THE BRIEF REVIEW ON HEAVY METALS IN PLANT
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ABSTRACT
Heavy metals are natural constituents of the earth’s crust, but indiscriminate human activities have drastically altered their geochemical cycles and biochemical balance. This results in accumulation of metals in plant parts having secondary metabolites, which is responsible for a particular pharmacological activity. Prolonged exposure to heavy metals such as cadmium, copper, lead, nickel, and zinc can cause deleterious health effects in humans. Heavy metals, such as cadmium, copper, lead, chromium and mercury are major environmental pollutants, particularly in areas with high anthropogenic pressure. Heavy metal accumulation in soils is of great concern in agricultural production due to the adverse effects on food safety and marketability, crop growth due to phytotoxicity, and environmental health of soil organisms. The influence of plants and their metabolic activities affects the geological and biological redistribution of heavy metals through pollution of the air, water and soil.

Keywords: Heavy Metals, Environment, Occurrence, Effect On Plants.

I. INTRODUCTION
A heavy metal is toxic when relatively it is dense metal or metalloid that is noted for its potential toxicity, especially in environmental contexts. Heavy metal toxicity means excess of required concentration or it is unwanted which were found naturally on the earth, and become concentrated as a result of human caused activities, enter in plant, animal and human tissues via inhalation, diet and manual handling, and can bind to, and interfere with the functioning of vital cellular components. Heavy metals were significant environmental pollutants; their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons. They are group of metals and metalloids with atomic density greater than 4 g/cm³, or 5 times or more, greater than water, including copper (Cu), manganese (Mn), lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), iron (Fe), zinc (Zn), chromium (Cr), iron (Fe), arsenic (As), silver (Ag) and the platinum. Environmentally it is defined as total circumstances surrounding an organism or group of organisms especially, the combination of external physical conditions that affect and influence the growth, development and survival of the organisms [1].

From a chemical point of view, the term heavy metal is strictly ascribed to transition metals with atomic mass over 20 and specific gravity above 5. In biology, “heavy” refers to a series of metals and also metalloids that can be toxic to both plants and animals even at very low concentrations. Here the term “heavy metals” will be for these potentially phytotoxic elements. Some of these heavy metals, These latter elements can easily lead to poisoning when their concentration rises to supra-optimal values. Heavy metal phytotoxicity may result from alterations of numerous physiological processes caused at cellular/molecular level by inactivating enzymes, blocking functional groups of metabolically important molecules, displacing or substituting for essential elements and disrupting membrane integrity. A rather common consequence of heavy metal poisoning is the enhanced production of reactive oxygen species (ROS) due to interference with electron transport activities, especially that of chloroplast membranes. This increase in ROS exposes cells to oxidative stress leading to lipid peroxidation, biological macromolecule deterioration, membrane dismantling, ion leakage, and DNA-strand cleavage. Plants resort to a series of defence mechanisms that control uptake, accumulation and translocation of these dangerous elements and detoxify them by excluding the free ionic forms from the cytoplasm (Fig. 1). One commonly employed strategy lies in hindering the entrance of heavy metals into root cells through entrapment in the apoplastic environment by binding them to exuded organic acids or to anionic groups of cell walls. Most of the heavy metals that do enter the plant are then kept in root cells, where they are detoxified by complexation with amino acids, organic acids or metal-binding peptides and/or sequestered into vacuoles. This greatly restricts translocation to the above-ground organs thus protecting the leaf tissues, and particularly the
metabolically active photosynthetic cells from heavy metal damage. A further defense mechanism generally adopted by heavy metal-exposed plants is enhancement of cell antioxidant systems which counteracts oxidative stress [2].

Naturally plants are exposed with many adverse environmental conditions like biotic and abiotic stress. Despite all others stresses heavy metal stress is one of great importance which has a notable adverse effects on crop productivity and growth. Heavy metal stress triggers different responses in plants, ranging from biochemical responses to crop yield. The term “heavy metals” refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech Water Treatment and Air Purification, 2004). “Heavy metals” in a general collective term, applies to the group of metals and metalloids with atomic density greater than 4 g/cm³, or 5 times or more, greater than water (Hawkes, 1997). However, chemical properties of the heavy metals are the most influencing factors compared to their density. Heavy metals include lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), iron (Fe), zinc (Zn), chromium (Cr), iron (Fe), arsenic (As), silver (Ag) and the platinum group elements. Heavy metals are largely found in dispersed form in rock formations. Industrialization and urbanization have increased the anthropogenic contribution of heavy metals in biosphere. 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 these heavy metals like Cu and Zn either serve as cofactor and activators of enzyme reactions e.g., in forming enzymes/substrate metal complex (Mildvan, 1970) or exert a catalytic property such as prosthetic group in metalloproteins. [3]

