The effect of different environmental pollutants on metabolic activities in aquatic plants

Abstract

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Many heavy metal ions have direct influence on various physiological and biochemical processes in plants. Metal ions and their complex exhibit a wide range of the toxicity to the organism i.e. sub lethal to lethal, depending upon the time of exposure and the prevailing conditions in the ambient water. Some metal such as Cu, Zn and Fe are essential for biological system while Pb, Cd, Cr, Ni, As & Hg are highly toxic even in low concentration. As the growth reflects the metabolism of the cell, it has been used as a key indicator of the toxicity of heavy metal ions in microorganisms and it depends on the proper functioning of various metabolic processes, such as photosynthesis, respiration and nutrient uptake. Like all living organisms, plants are often sensitive both to the deficiency and to the excess availability of some heavy metal ions as essential micronutrient, while the same at higher concentrations and even more ions such as Cd, Hg, As are strongly poisonous to the metabolic activities. Aquatic plants provide a valuable alternative source for metal remediation. Many scientists have studied accumulation of heavy metal in aquatic plants. Heavy metal ions can cause plasma membrane depolarization and acidification of the cytoplasm.

Key words- Toxicity, Chlorosis, Senescence, Heavy metal, Depolarization

1. INTRODUCTION

Natural resources are the most valuable gifts of nature as defined by human judgement. It provides plant and animal products, minerals, energy sources and recreational avenues for use of humans. The inputs of industrial wastes, washouts of crop fields containing fertilizers, pesticides and poisonous chemicals, domestic sewage containing detergents, cosmetics and a host of other chemical substances affect the ecosystem. The lake ecosystems are also subjected to increasing stress due to accelerated eutrophication, invasive species, over fishing, toxic contamination and climate change. Despite their well-understood importance, nearly half of the worlds aquatic habitats have been destroyed by human activities during the last two decades. Typical results of human activities have elevated the levels of heavy metals present in fresh water and among these microelements; lead (Pb), cadmium (Cd), mercury (Hg) and chromium (Cr) are most specific. These are considered as most important pollutants of the aquatic ecosystems due to their environmental persistence and tendency to be concentrated in aquatic organisms. In addition, heavy metals show harmful effects even at very low concentration on the aquatic organisms including plankton, aquatic plants, invertebrates and vertebrates. Many heavy metal ions have direct influence on various physiological and biochemical processes in plants. Metal ions and their complex exhibit a wide range of the toxicity to the organism i.e. sub lethal to lethal, depending upon the time of exposure and the prevailing conditions in the ambient water. Some metal such as Cu, Zn and Fe are essential for biological system while Pb, Cd, Cr, Ni, As & Hg are highly toxic even in low concentration. As the growth reflects the metabolism of the cell, it has been used as a key indicator of the toxicity of heavy metal ions in microorganisms and it depends on the proper functioning of various metabolic processes, such as photosynthesis, respiration and nutrient uptake, *etc*. Like all living organisms, plants are often sensitive both to the deficiency and to the excess availability of some heavy metal ions as essential micronutrient, while the same at higher concentrations and even more ions such as Cd, Hg, As are strongly poisonous to the metabolic activities. Researches have been conducted throughout the world to determine the effects of toxic heavy metals on plants. Much work has been carried out in India regarding the occurrence of heavy metals in lentic water bodies causing a sharp increase in pollution,

2. Characteristics-

Heavy metals are a natural part of environment but human activities contribute significantly to the total environmental exposure of these substances. Industrial effluents, agricultural runoff, transport, burning of fossil fuel, coal and oil combustion, animal and human excreta, geological weathering and domestic wastes contribute to the release of heavy metals into the water bodies (Nhapi et al.,2012, Paulette et al., 2015).Some of these metals are necessary for human health and metabolic activities in trace amounts (Syandri et al.,2014).While, others, such as mercury, cadmium, lead and chromium, are toxic even in low concentration.(Suresh et al.,2012,Vukosav et al., 2014).Trace metals derived from natural inputs and anthropogenic emissions are ubiquitous in the global environment (Zeng and Wu, 2013). Since heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic plants and animals and thus, causing heavy metal pollution in water bodies. Therefore, metals that are deposited in aquatic environment accumulate in the food chain and pose a threat to human health due to biomagnifications over time.

