn up with a negative impact on the physiological activities of the plants (e.g., photosynthesis, gaseous exchange, and nutrient absorption), leading to a reduction in plant growth, dry matter accumulation and yield (Devkota *et al.*, 2000). In insignificant concentrations, heavy metal traces in plants or animals are not toxic (De Vries *et al.*, 2007). Elevated concentration of the metal in the environment has a wide-range impact on plants, animals, and microbial species. Cadmium, lead, and mercury are exceptions; they are lethal even in very minimal concentrations. Zinc (Zn) is well known as it is involved in a variety of enzymes (dehydrogenases, proteinases, peptidases) when concerning to metabolism of carbohydrates, proteins, phosphate, auxins and in RNA and ribosome formation in plants (Kabata-Pendias and Pendias, 2001).

Drinking arsenic-contaminated water for a long time is toxic and affects all organs and systems of the

body (Khan *et al.*, 2007; Spallholz *et al.*, 2004). The most common manifestations among arsenicosis patients are skin lesions (Khan *et al.*, 2003). Additionally, victims of arsenicosis may develop cardiovascular, gastrointestinal, hepatic, renal, neurological, malignancies and reproductive problems (Khan *et al.*, 2006). Moreover, arsenicosis may also cause psychological damage and alter mental well-being. Gaseous arsines are the most toxic because they can combine with haemoglobin inside red blood cells which may cause evastation or acute swelling of cells and make them non-functional. The excessive uptake of heavy metals by animals and humans is the consequence of the successive accumulation of these elements in the food cycle, as the beginning point of the food cycle is being contaminated in the soil (as the origin of contamination in soil). Each 1000 kg of "normal soil" hypothetically comprises 200 g chromium, 80 g nickel, 16 g lead, 0.5 g mercury and 0.2 g cadmium (IOCC, 1996).

#### CONTAMINANTS SOURCE

Surface water and groundwater may get contaminated due to the metals from wastewater discharges or by direct contact with metal-contaminated soils, sludges, mining wastes, and debris. Airborne emissions of processed solid wastes, sludges, or spills can be the origin of contaminants from sites forming metal-bearing solids. The contaminant sources influence the heterogeneity of contaminated sites on a macroscopic and microscopic scale. Concentration variations and matrix of contaminants influence the risks related to metal contamination and the treatment options.

##### Airborne Sources

Airborne sources of metals contain heaps of duct emissions in the form of air, gas or vapour streams and fugitive emissions like dust from the storage areas. Gas streams containing particulates are mostly seen as airborne sources. Some of the heavy metals like arsenic, cadmium and lead volatilize at the time of high-temperature processing. These metals will convert to oxides and condense as fine particulates unless a reducing atmosphere is maintained. Stack emissions are disseminated across wide areas with the assistance of natural air streams until dry, whereas the wet precipitation processes eliminate this type of emissions from the gas stream. Fugitive emissions are frequently dispersed across a

tinier area because these types of emissions are produced near the ground. Usually, the contaminant strengths are smaller in the fugitive emissions when equated to stack emissions. The type and quantity of metals released from the stack and fugitive emissions are dependent on site-specific circumstances (Brauning *et al.*, 1995).

##### Processed Solid Wastes

A wide-ranging industrial process generates process solid waste. This type of solid waste with metals is discarded in terms of waste piles above the ground surface, below the ground or under cover in landfills. Process solid waste may include abrasive wastes, fly ash, ion exchange resin, mould, slugs, spent catalysts, sands, spent stimulated carbon, and refractory bricks. The compositions of process waste affect waste's porosity, density, and leach resistance. These parameters should be considered during the evaluation of the contaminated matrix. As the waste piles are over the ground surface, they are subjected to weathering, which may disperse waste piles towards adjacent soil, air, and water resulting in the creation of leachate. These leachates will infiltrate into the natural subsurface environment. The competence of landfills to confine process solid waste fluctuates owing to the array of accessible landfill designs. These uncontained landfills may release contaminants into the infiltrating shallow or groundwater through the erosion of wind and surface (Zimmerman and Coles, 1992).

##### Sludges

Sludge composition mostly depends on the initial waste stream or the derived process. Uniform waste stream sludge resulting from the wastewater treatment sludge is usually homogeneous and may have more consistent matrix characteristics. Sludge pits regularly encompass a combination of aged and weathered wastes, causing an array of reactions to arise. They frequently require a certain method of pre-treatment before waste treatment or recycling (Brauning *et al.*, 1995).