Any toxic metal may be called heavy metal, irrespective of their atomic mass or density. Heavy metals are a member of an ill-defined subset of elements that exhibit metallic properties. These include the transition metals, some metalloids, lanthanides, and actinides. One source defines heavy metal as one of the common transition metals, such as copper, lead, and zinc. These metals are a cause of environmental pollution from sources such as leaded petrol, industrial effluents, and leaching of metal ions from the soil into lakes and rivers by acid rain. Three principal systems of medicine are practiced in India: Ayurveda, Siddha and Unani-Tibb. These systems utilize drugs of natural origin constituting plants, animals, and mineral preparations.[10]

### Heavy Metals/Metalloids

Any metal (or metalloid) species may be considered a “contaminant” if it occurs where it is unwanted, or in a form or concentration that causes a detrimental human or environmental effect. Metals/metalloids include lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), copper (Cu), selenium (Se), nickel (Ni), silver (Ag), and the platinum group elements.
Some of heavy metals (Fe, Cu and Zn) are essential for plants and animals, their availability 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 result in toxic effects [8]. Range of a few important heavy metals in plants like As 0.02-7; Cd 0.12.4; Hg 0.005-0.02; Pb 1-13; Sb 0.02-0.06; Co 0.05-0.5; Cr 0.2-1; Cu 4.15; Fe 140; Mn 15-100; Mo 1-10; Ni 1; Sr 0.30 and Zn 8-100 in µg g⁻¹ dry wt. on land plants [1]

Nature of heavy metals: Heavy metals are natural components cannot be degraded or destroyed biologically. Life can't develop and survive without the metal ions as life is as much inorganic as organic. Trace element to designate the elements which occur in small concentrations in natural biological systems concern over the deteriorating quality of the environment led to a trace element. The elementary constituents of plant, animal and human life may be classified as major and trace elements, the latter group comprising both essential and non-essential elements (including toxic elements). [2]

Essential heavy metals: Some of heavy metals (Fe, Cu and Zn) are essential for plants and animals, their availability 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 result in toxic effects [8]. Range of a few important heavy metals in plants like As 0.02-7; Cd 0.12.4; Hg 0.005-0.02; Pb 1-13; Sb 0.02-0.06; Co 0.05-0.5; Cr 0.2-1; Cu 4.15; Fe 140; Mn 15-100; Mo 1-10; Ni 1; Sr 0.30 and Zn 8-100 in µg g⁻¹ dry wt. on land plants [1]

Source of contamination: There are different sources of heavy metals in the environment such as: natural, agricultural, industrial, domestic effluent, atmospheric sources and other sources. Activities such as mining and smelting operations and agriculture have contaminated extensive areas of world such as Japan, Indonesia and China mostly by heavy metals such as Cd, Cu and Zn (Herawati et al., 2000). Natural sources of heavy metals Heavy metals originate within the Earth's crust; hence their natural occurrence in soil is simply a product of weathering process. The composition and concentration of heavy metals depend on the rock type and environmental conditions, activating the weathering process. The geologic plant materials generally have high concentrations of Cr, Mn, Co, Ni, Cu, Zn, Cd, Sn, Hg and Pb. However, class-wise the heavy metal concentrations vary with in the rocks. Soil formation takes place mostly from sedimentary rock, but is only a small source of heavy metals, since it is not generally or easily weathered [4]

Mode of Action of Toxic heavy metals in Plant Cells: The toxicity of heavy metals is manifested in many ways when plant cells accumulate them at high levels. Heavy metals can be divided into two groups: redox active (Fe, Cu, Cr, Co) and redox inactive (Cd, Zn, Ni, Al, etc.). The redox active heavy metals are directly involved in the redox reaction in cells and result in the formation of O2• and subsequently in H2O2 and •OH production via the Haber-Weiss and Fenton reactions (Schutzenzubel and Polle, 2002). Exposure of plants to redox inactive heavy metals also results in oxidative stress through indirect mechanisms such as interaction with the antioxidant defense system, disruption of the electron transport chain, or induction of lipid peroxidation. The latter can be due to an heavy metal-induced increase in lipoxygenase (LOX) activity.