Aquatic organisms have been widely used in biological monitoring and assessment of safety levels of heavy metals in the environment. They have been reported to accumulate heavy metals in their tissues several times above ambient levels. High concentration of heavy metals are present in the sediments than the water, because sediments accumulate more heavy metals. Heavy metals have largest availability in soil and aquatic ecosystems and to a relatively smaller proportion in atmosphere as particulate or vapors. Heavy metal toxicity in plants varies with plant species, specific metal, concentration, chemical form and soil composition and pH, as many heavy metals are considered to be essential for plant growth. Some of heavy metals (Fe, Cu and Zn) are essential for plants and animals. The availability of heavy metals in medium varies, and metals such as Cu, Zn, Fe, Mn, Mo, Ni and Co are essential micronutrients whose uptake in excess to the plant requirements results in toxic effects. some of these heavy metals are bioaccumulative , and they neither break down in the environment nor easily metabolized. Such metals accumulate in ecological food chain through uptake at primary producer level and then through consumption at consumer levels. Plants are stationary, and roots of a plant are the primary contact site for heavy metal ions. In aquatic systems, whole plant body is exposed to these ions. Heavy metals are also absorbed directly to the leaves due to particles deposited on the foliar surfaces. The presence of heavy metals in the coastal lagoon of manila bay are due to the direct deposition of these metals from air pollution.The transport of elements between sediment and water may be a result of adsorption, desorption, precipitation, diffusion,
chemical reaction and biological activity and combination of all these phenomena.The concentration of metals in the sediments is 103 to 105 times higher than those in water. The high amount of metals in sediment may also be due to high alkalinity of water, when most of the metals are precipitated (Copat et al., 2012). This has also been reported that most of the metals in water precipitated down into the sediment if pH of water is higher than 5 (eg. above 5.3 pH for Cu++, 6.0 for Pb++ and above 7.0 for Zn++ and the other metals in the water also get precipitated at higher pH value).The information about the distribution of heavy metals in sediments can be of value in assessing the potential impact of sediment re-suspension upon water quality (Yin et al., 2011).

The information about selective distribution of heavy metals may also help in evaluating the relative availability of these metals in biological communities and their impact on reactions and transformations. Sediment act as a sink for the most of the heavy metals which they reenter the water column by various physico-chemical and biological processes. The sediment thus serves as a buffer long after the input has been discontinued. The sediment concentration profiles for Cu, Zn, Co, Cr, Ni, Pb and Hg are all largely controlled by changes in sediment supply (Liu and Shen, 2014, Qin et al., 2014). High levels of heavy metals in sediments reflect the deposition by the settling of dead planktons and aquatic plants. With the rapid industrial development, various wastes containing different metal ions are directly or indirectly discharged into the environment, bringing about serious environmental pollution, and threatening marine life. Heavy metal disperses through various trophic levels of an ecosystem, depending on the bioaccumulation characteristics of the metal of concern (Abdussalam et al.,2013 and Swapna et al., 2014). However, heavy metal bioavailability, accumulation and toxicity in aquatic biota depend essentially on many environmental variables (Cioruta et al., 2013).The physical and chemical forms of heavy metals in the marine environment are governed by environmental variables such as salinity, tem-perature, pH, redox potential, organic and particulate matter, biological activities, and metalic properties.The solubility of heavy metals in aqueous solutions permits their mobility and is regarded as a source of water and soil contamination (Qihang et al.,2015). At high pH elements are present as cations, while at low pH the bioavailability of metals ions is enhanced. Temperature affects the water quality and the metabolic rate of the organisms and hence also their heavy metal uptake. Indeed, temperature affects the distribution of organisms in an ecosystem. On the other hand seasonal variation in temperature does not affect heavy metal accumulation.The concentration of heavy metal in water and sediment is higher in summer than other season. The high level of these metals in the sediment also reflects the deposition by the settling of dead plankton and nekton which have already concentrated them out of the water. The concentrations of heavy metals in lake ecosystem are controlled primarily by direct deposition from polluted air, local point source, water chemistry, total organic carbon and structure of bedrock and soil. pH of soil and surface water are the most important factors for the mobilization of metals from the catchments. These factors also regulate sedimentation rates of heavy metal in lakes and remobilization of metals from sediments.The survey of heavy metal content in the water and sediment is of great concern because of its high potential toxicity to the various biological forms. The heavy metal toxicity is affected by temperature, DO concentration and pH. Increase in pH generally decreases the solubility of many toxic heavy metals.As heavy metals are not decomposed biologically, they may exist in the lake for a long time and may be linked to long term health related problems by entering into food chain.The influence of heavy metals Cu, Ni, Zn, Hg, Cr, Pb and Cd on seed germination and early seedling growth in oil crop *Eruca sativa* was evaluated by Hu et al., (2015). The essential heavy metals (Cu, Zn, Fe, Mn and Mo) play biochemical and physiological functions in plants and animals. The major functions of essential heavy metals are the Participation in redox reaction.Due to increased load of heavy metals, aquatic ecosystems have severely disrupted.Their high concentration becomes lethal to aquatic organisms when the duration of exposure to these metals is prolonged (Deekay et al., 2011). The high concentration is posing a big threat to valuable flora and fauna existing their. Metal ions and their complex exhibit a wide range of the toxicity to the organism i.e. sub lethal to lethal, depending upon the time of exposure and the prevailing conditions in the ambient water. Some metal such as Cu, Zn and Fe are essential for biological system while Pb, Cd, Cr, Ni, As & Hg are highly toxic even in low concentration. Heavymetal contamination of the environment is a worldwide phenomenon and they cannot be estimated from the water body but they remain in the sediment, released in the water, enter into the aquatic organisms including algae and hydrophytes.