##### Soils

Soil comprises of weathered minerals mixture with variable quantities of organic matter. Soil may get contaminated waste if they are directly in contact with this type of harmful stream. Soil and groundwater interaction affects the solubility of metals. Chemical factors like ion exchange capacity, pH and chelation with all other organic matter

unambiguously disturb metal solubility in soil (Evans, 1989).

### Direct Ground-Water Contamination

The groundwater may get contaminated with the metals, regularly by permeation of the leachate from solid wastes land disposal, liquid, or sludge sewage, mine tailings leachate and other wastes from mining, industrial waste leachate or spills and seepages from industrial metal processing services like plating shops and steel plants, etc. A sequence of reactions influences the speciation and movement of the metal contaminants containing acid or base, precipitation or dissolution, reduction or oxidation, ion exchange or sorption. The precipitation, sorption, and ion exchange reaction may hinder metal's movement in groundwater. The speed and magnitude of these types of reactions will always hinge on factors like pH, complications with other suspended components, sorption, and the ion exchange capacity of geological elements and contents of the organic matter. Ground-water flow feature influences metal contaminants transport. The sorption magnitude of numerous metallic cations and anions on top of iron oxide is analysed as a function of pH for the background of the electrolyte composition. Reports suggest lead (Pb) sorbs significantly at low pH value than zinc (Zn) or cadmium (Cd) (Kinniburgh *et al.*, 1976).

### Chemical Fate and Movement

The fate and movement of metals in soil and groundwater substantially depend on the chemical arrangement and metal speciation. Metals mobility in ground-water arrangements is impeded by the reactions caused by adsorb or precipitate metals. This interaction manages to keep metals related to the solid phase and inhibits their dissolving. This type of mechanism can inhibit metal movement and act as a long-term cause of metal contaminants. Although, various metals will undergo equivalent reactions in several aspects. The scope and nature of these types of reactions fluctuate under different conditions (Allen *et al.*, 1991).

### Sources, occurrence, and consequences of various metal contaminations

#### Lead

Lead (Pb) has been used in large amounts for 2500 years, but nowadays, lead is frequently utilized as a fuel additive, although the toxicity of lead for animals and man has been well-known for a long-

time. Oxidized lead occurs very frequently but, Lead (II) is referred to as the most reactive lead form, and it forms mononuclear hydroxide and polynuclear oxide. Nearly in all conditions,  $Pb^{2+}$  and the complex of lead hydroxy are extremely stable structures of lead. Little solubility of lead is seen when it forms a complex compound with an inorganic structure like/such as  $Cl^-$ ,  $CO_3^{2-}$ ,  $PO_4^{3-}$ ,  $SO_4^{2-}$  and organic ligands like fulvic acids, humic, amino acids and EDTA. Solid lead carbonate is observed in high pH than 6; when high concentrations of sulphide are present,  $PbS$  is a more stable solid under its reducing conditions (Brauning *et al.*, 1995 and Johnson, 1998).

Principal industrial source for the contamination of lead includes the smelting of metal and Pb processing, production of secondary metals, lead battery manufacturing, pigment and chemical manufacturing and wastes with lead contamination. Extensive contamination caused by past lead use in gasoline is alarming. Lead released on the land and in the ground and surface water is usually in the form of elemental lead, lead oxides and hydroxides and lead metal oxyanion complexes (Brauning *et al.*, 1995).

Soil retained most of the lead released in the environment. The fundamental processes which influence the fate of lead in the soil include the mechanism of adsorption and precipitation, ion exchange and complexation along with sorbed organic matter. All these processes restrict the quantity of lead transported onto the surface or groundwater. The process of alkylation in sediments is seen by anaerobic microorganisms. This microbe forms a volatile organo-lead compound named tetramethyl lead. Dissolution of the lead amount in surface and groundwater always depends on the pH and concentration of dissolved salts. Various types of mineral surfaces present also affect lead dissolution. Many times, surface and ground-water systems have a significant portion of the lead in an undissolved state. They arise as precipitates of sorbed ions of  $PbCO_3$ ,  $Pb_2O$ ,  $Pb(OH)_2$  and  $PbSO_4$ , i.e., surface coating on minerals or in the form of suspended organic matter (Evans, 1989 and Brauning *et al.*, 1995).