Occurrence of heavy metals
1. Cadmium is released mainly from nickel-cadmium batteries, fossil fuel combustion, coating & plating, and cement production. It also releases from industrial discharge and domestic waste. Natural processes like a dust storm, volcanic activities, wildfire, weathering of rocks, and erosion also increase the Cd levels. Global consumption of Cd around 20000–24000 t/year.
2. Nickel released from Natural sources like wind-blown, weathering of rocks, and wildfires. Anthropogenic activities like casting and battery manufacturing factories also release Ni in the the environment. Ni also releases from tobacco and stainlesssteel kitchen utensils.
3. Arsenic- It is released mainly from various anthropogenic sources such as mining, combustion of fossil, smelting and chemotherapeutic drug of cancer. It also releases from paints, wood preservatives.
4. Mercury- It originates from geothermal activity, gold mining, coal combustion and anthropogenic emission. Medicinal waste, plastic, scientific like thermometer, thermostat and dental amalgam also contain Hg. The use of Hg-containing pesticides and fertilizer increases the concentration of Hg in the environment. Lead is mainly released from mining, ore processing and recycling of lead-acid batteries. Most of lead is used in battery manufacturing plants.
5. Lead also releases from lead-based paint, plumbing pipes, automobile exhaust and industrial waste. Natural sources like sea salt spray, volcanic eruptions also increase the amount of lead in the environment.[11]
Fig. no 2: Possible biochemical and molecular mechanisms of heavy metal-mediated ROS induction and damage to the development of higher plants. [4]

Heavy Metals and Living Organism

Living organisms require varying amounts of heavy metals. Iron, cobalt, copper, manganese, molybdenum, and zinc are required by humans.[10] All metals are toxic at higher concentrations. Excessive levels can be damaging to the organism. Other heavy metals such as mercury, plutonium, and lead are toxic metals that have no known vital or beneficial effect on organisms, and their accumulation over time in the bodies of animals can cause serious illness. Certain elements that are normally toxic are for certain organisms or under certain conditions, beneficial. Examples include vanadium, tungsten, and even cadmium.[10] The Types of heavy metals and their effect on human health with their permissible limits are enumerated in Table 1. Heavy metals disrupt metabolic functions in two ways:

1. They accumulate and thereby disrupt function in vital organs and glands such as the heart, brain, kidneys, bone, liver, etc.

2. They displace the vital nutritional minerals from their original place, thereb, hindering their biological function.

It is, however, impossible to live in an environment free of heavy metals. There are many ways by which these toxins can be introduced into the body such as consumption of foods, beverages, skin exposure, and the inhaled air.[10]

Plants experience oxidative stress upon exposure to heavy metals that leads to cellular damage and disturbance of cellular ionic homeostasis. To minimize the detrimental effects of heavy metal exposure and their accumulation, plants have evolved detoxification mechanisms mainly based on chelation and subcellular compartmentalization. A principal class of heavy metal chelator known in plants is phytochelatins (PCs), are
synthesized no-translationally from reduced glutathione (GSH) in a transpeptidation reaction catalyzed by the enzyme phytochelatin synthase (PCS). Therefore, availability of glutathione is very essential for PCs synthesis in plants at least during their exposure to heavy metals [10].