3.Source and uses :

3.1 Copper: It is widely distributed and it is an essential metal required by all living organism, in some of these, as component of the enzyme systems, but at higher concentration it works essentially as pollutant. Cu is a constituent of primary electron donor in photosystem I of plants. Because Cu can readily gain and lose an electron, it is a cofactor of oxidase, mono- and di-oxygenase (e.g., amine oxidases, ammonia monoxidase, ceruloplasmin, lysyl oxidase) and of enzymes involved in the elimination of superoxide radicals (e.g., superoxide dismutase and ascorbate oxidase).Copper reaches the aquatic environment through wet and dry depositions, industrial,domestic and agricultural waste disposal (Pandey et al., 2010). The fate of elemental copper in water is complex and influenced by pH, dissolved oxygen and the presence of oxidizing agents and chelating compounds or ions.

3.2 Manganese: It is an essential macronutrient in all stages of plant development. It is important for vital plant function and act as a cofactor in various enzymes. Manganese plays an important role in reactions of enzymes like mallic dehydrogenase and oxalosuccinic decarboxylase. It is also needed for water splitting at photosystem II and for superoxide disumutase.

3.3 Lead: It is highly toxic metal and its concentration in natural water and sediment increases mainly through pesticide run off from the nearby agricultural lands as well as prawn cultivation areas (Yacoub and Gad, 2012).Lead has been known to accumulate in aquatic macrophytes in considerable levels based on the rooted and floating species (Zahra et al., 2014).

3.4 Nickel: It has been considered to be an essential trace element for human and animal health (Zigham Hassan et al., 2012). It is a component of the enzyme urease, which is essential for its functioning and thereby good health in animals.The maximum allowable concentration of nickel in drinking water is not fixed either by W.H.O. or by ICMR. But the recommended maximum concentration of nickel in irrigation water fixed to be 0.5mg/l (Adefemi and Awokumi,2010). The permissible limit of Nickel in plants recommended by W.H.O is 10mg/kg.

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3.5 Zinc: It is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Several enzymes contain Zn, such as carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase and RNA polymerase. Zinc is required to maintain the integrity of ribosome.It takes part in the formation of carbohydrates and catalyzes the oxidation processes in plants. Zinc also provides a structural role in many transcription factors and is a cofactor of RNA polymerase. Nevertheless, higher concentrations of zinc can be toxic to the organism. It plays an important role in protein synthesis and is a metal which shows fairly low concentration in surface water due to its restricted mobility from the place of rock weathering or from the natural sources. The oral toxicity of humans to most zinc compounds is relatively low. High concentrations of zinc in the marine environment may exist from the discharge of industries.