Lead acts on the central nervous system, blood pressure and reproduction. Lead is absorbed primarily in gastrointestinal and respiratory tracts and deposited in soft tissues (e.g., kidney, liver, and the central nervous system) and bone/s. Symptoms of lead intoxication which vary according to exposure degree, include anorexia, muscle pain and

weakness, abdominal pain, infertility, still birth and encephalopathy (a disorder of the brain's cerebral cortex) (Panariti and Berxholi, 1998).

### Chromium

Chromium (Cr) is a rare element that certainly does not occur in elemental form. They are merely found in compound complexes. Chromium is a product termed primary ore, which is mined in the form of mineral chromite, i.e.,  $\text{FeCr}_2\text{O}_4$ . The main source of chromium contamination processes like electroplating and dumping chromium wastes (Brauning *et al.*, 1995). Cr(VI) is a type of chromium which is normally found only at contaminated sites. It can similarly occur in a +III state of oxidation, reliant on its pH and redox condition. Cr(VI) is the principal type of chromium located in the shallow aquifers of aerobic environments. Cr(VI) is reduced to Cr(III) by the soil organic matter ( $\text{S}^{2-}$  and  $\text{Fe}^{2+}$  ions under anaerobic environments often encountered in the deeper groundwater). Major Cr(VI) species consist of chromate ( $\text{CrO}_4^{2-}$ ) and dichromate ( $\text{Cr}_2\text{O}_7^{2-}$ ) which precipitates easily in presence of metal cations like  $\text{Ba}^{2+}$ ,  $\text{Pb}^{2+}$ , and  $\text{Ag}^+$ . The chromate and dichromate are adsorbed on soil surfaces and Cr(III) is the main kind of chromium at low pH (<4).  $\text{Cr}^{3+}$  forms are soluble with the complexes of  $\text{NH}_3$ ,  $\text{OH}^-$ ,  $\text{Cl}^-$ ,  $\text{F}^-$ ,  $\text{CN}^-$ ,  $\text{SO}_4^{2-}$  and soluble organic ligands. Cr(VI) is the more toxic and more mobile form of chromium; whereas Cr(III) mobility is reduced by adsorption by clays and oxide minerals below pH 5 and low solubility is seen above pH 5 due to the formation of compound  $\text{Cr}(\text{OH})_3(\text{s})$ . Chromium in nature exists primarily as the soluble, highly toxic  $\text{Cr}^{6+}$  cation and the less soluble less toxic  $\text{Cr}^{3+}$ , the trivalent cation. Reduction/oxidation reactions between the two states are thermodynamically possible under physiological conditions, thus  $\text{Cr}^{6+}$  and  $\text{Cr}^{3+}$  are both biologically important ions. Chromate is more toxic than  $\text{Cr}^{3+}$ , so beneficial functions of chromium can only be performed by  $\text{Cr}^{3+}$  (Arias and Tebo, 2003). Chromium mobility mostly depends on the adsorption features of soil, including its clay, iron oxide content and the amount of organic matter existing in the composition. Chromium can be transported by surface runoff to surface waters in its soluble or precipitated form. This soluble and unadsorbed chromium compound leaches from the soil into groundwater. The leaching ability of Cr(VI) increases as soil pH increases. Most of the chromium released into natural waters is particle-associated and is ultimately deposited into

the sediment (Brauning *et al.*, 1995).

In man, the chromium cation binds to a low-molecular-mass binding substance, a small polypeptide, at a ratio of 4 Cr/peptide. The resulting Cr-containing peptide can specifically activate the insulin receptor tyrosine kinase. Chromium absence in humans leads to reduced glucose tolerance in a physiological condition like diabetes. In trivalent form chromium acts as an insulin cofactor, thus it is an essential trace element. Chromate, on the other hand, is toxic. Chromate reduction to chromium produces radicals, which make this metal very toxic. Long-term exposure to chromium may cause renal and hepatic toxicity in humans and cardiovascular, reproductive, and developmental toxicity in animals. Chromium can cause contact dermatitis, characterized by deep ulcers in the skin and nasal septum, moreover, it is carcinogenic and allergenic (Mason's allergy) to men (Hamilton *et al.*, 2000).

### Arsenic

Arsenic (As) is an element found in a semi-metallic form that arises in a wide-ranging diversity of minerals, mostly found as  $\text{As}_2\text{O}_3$ . It can also be gained again from the processing of ores which contains copper, gold, lead, silver, and zinc. Arsenic also exists in ashes from coal combustion. It shows a complex interaction and is present in many numerous oxidation states (Brauning *et al.*, 1995).