### Table 1: Sources and side-effects of heavy metal ions [9]

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Limit in mg L⁻¹</th>
<th>Sources</th>
<th>Side-effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb²⁺</td>
<td>0.05</td>
<td>Paint, gasoline, smelting, lead containing pipes, battery</td>
<td>Behavioural changes and learning problems in children. Damage of kidney and nervous system, anaemia, miscarriage in pregnant carcinogenic</td>
</tr>
<tr>
<td>Cd²⁺</td>
<td>0.005</td>
<td>Fossil fuel, agricultural activity, cigarette smoke and sewage sludge</td>
<td>Cancers, effects on cardiovascular system, respiratory problem and damage of nervous system</td>
</tr>
<tr>
<td>As³⁺</td>
<td>0.05</td>
<td>Wood preservatives, alloying, semiconductors, glassware and pesticides</td>
<td>Inorganic arsenic causes lung and bladder cancer, diabetes, heart problems, neurological disorders and effects on reproductive system</td>
</tr>
<tr>
<td>Cr³⁺</td>
<td>0.05</td>
<td>Steel industries, construction materials, transportation, electroplating, paint, dyes, plastics, leathers and photographs</td>
<td>Mutagenic and cancers, nausea, stomach pain, vomiting, haemorrhage and indigestion</td>
</tr>
<tr>
<td>Fe³⁺</td>
<td>0.1</td>
<td>Rock weathering, minerals, sewage, landfill leachate, acid mine drainage and engineering industries</td>
<td>Poor growth, diabetes and heart problems</td>
</tr>
<tr>
<td>Cu²⁺</td>
<td>1.5</td>
<td>Rock weathering, animal manure, fossil fuel burning, bursting, and aerosols</td>
<td>Depression, anxiety, allergies, anorexia, fatigue and premenstrual syndrome bubble</td>
</tr>
<tr>
<td>Zn²⁺</td>
<td>5.0</td>
<td>Electroplating, vegetable fat producing industries, paint, galvanizing plants and porcelain enameling industry and Petroleum, metallurgy, petroleum procedure, nickel cadmium batteries and plating Respiratory problems, lung cancer, nasal cancer,</td>
<td>Dizziness, stomach pain and lack of muscular coordination are some of complication woman, infertility in males and gastrointestinal problems, heart diseases and epigenetic effects</td>
</tr>
<tr>
<td>Ni²⁺</td>
<td>0.1</td>
<td>Volcanic eruptions and naturally occurs as mercury salts</td>
<td>Damages nervous system, kidney and cardiovascular systems. It also effects on reproductive, gastrointestinal, immune and hematologic system</td>
</tr>
<tr>
<td>Hg²⁺</td>
<td>0.001</td>
<td>Mining, manufacturing units of electronic devices, petroleum industries and electro plating</td>
<td>Cancers and neurotoxicological disorders</td>
</tr>
</tbody>
</table>
Table 2: Various processes for removal of heavy metals [10]

<table>
<thead>
<tr>
<th>Metal</th>
<th>Removing agent</th>
<th>Major method</th>
<th>Other methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy metals in Water</td>
<td>Natural zeolites, Conductive electroactive Polymers</td>
<td>Ion exchange</td>
<td>Biosorption, immobilization in matrix, complexation, bioremediation</td>
</tr>
<tr>
<td></td>
<td>Calcium alginate microparticles, Dithiocarbamates, chitosan-capped gold nanoparticles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromium ions [mainly from industrial waste]</td>
<td>Activated carbon</td>
<td>Ion-exchange adsorbents</td>
<td>Chemical sedimentation, surface absorption, ionexchanger and reverse osmosis</td>
</tr>
<tr>
<td>Mercury</td>
<td>Activated carbon, Bentonite</td>
<td>Ion exchangers</td>
<td>Reduction, precipitation, extraction and ion exchange</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Poly(ethylene glycol) and its composites, poly(vinyl alcohol) and hydroxypropylcellulose</td>
<td>Oxidation</td>
<td>Oxidation, by adsorbents and surfactants, capacitive deionization</td>
</tr>
</tbody>
</table>

Heavy Metals and Polymers

Metal ions are not only valuable intermediates in metal extraction, but also important raw materials for technical applications. Complexation, separation, and removal of metal ions have become increasingly attractive areas of research and have led to new technological developments. Metal--chelating and ion exchange polymers were used in hydrometallurgical applications such as recovery of rare metal ions from seawater and removal of traces of radioactive metal ions from wastes. A polymeric ligand is used to selectively bind a specific metal ion in a mixture to isolate important metal ions from wastewater and aqueous media.

It is usually used in an insoluble resin form to separate a specific metal ion from a liquid containing a mixture of metal ions. For example, uranium is a potential environmental pollutant, especially in mining industry wastewater, and the migration of uranium in nature is important in this context. Many types of adsorbents were developed and studied for the recovery of uranium from seawater and aqueous media. Among them, amidoxime group containing adsorbents were shown to be the most effective for the recovery of uranium from seawater and aqueous media. The unique advantage of these polymers is that due to its unique chemical structure, it recovers uranium and other transition metal ions from seawater, and aqueous media at very low concentration levels more efficiently.[10] Aspergillus niger immobilized by inclusion in two different polymers: polyvinyl alcohol hydrogel (PVA) and Ca alginate. A. niger biomass absorbed Fe3+, Pb2+, and Cd2+ ions from industrial wastewater more rapidly than other ions within 15 to 20 min. The removal percentages order at equilibrium reported was: Cd2+ (95%) > Pb2+ (88%) > Fe3+ (70%) > Cu2+ (60%) > Ni2+ (48.9%) > Mn2+ (37.7%) > Zn2+ (15.4%). The results showed that immobilized biomass of A. niger, appears as a possible biosorbent to be used for treatment of meta-polluted industrial wastewaters [10]