3.6 Iron: It is an essential element in many metabolic processes and is indispensable for all organisms. It is a component of heme-containing protein such as hemoglobin, myoglobin and cytochrome, and innumerable non-heme iron-containing proteins with vital functions in many metabolic processes. Fe and Mn are strongly correlated to organic matter but in two different ways. Fe and Mn are released from Fe/Mn hydroxides in bog areas where the redox potential is so low that Mn+4 and Fe+3 are reduced to Mn+2 and Fe+2. In surface water, Fe is strongly bound to humic substance, while Mn is free. When Fe and Mn oxides are dissolved, other trace metals adsorbed on the oxide particles are dissolved as well (Alfy, 2011). The maximum allowed concentration of iron in drinking water is 1.0 mg/L according to W.H.O report (Gutam Patel, et al., 2011).

3.7 Cobalt: (Co) naturally occurs in the earth's crust as cobaltite [CoAsS], erythrite [Co3(AsO4)2] and smaltite [CoAs2]. Plants can accumulate small amount of Co from the soil. The uptake and distribution of Co in plants is species dependent and controlled by different mechanisms.

3.8 Cadmium: Generally application of phosphate fertilizers are the main anthropological sources of Cd in the environment as phosphate fertilizers contains significant amount of metals, particulate Cd, as impurities(Sayadi et al., 2015, Xia et al., 2011,Kong et al.,2015,Yu, et al.,2013,Bahnasawy et al., 2011,Serey et al., 2012). The maximum permissible limit for Cd in water is 0.01mg/l.The permissible limit of Cadmium in plants, recommended by W.H.O is 0.02 mg/kg.

3.9 Chromium: It enters the aquatic environment from paint and chemical works, oil drilling and recovery rigs. Large quantities of chromium may be released from petrochemical industries and cement, fertilizer, power, and chloro-alkali plants. Furthermore, untreated domestic sewage was discharged into the sea from activities at the coastal area (Gurkan et al., 2012, Ghani, 2011). The permissible limit of Chromium for plants is 1.30mg/kg recommended by W.H.O.

3.10 Mercury and mercury compounds have no known beneficial biological function. Forms of mercury with relatively low toxicity can be transformed into forms with very high toxicity. Methylmercury can be accumulated through food chains resulting in higher exposure to upper trophic levels. Biomagnification (sometimes called bioamplification) of mercury through a food chain is a primary cause of much concern with the metal. This term defines the process where at each level in a food chain, from bacteria to plankton to tiny crustacean, small fish, larger fish, and fish-eaters, organisms take in more mercury than they excrete thereby accumulating the excess in their organs.Thus the ultimate concentration in any organism is higher than the mercury concentration in its food. This results is elevated concentration of mercury in higher trophic (feeding) levels of the food chain. These concentrations can be harmful to the organism itself, or to predators of those organisms. Out of a variety of pathways for heavy metals pollution, these include both natural and anthropogenic sources such as atmospheric deposition, weathering of rocks, erosion, runoff, untreated sewage, agricultural activities, and industries (Chen et al., 2012). About 180 tons of mercury is introduced into the Indian environment every year of which 166 tons come from 38 caustic soda plants. This untreated water finally enters into the aquatic food chain and suffers magnification.

4. Effects of heavy metals on plants

Many heavy metal ions have direct influence on various physiological and biochemical processes in plants. Metal ions and their complex exhibit a wide range of the toxicity to the organism i.e. sub lethal to lethal, depending upon the time of exposure and the prevailing conditions in the ambient water. Some metal such as Cu, Zn and Fe are essential for biological system while Pb, Cd, Cr, Ni, As & Hg are highly toxic even in low concentration.