In aerobic conditions Arsenic(V) is dominant, i.e., the form of arsenate ( $\text{AsO}_4^{3-}$ ) in innumerable protonation states like  $\text{H}_3\text{AsO}_4$ ,  $\text{H}_2\text{AsO}_4^-$ ,  $\text{HAsO}_4^{2-}$  and  $\text{AsO}_4^{3-}$ . The arsenate and additional anionic forms of arsenic act as chelates. Arsenate precipitates metal cations when present in anionic form. Metal arsenate complexes are stable only under certain conditions. As(V) can be coprecipitated with or adsorbed onto iron oxyhydroxides mostly under acidic and moderately reducing conditions. Coprecipitates are immobile under these conditions, but arsenic mobility increases as pH increases (Brauning *et al.*, 1995). Under reducing conditions As(III) dominates, existing as arsenite ( $\text{AsO}_3^{3-}$ ) and its protonated forms:  $\text{H}_3\text{AsO}_3$ ,  $\text{H}_2\text{AsO}_3^-$ ,  $\text{HAsO}_3^{2-}$ . Arsenite can absorb or coprecipitate with metal sulphides and has a high affinity for other sulphur compounds. Arsenic and arsine  $\text{AsH}_3$  are elemental forms and may be present under extremely reducing conditions. Biotransformation (via methylation) of arsenic creates methylated derivatives of arsine,

such as dimethyl arsine has  $\text{As}(\text{CH}_3)_2$  and trimethylarsine  $\text{As}(\text{CH}_3)_3$  which are highly volatile. Since arsenic is often present in anionic form, it does not form complexes with simple anions such as  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ . Arsenic speciation also includes organometallic forms such as methyl arsenic acid  $(\text{CH}_3)\text{AsO}_2\text{H}_2$  and dimethylarsinic acid  $(\text{CH}_3)_2\text{AsO}_2\text{H}$ .

Many arsenic compounds sorb strongly to soils and are therefore transported only over short distances in groundwater and surface water. Sorption and coprecipitation with hydrous iron oxides are the most important removal mechanisms under most environmental conditions. It is seen that arsenates are easily leached if the amount of reactive metal in the soil is low or negligible.  $\text{As}(\text{V})$  can also be mobilized under reducing conditions that encourage the formation of  $\text{As}(\text{III})$ , under alkaline and saline conditions, in the presence of other ions that compete for sorption sites, and in the presence of organic compounds that form complexes with arsenic (Brauning *et al.*, 1995).

### Zinc

Zinc (Zn) is one element which does not occur naturally in elemental form. It is generally mined from mineral ores to form zinc oxide ( $\text{ZnO}$ ). The prime use of Zinc in the industry is mainly for corrosion-resistant coating of iron or steel (Brauning *et al.*, 1995). Zinc usually occurs in the +II oxidation state and forms complexes with several anions, amino acids, and organic acids. Zn may precipitate as  $\text{Zn}(\text{OH})_2(\text{s})$ ,  $\text{ZnCO}_3(\text{s})$ ,  $\text{ZnS}(\text{s})$ , or  $\text{Zn}(\text{CN})_2(\text{s})$ . Zinc is also one of the most moveable heavy metals in surface waters and groundwater because it is found mostly in soluble compounds at neutral and acidic pH values. At higher pH value range zinc forms carbonate and hydroxide complexes which are directly proportional to control zinc solubility. Zinc readily precipitates under reducing conditions and in highly polluted systems when it is present at very high concentrations and may coprecipitate with hydrous oxides of iron or manganese (Brauning *et al.*, 1995). Sorption to sediments or suspended solids, including hydrous iron and manganese oxides, clay minerals, and organic matter, is the primary fate of zinc in aquatic environments. It is found that the sorption of zinc mostly increases as pH increases and salinity decreases.

### Cadmium

Cadmium (Cd) is a non-essential metal and hence is

mostly not involved in any known biological processes but may be relatively toxic when it is accumulated by organisms. It is mainly known for its disturbance in enzyme activities. One of its inhibitions is seen in the DNA-mediated transformation in microorganisms, as Cd interferes with the symbiosis of microbes and plants, along with the increase in plant predisposition to fungal invasion. In humans, the effect of cadmium is based on the nature and extent of exposure of a person to cadmium-contaminated soil, air or water. Exposure to 1-5  $\text{mg}/\text{m}^3$  of cadmium for 8 hours may be fatal. The harmful effect of cadmium depends on the amount taken in and whether it is breathed in or ingested. Higher levels of cadmium in foods and drinking water severely irritate the stomach which may cause vomiting and diarrhoea/diarrhoea. Accumulation of cadmium over a long period may damage the kidneys and may also cause bones to become fragile. Breathing high levels of cadmium may affect the lungs, bones and kidneys and may also increase the risk of developing lung cancer (Kabata-Pendias and Pendias, 2001).