Effect of heavy metals on plants:
The heavy metals available for plant uptake are those present as soluble components in the soil solution or those solubilized by root exudates. Plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals can become toxic to plants and ability of plants to accumulate essential metals equally enables them to acquire other nonessential metals. As metals cannot be broken down, when concentrations
The negative influence of heavy metals on the growth and activities of soil organic matter decomposition leading to a less fertility of soil. Enzyme activities are very much useful for plant metabolism, hampered due to heavy metal interference with activities of soil microorganisms. These toxic effects (both direct and indirect) lead to a decrease in plant growth which finally results in the death of plant.\[1\]

The effect of heavy metal toxicity on the growth and development of plants differs according to the particular heavy metal for that process. Metals such as Pb, Cd, Hg, and As which do not play any beneficial role in plant growth, adverse effects have been recorded at very low concentrations of these metals in the growth medium. Kibra noticed significant reduction in height of rice plants growing on the soil contaminated with 1 mg Hg/kg with reduction in tiller and panicle formation. For Cd toxicity which reduces the shoot and root growth in wheat plants when Cd as low as 5 mg/L in the soil \[1\]

1. Effects of copper on plants

Copper is an essential metal for normal plant growth and development, although it is also potentially toxic. Copper (Cu) is considered as a micronutrient for plants \[55\] and plays an important role in CO2 assimilation and ATP synthesis, Study conducted at Malankhand Copper Project (MCP) of Hindustan Copper Limited (HCL) at Malankhahnd, district Balaghat, M.P in which it was found that copper dust had adverse effect on various photosynthesis pigmentation secretions in many trees species leaves . Cu is also an essential component of various proteins like plastocyanin of photosynthetic system and cytochrome oxidase of respiratory electron transport chain . But enhanced industrial and mining activities have contributed to the increasing occurrence of Cu in ecosystems. Cu is also added to soils from different human activities including mining and smelting of Cu containing ores. Mining activities generate a large amount of waste rocks and tailings, which get deposited at the surface. Excess of Cu in soil plays a cytotoxic role, induces stress and causes injury to plants. This leads to plant growth retardation and leaf chlorosis, Exposure of plants to excess Cu generates oxidative stress and ROS. Oxidative stress causes disturbance of metabolic pathways and damage to macromolecules, Copper reduces the root growth in rhodes grass \[1\]

2. Effect of zinc on plants

The function of zinc is to help a plant to produce chlorophyll. Leaves get discolor when the soil is deficient in zinc and plant growth is stunted, Zinc deficiency causes leaf discoloration called chlorosis tissue of the veins to turn yellow. Chlorosis by zinc deficiency usually affects the base of the leaf near the stem. Chlorosis appears on the lower leaves first, and then gradually moves up to the plant. In severe cases, the upper leaves become chlorotic and the lower leaves turn brown or purple and die. When plants show symptoms this severe, it's best to pull them up and treat the soil before replanting. 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 such as Phaseolus vulgaris and Brassica juncea \[1\]

3. Effects of cadmium on plants

The permissible limit of cadmium (Cd) in agricultural soil is 100 mg/kg soil \[70\]. Plants grown in soil containing high levels of Cd show visible symptoms of injury reflected in terms of chlorosis, growth inhibition, browning of root tips and finally death. The inhibition of root Fe (III) reductase induced by Cd led to Fe (II) deficiency, and it seriously affected photosynthesis. In general, 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 . Appreciable inhibition of the nitrate reductase activity was also found in plants of Silene cucubalus . 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 \[1\]
4. Effects of mercury on plants