As the growth reflects the metabolism of the cell, it has been used as a key indicator of the toxicity of heavy metal ions in microorganisms and it depends on the proper functioning of various metabolic processes, such as photosynthesis, respiration and nutrient uptake, *etc*. Like all living organisms, plants are often sensitive both to the deficiency and to the excess availability of some heavy metal ions as essential micronutrient, while the same at higher concentrations and even more ions such as Cd, Hg, As are strongly poisonous to the metabolic activities. Researches have been conducted throughout the world to determine the effects of toxic heavy metals on plants (Jaishankar et al., 2014, Nagajyoti et al., 2010). Much work has been carried out in India regarding the occurrence of heavy metals in lentic water bodies causing a sharp increase in pollution,

Aquatic plants provide a valuable alternative source for metal remediation. Many scientists have reported the trace metal concentration in several freshwater macrophytes. Bioaccumulation of macro and micro elements in *Typha angustiana Phragmites australis and Salvinia sp.* were assessed by many scientists. High levels of heavy metals such as Al, Fe, Si, Mn were found in *Vallisneria spiralis, Hydrilla verticillata* and *Azolla pinnata.*

Many scientists have studied the accumulation of lead and chromium by the filamentous algae *Oedogonium, Ricia fluitans*. Some have reported that algae as a good source of absorbent for Arsenite compounds. Wetland plants possess higher capacities in accumulating trace elements like Cu, Ni, Zn, Pb etc. *Lemna minor, Eichhornia crassipes* were found as good accumulators of Cd, Si and Cu. Laboratory studies on *E. crassipes* proved the potentiality of removing metals from polluted water and have shown that metal concentration of the plant and the water columns are correlated. Physiological responses on *Hydrilla* sp, *Nasturtium officinale, E. crassipes* and *Lemna major* act as good accumulators of Pb, Cu, Fe and Cd. The micronutrient deposition in *Typha angustata and Phragmites australis is* in relation to the spathial gradients of lake.

Heavy metal ions can cause plasma membrane depolarization and acidification of the cytoplasm. In fact, membrane injury is one important effect of heavy metal ions that may lead to the disruption of cellular homeostasis. A chain of metabolic events, beginning with the respiration and photosynthesis and continuing with uptake and assimilation of nutrients, dilution of intracellular level of the heavy metal ions, *etc*. seems to play an important role in balancing the cellular homeostasis, regardless of whether they are strongly or weakly correlated with the algal growth.

4.1 Copper effects on plants

Copper (Cu) is considered as a micronutrient for plants and plays important role in CO2 assimilation and ATP synthesis. Cu is also an essential component of various proteins like plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron transport chain. Excess concentration causes plant growth retardation and leaf chlorosis. Oxidative stress causes disturbance of metabolic pathways and damage to macromolecules. Nevertheless, copper (Cu) is known to reduce photosynthesis rates and respiration of aquatic moss, *Fontinalis antipyretica*.

4.2 Manganese effects on plants

Accumulation of excessive manganese (Mn) in leaves causes a reduction of photosynthetic rate. Necrotic brown spotting on leaves, petioles and stems is a common symptom of Mn toxicity. This spotting starts on the lower leaves and progresses with time toward the upper leaves.With time, the speckles can increase in both number and size resulting in necrotic lesions, leaf browning and death. It is also associated with chlorosis and browning of these tissues. Roots exhibiting Mn toxicity are commonly brown in color. Chlorosis in younger leaves by Mn toxicity is thought to be caused through Mn-induced Fe deficiency. Excess Mn is reported to inhibit synthesis of chlorophyll by blocking a Fe-concerning process.Manganese toxicity in some species starts with chlorosis of older leaves moving toward the younger leaves with time.

4.3 Lead effects on plants

Lead is an extremely toxic heavy metal that disturbs various plant physiological processes and unlike other metals, such as zinc, copper and manganese, it does not play any biological functions. A plant with high lead concentration fastens the production of reactive oxygen species (ROS), causing lipid membrane damage that ultimately leads to damage of chlorophyll and photosynthetic processes and suppresses the overall growth of the plant (Najeeb et al., 2014,). Even at low concentrations, lead treatment was found to cause huge instability in ion uptake by plants, which in turn leads to significant metabolic changes in photosynthetic capacity and ultimately in a strong inhibition of plant growth. High level of Pb also causes inhibition of enzyme activities, water imbalance, alterations in membrane permeability and disturbs mineral nutrition. Pb inhibits the activity of enzymes at cellular level by reacting with their sulfhydril groups. High Pb concentration also induces oxidative stress by increasing the production of ROS in plants. Ions of heavy metals (such as Pb2+) are capable of binding to thylakoid membrane resulting in the alteration of the ultrastructure of thylakoids, which would eventually deteriorate the routine functions of thylakoids.The higher concentration of lead in drinking water causes disruption in the synthesis of hemoglobin and, enzymes and cause damage to nervous system, kidney and brain. The average Pb value as shown in the study is high with comparison to the concentrations allowed for irrigation water.Hence it has lethal effect on aquatic plants.