Cadmium (Cd) occurs naturally in the form of  $\text{CdS}$  or  $\text{CdCO}_3$ . It is recovered as a by-product from the mining of sulphide ores of lead, zinc, and copper. Sources of cadmium contamination include plating operations and disposal of cadmium-containing wastes (Brauning *et al.*, 1995). The form of cadmium encountered mostly depends upon the solution and the soil chemistry. Its solubility depends on the state in which waste cadmium is disposed of, thus affecting its treatment. The most common forms of cadmium include  $\text{Cd}^{2+}$  cadmium-cyanide complexes or  $\text{Cd}(\text{OH})_2$  solid sludge (Brauning *et al.*, 1995). Hydroxide [ $\text{Cd}(\text{OH})_2$ ] and carbonate ( $\text{CdCO}_3$ ) solids dominate at high pH whereas  $\text{Cd}^{2+}$  and aqueous sulphate species are the dominant forms of cadmium at lower pH (<8). Under reducing conditions when sulphur is present, the stable solid  $\text{CdS}(\text{s})$  is formed. Cadmium will also precipitate in the presence of phosphate, arsenate, chromate, and other anions, although solubility will vary with pH and other chemical factors.

Cadmium is relatively mobile in surface water and groundwater systems and exists primarily as hydrated ions or as complexes with humic acids and other organic ligands. Under acidic conditions, cadmium may also form complexes with chloride and sulphate. Cadmium is removed from natural waters by precipitation and sorption to mineral surfaces, especially oxide minerals, at higher pH

values (>pH 6). Removal by these mechanisms increases as pH increases. Sorption is also influenced by the cation exchange capacity (CEC) of clays, carbonate minerals, and organic matter present in soils and sediments. Under reducing conditions, precipitation as CdS controls the mobility of cadmium (Brauning *et al.*, 1995).

### Copper

Copper (Cu) is a major contributor to numerous physiological processes in plants like photosynthesis, respiration, carbohydrate distribution, nitrogen and cell wall metabolism, seed production and in disease resistance (Kabata-Pendias and Pendias, 2001). Long-term exposure to copper dust can irritate the nose, mouth and eyes, and cause headaches, dizziness, nausea and diarrhoea. Drinking water containing higher levels of copper may result in vomiting, diarrhoea, stomach cramps, and nausea. In severe cases, it can cause liver and kidney damage and even death. It has also been found to be a causative agent for metal fume fever (Borak *et al.*, 2000).

The functioning of the various metabolisms in humans and bacteria is also dependent on Cu and Zn. However, at high concentrations, these metals exhibit toxic effects on the cells. Copper (Cu) is mined as a primary ore product from copper sulphide and oxide ores. Copper contamination is mainly due to mining activities in surface waters and groundwater. Additional sources of copper consist of algaecides, chromate copper arsenate (CCA) pressure-treated lumber and copper pipes. Solution and soil chemistry strongly influence the speciation of copper in ground-water systems. In aerobic, sufficiently alkaline systems,  $\text{CuCO}_3$  is the dominant soluble copper species. Soluble copper is commonly present in the form of cupric ion ( $\text{Cu}^{2+}$ ) and hydroxide complexes  $\text{CuOH}^+$  and  $\text{Cu}(\text{OH})_2$ . Copper and humic acids form strong solution complexes. The affinity of Cu for humates is directly proportional to pH and indirectly proportional to ionic strength. Under anaerobic environments,  $\text{CuS(s)}$  will form when sulphur is present (Adriano, 2001; Blencowe and Morby, 2003; Cavet *et al.*, 2003).

Copper mobility decreases as its sorption to mineral surfaces is seen.  $\text{Cu}^{2+}$  sorbs strongly to mineral surfaces over a wide range of pH values. The most toxic species of copper is the cupric ion ( $\text{Cu}^{2+}$ ). Copper toxicity is also seen for  $\text{CuOH}^+$  and  $\text{Cu}_2(\text{OH})_2^{2+}$  (LaGrega *et al.*, 2010).