Mercury is not essential for plant growth. Contamination of soils by Hg is often due to the addition of this heavy metal as part of fertilizers, lime, sludges, and manures. The dynamics between the amount of Hg that exist in the soil and its uptake by plants is not linear and depends on several variables (e.g., cation-exchange capacity, soil pH, soil aeration, and plant species). The large input of mercury (Hg) into the arable lands has resulted in the widespread occurrence of mercury contamination in the entire food chain. Hg is a unique metal due to its existence in different forms e.g., HgS, Hg²⁺, Hg⁰ and methyl-Hg. However, in agricultural soil, ionic form (Hg²⁺) 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⁺² can readily accumulate in higher and aquatic plants [82, 83]. High level of Hg⁺² is strongly phytotoxic to plant cells. Toxic level of Hg⁺² can induce visible injuries and physiological disorders in plants. For example, Hg⁺² can bind to water channel proteins, thus inducing leaf stomata to close and physical obstruction of water flow in plants. High level of Hg⁺² interfere the mitochondrial activity and induce oxidative stress by triggering the generation of ROS. This leads to the disruption of bio-membrane lipids and cellular metabolism in plants. In rice (Oryza sativa) excess of mercury decreases plant height, reduces tiller and panicle formation, yield reduction and increase of its bioaccumulation in shoot and root of seedling [1].

5. Effects of chromium on plants

Chromium is known to be a toxic metal that can cause severe damage to plants and animals. Chromium induced oxidative stress involves induction of lipid peroxidation in plants that causes severe damage to cell membranes. Oxidative stress induced by chromium initiates the degradation of photosynthetic pigments causing decline in growth. High chromium concentration can disturb the chloroplast ultra structure there by disturbing the photosynthetic process. Since seed germination is the first physiological process affected by Cr, the ability of a seed to germinate in a medium containing Cr would be indicative of its level of tolerance to this metal. Seed germination of the weed Echinochloa colona was reduced to 25% with 200 µM Cr. High levels (500 ppm) of hexavalent Cr in soil reduced germination up to 48% in the bush bean Phaseolus vulgaris. Peralta found that 40 ppm of Cr (VI) reduced by 23% the ability of seeds of Lucerne (Medicago sativa) to germinate and grow in the contaminated medium [90]. Reductions of 32–57% in sugarcane bud germination were observed with 20 and 80 ppm Cr, respectively. The reduced germination of seeds under Cr stress could be a depressive effect of Cr on the activity of amylases and on the sub sequent transport of sugars to the embryo axes. Protease activity, on the other hand, increases with the Cr treatment, which could also contribute to the reduction in germination of Cr treated seeds. Decrease in root growth is a well-documented effect due to heavy metals in trees and crops. Prasad reported that the order of metal toxicity to new root primordia in Salix viminalis is Cd > Cr > Pb, whereas root length was more affected by Cr than by other heavy metals studied. Chromium stress is one of the important factors that affect photosynthesis in terms of CO₂ fixation, electron transport, photophosphorylation and enzyme activities [1].

6. Effects of lead on plants

Plants on land tend to absorb lead from the soil and retain most of this in their roots. There is some evidence that plant foliage may also take up lead (and it is possible that this lead is moved to other parts of the plant). The uptake of lead by the roots of the plant may be reduced with the application of calcium and phosphorus to the soil. Lead (Pb) is one of the ubiquitously distributed most abundant toxic elements in the soil. It exerts adverse effect on morphology, growth and photosynthetic processes of plants. Lead is known to inhibit seed germination of Spartania alterniflora, Pinus helipensis. Inhibition of germination may result from the interference of lead with important enzymes. Mukherji and Maitra observed 60 µM lead acetate inhibited protease and amylase by about 50% in rice endosperm. Early seedling growth was also inhibited by lead in soybean, rice, maize, barley, tomato and certain legumes. Lead also inhibited root and stem elongation and leaf expansion in Alilium species barley and Raphanus sativas. The degree to which root elongation is inhibited depends upon the concentration of lead and ionic composition and pH of the medium. Concentration dependent inhibition of root growth has been observed in Sesamum indicum. A high lead level in soil induces abnormal morphology in many plant species. For example, lead causes irregular radial thickening in pea roots, cell walls of the endodermis and lignification of cortical parenchyma. Lead also induces proliferation effects on the repair process of vascular plants. Lead administrated to potted sugar beet plants at rates of 100–200 ppm
caused chlorosis and growth reduction. High Pb concentration also induces oxidative stress by increasing the production of ROS in plants [1]