4.4 Nickel effects on plants

Nickel (Ni) is a transition metal and found in natural soils at trace concentrations. Ni concentration in polluted soil may range from 20- to 30-fold (200–26,000 mg/kg) higher than the overall range (10–1,000 mg/kg) found in natural soil .Excess of Ni in soil causes various physiological alterations and diverse toxicity symptoms such as chlorosis and necrosis in different plant species. Plants grown in high-Ni-containing soil showed impairment of nutrient balance and resulted in disorder of cell membrane functions. High uptake of Ni induced a decline in water content of dicot and monocot plant species. The decrease in water uptake is used as an indicator of the progression of Ni toxicity in plants.

4.5 Zinc effects on plants

Zinc (Zn) is an essential micronutrient that affects several metabolic processes of plants and has a long biological half-life. The phytotoxicity of Zn and Cd is indicated by decrease in growth and development, metabolism and an induction of oxidative damage in various plant species. Concentrations of Zn found in contaminated soils frequently exceed to those required as nutrients and may cause phytotoxicity. Zn concentrations in the range of 150–300 mg/kg have been measured in polluted soils. High levels of Zn in soil inhibit many plant metabolic functions, result in retarded growth and cause senescence. Zinc toxicity in plants limited the growth of both root and shoot . Zinc toxicity also causes chlorosis in the younger leaves, which can extend to older leaves after prolonged exposure to high soil Zn levels. Another typical effect of Zn toxicity is the appearance of a purplish-red color in leaves.

4.6 Iron effects on plants

Iron as an essential element for all plants has many important biological roles in the processes as diverse as photosynthesis,chloroplast development and chlorophyll biosynthesis. Iron is a major constituent of the cell redox systems such as heme proteins including cytochromes, catalase, peroxidase and leghemoglobin and iron sulfur proteins including ferredoxin, acontiase and superoxide disumutase Although most mineral soils are rich in iron, the expression of iron toxicity symptoms in leaf tissues occurs only under flooded conditions, which involves the microbial reduction of Fe. The appearance of iron toxicity in plants is related to high Fe uptake by roots and its transportation to leaves and via transpiration stream. The Excess Fe causes free radical production that impairs cellular structure irreversibly and damages membranes, DNA and proteins. Iron toxicity in tobacco, canola, soybean and Hydrilla verticillata are accompanied with reduction of plant photosynthesis and yield. A study of iron toxicity on aquatic plants, particularly rice, reported that the growth of species of aquatic reed was found to be inhibited by concentration of 1 mg/L total iron.

4.7 Cobalt effects on plants

Very little information is available regarding the phytotoxic effect of excess Co. Phytotoxicity study of Co in barley (Hordeum vulgare L.), oilseed rape (Brassica napus L.) and tomato (Lycopersicon esculentum L.) has recently shown the adverse effect on shoot growth and biomass. In addition to biomass, excess of Co restricted the concentration of Fe, chlorophyll, protein and catalase activity. Further, high level of Co also affected the translocation of P, S, Mn, Zn and Cu from roots to tops. In contrast to excess Cu or Cr, Co significantly decreased water potential and transpiration rate. While diffusive resistance and relative water content increased in leaves upon exposure to excess Co.