### Mercury

Mercury occurs in several toxic forms. But its organic form is readily absorbed in the gastrointestinal tract, and lesser but still significant quantities of inorganic mercury are absorbed. In humans, the major target organ for inorganic mercury salt is the kidney, while the major target organ for elemental mercury and organic mercury compound is the nervous system. Prolonged exposure to mercurous chloride can produce a syndrome, which can be characterized by irritability, painful extremities, rash and photophobia and weight loss. Mercury vapour exposure from occupational or domestic accidents can cause intestinal tumours, abnormal emotions and salivation and can impair memory and cognitive function (Roberts, 1999).

The primary source of mercury is the sulphide ore cinnabar. Mercury (Hg) is generally collected as a by-product of ore processing. Released mercury particles from coal combustion are a chief source of mercury contamination. Releases from manometers at pressure measuring stations along gas/oil pipelines also contribute to mercury contamination. After release into the environment, mercury usually exists in mercuric ( $\text{Hg}^{2+}$ ), mercurous ( $\text{Hg}_2^{2+}$ ), elemental ( $\text{Hg}^0$ ), or alkylated form (methyl/ethyl mercury). The redox potential and pH of the system determine the stable forms of mercury that will be present. Mercurous and mercuric ions are more stable under oxidizing conditions. Mild reducing conditions promote organic or inorganic mercury to be reduced to elemental mercury. Later, elemental mercury is then converted to alkylated forms by biotic or abiotic processes. Mercury is most toxic in its alkylated forms which are soluble in water and volatile in air.  $\text{Hg(II)}$  is seen to form strong complexes with variations of both inorganic and organic ligands, which results in its very soluble form in oxidized aquatic systems. Sorption to soils, sediments, and humic materials is an important mechanism for the removal of mercury from the solution. Sorption is pH-dependent and increases as pH increases. Mercury is mainly removed from the solution by a method of co-precipitation with sulphides. Under anaerobic conditions, both organic and inorganic forms of mercury may be converted to alkylated forms by microbial activity, such as by sulphur-reducing bacteria. Elemental mercury is formed when anaerobic conditions by a process of demethylation of methyl mercury or by reduction of

Hg(II). It is seen that acidic conditions like  $\text{pH} < 4$  favour the formation of methyl mercury, whereas higher pH values also favour the precipitation of  $\text{HgS(s)}$  (Brauning *et al.*, 1995).

### CONCLUSION

Organic, inorganic, and physical properties of the contaminated matrix affect the mobility and the technology selected for the remediation of metals in soils and groundwater. Contamination exists in three forms in the soil matrix: solubilised contaminants in the soil moisture, adsorbed contaminants on soil surfaces, and contaminants fixed chemically as solid compounds. The presence of inorganic anions (carbonate, phosphate, and sulphide) in the soil water can influence the soil's ability to fix metals chemically. These anions can form relatively insoluble complexes with metal ions and cause metals to desorb and/or precipitate in their presence. Soil pH values generally range between 4.0 and 8.5 with buffering by Al at low pH and by  $\text{CaCO}_3$  at high pH. Metal cations are mostly mobile in acidic conditions whereas anions tend to sorb to oxide minerals in this pH range.

At high pH, cations precipitate or adsorb to mineral surfaces and metal anions are mobilized. The presence of hydrous metal oxides of Fe, Al, and Mn can strongly influence metal concentrations because these minerals can remove cations and anions from solution by ion exchange, surface precipitation and specific adsorption. Sorption of metal cations onto hydrous oxides generally increases sharply with pH and is most significant at pH values above the neutral range, while sorption of metal anions is highest at low pH which decreases as pH is increased. Cation exchange capacity (CEC) refers to the concentration of readily exchangeable cations on a mineral surface and is often used to indicate the affinity of soils for the uptake of cations such as metals. Anion exchange capacity (AEC) indicates the affinity of soils for the uptake of anions and is usually significantly lower than the CEC of the soil. In addition to hydrous oxides, clays are also important ion exchange materials for metals. The presence of natural organic matter (NOM) influences the sorption of metal ions to mineral surfaces. NOM has been observed to enhance the sorption of  $\text{Cu}^{2+}$  at low pH and suppress  $\text{Cu}^{2+}$  sorption at high pH. Hence, it is observed from all available data that heavy metals play a vital role in dreadful conditions of the environment as abiotic

factors greatly influence the degradation of the environment. Elevated metal concentration in the environment has a wide-ranging impact on animals, plants, and microbes. Lead, cadmium, and mercury are threats as they are toxic even in very low concentrations.

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