4.8 Cadmium effects on plants

It is well known that Cd^{2+} disorganizes chloroplast causing the damage of photosynthetic pig-ments. As a consequence of this, the photosynthetic activity could be severely affected causing growth inhibition or complete death of the cells. Biosynthesis of phycocyanin and carotenoid could be affected by this heavy metal ions. Cd affects the photosynthesis and reduces the primary productivity of phytoplankton even at 0.2 and 5mg/l, respectively.Cd has been shown to interfere with the uptake, transport and use of several elements (Ca, Mg, P and K) and water by plants. Cd also reduced the absorption of nitrate and its transport from roots to shoots, by inhibiting the nitrate reductase activity in the shoots. Nitrogen fixation and primary ammonia assimilation decreased in nodules of soybean plants during Cd treatments. Metal toxicity can affect the plasma membrane permeability, causing a reduction in water content, in particular, Cd has been reported to interact with the water balance. Cadmium produces alterations in the functionality of membranes by inducing lipid peroxidation and disturbances in chloroplast metabolism by inhibiting chlorophyll biosynthesis and reducing the activity of enzymes involved in CO_2 fixation. Cadmium is predominantly found in fruits and vegetables due to its high rate of soil-to-plant transfer (Satarug et al., 2011). Cadmium is a highly toxic nonessential heavy metal that is well recognized for its adverse influence on the enzymatic systems of cells, oxidative stress and for inducing nutritional deficiency in plants (Irfan et al., 2013).

4.9 Chromium effects on plants

Chromium (Cr) compounds are highly toxic to plants and are detrimental to their growth and development. Cr is toxic to most higher plants at 100 kg-1 dry weight. Seed germination of the weed Echinochloa colona was reduced to 25% with 200 lM Cr.The presence of excess of chromium beyond the permissible limit is destructive to plants since it severely affects the biological factors of the plant and enters the food chain on consumption of these plant materials. Common features due to Cr phytotoxicity are reduction in root growth, leaf chlorosis, inhibition of seed germination and depressed biomass. Chromium toxicity greatly affects the biological processes in various plants such as maize, wheat, barley, cauliflower, citrullus and in vegetables. Chromium toxicity causes chlorosis and necrosis in plants (Ghani, 2011). Enzymes like catalase, peroxidase and cytochrome oxidase with iron as their component are affected by chromium toxicity. The catalase activity stimulated with excess supply of chromium inducing toxicity has been studied with respect to photosynthesis, nitrate reductase activity, protein content in algae and photosynthetic pigments.

4.10 Mercury effects on plants

Hg is a unique metal due to its existence in different forms. However, in agricultural soil, ionic form is predominant. Hg released to the soil mainly remains in solid phase through adsorption onto sulfides, clay particles and organic matters. Increasing evidence has shown that Hg can readily accumulate in higher and aquatic plants. High level of Hg is strongly phytotoxic to plant cells. Toxic level of Hg can induce visible injuries and physiological disorders in plants. For example, Hg can bind to water channel proteins, thus inducing leaf stomata to close and physical obstruction of water flow in plants. High level of Hg interfere the mitochondrial activity and induces oxidative stress by triggering the generation of ROS. This leads to the disruption of biomembrane lipids and cellular metabolism in plants.

In lake environment the accumulation of Hg is fast but elimination is slow. High concentration of Hg have been associated with developmental and behavioral abnormalities, impaired reproduction and survival, and in some cases with direct mortality. Planktonic unicellular algae, such as *Chlorella vulgaris,* have a high capacity to bioaccumulate organic mercury, as do fresh water macrophytes such as *Elodea densa.* Experimental exposure of this plant to a 1 ppb concentration of methyl mercury chloride for 10 days produced an average concentration in the leaves of 15ppm, a 15,000-fold bioconcentration factor primary consumers, such as the crustacean Daphnia, readily accumulate mercury by eating contaminated algae. They too accumulate a higher concentration of MeHg than their algal food. Thus begins the biomagnifications of mercury in the food chain. The heavy metal ions can inhibit the growth of algae and aquatic plants in different ways, which depend on the species, the metal types and the condition in the growing media.

5.CONCLUSION

Environmentalism is not simply concerned with nature per se but with the sustainable use of nature. To develop the ecosystem and the beneficiaries around it, the inbuilt balance should be well understood. For the sustainable development of natural resources and ecological subsistence, its ecosystem must be maintained and conserved. Proper steps must be taken to save its ecology from deterioration and degradation.

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