7. Effects of Cobalt on plants

Cobalt, a transition element, is an essential component of several enzymes and coenzymes. It has been shown to affect growth and metabolism of plants, in different degrees, depending on the concentration and status of cobalt in rhizosphere and soil. Cobalt interacts with other elements to form complexes. The cytotoxic and phytotoxic activities of cobalt and its compounds depend on the physicochemical properties of these complexes, including their electronic structure, ion parameters (charge-size relations) and coordination. The uptake and distribution of Co in plants is species dependent and controlled by different mechanisms. 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. 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 in leaves of cauliflower. Further, high level of Co also affected the translocation of P, S, Mn, Zn and Cu from roots to tops in cauliflower. In contrast to excess Cu or Cr, Co significantly decreased water potential and transpiration rate.[1]

8. Effects of nickel on plants

Nickel is an essential nutrient for plants. However, the amount of Ni required for normal growth of plants is very low. Hence, with the level of Ni pollution in the environment increasing, it is essential to understand the functional roles and toxic effects of Ni in plants. Ni+2 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. However, Ni+2 concentration is increasing in certain areas by human activities such as mining works, emission of smelters, burning of coal and oil, sewage, phosphate fertilizers and pesticides. Excess of Ni+2 in soil causes various physiological alterations and diverse toxicity symptoms such as chlorosis and necrosis in different plant species, including rice. Plants grown in high Ni+2 containing soil showed impairment of nutrient balance and resulted in disorder of cell membrane functions. Thus, Ni+2 affected the lipid composition and H-ATPase activity of the plasma membrane as reported in Oryza sativa shoots. Other symptoms observed in Ni+2 treated plants were related with changes in water balance. High uptake of Ni+2 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+2 toxicity in plants [1]

9. Effects of iron on plant

Iron is mainly involved in the process of plant photosynthesis. The micronutrient's availability to plant roots depends on the pH level of the soil with iron more readily available in soil with a low pH. Iron and manganese both play an important role in plant growth and development, but often compete for absorption, as an abundance of one of these micronutrients makes the other less available to plant roots. 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, aconitase and superoxide dismutase (SOD). 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. 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 micro-bial reduction of insoluble Fe+3 insoluble Fe+2. Iron toxicity in tobacco, canola, soybean and Hydrilla verticillata are accompanied with reduction of plant photosynthesis and yield and the increase in oxidative stress and ascorbate peroxidase activity. The appearance of iron toxicity in plants is related to high Fe+2 uptakes by roots and its transportation to leaves and via transpiration stream. The Fe+2 excess cause free radical production that impairs cellular structure irreversibly and damages membranes, DNA and proteins [1]

10. Effects of manganese on plants

Manganese (Mn) is an essential plant mineral nutrient, playing a key role in several physiological processes, particularly photosynthesis. Manganese deficiency is a widespread problem, most often occurring in sandy soils, organic soils with a pH above 6 and heavily weathered, tropical soils. Mn is readily transported from root
Heavy metals are found naturally in the ecosystem. Metals are helpful for human beings when they are present in low levels. They maintain biological processes such as Fe helps in haemoglobin formation, Cu help in oxygen and electron transport, Co helps in cell metabolism, Mn regulates enzyme regulation, Se helps in hormone and antioxidant production, and Ni helps in cell growth in humans, hence called essential metals. However, if heavy metals are present at a higher level, they cause toxic effects on human beings. Heavy metals are entered into the human body mainly through ingestion (eating or drinking) and inhalation (breathing) by various means such as living near a site where these metals are disposed improperly, drinking water, and eating foods contaminated by heavy metals, which cause adverse effects on human beings.

1. Effects of Cadmium (Cd) Cadmium is a highly toxic heavy metal.

Cd is identified as a human carcinogen by The International Agency for Research on Cancer and the US National Toxicology Program. Cd inhibits biosynthesis of DNA, RNA, proteins, and converts normal epithelial cells to malignant cells, and become carcinogen. In humans, prolonged exposure to Cd causes lung cancer and affects kidneys. Cd interacts with essential elements like An, Fe, Ca, Mg, Se and cause functional and morphological changes in many organs and also disturb secondary metabolism. Cd causes pneumonia, general weakness, fever, chest pain and causes death in severe cases. By deposition of high concentration of Cd in urine, blood and kidney cortex, women are more affected than men because, in women, dietary Cd in the intestine is increased [11]

2. Effects of Nickel (Ni) Nickel cause a deteriorating effect on human health.

Ni causes cancer mainly in the lungs, chronic bronchitis and reduces the function of the lungs. Due to chronic inhalation of fumes of carcinogenic form of Ni like nickel oxide, it caused respiratory cancer, asthma, and sinus problems. The most affected organ by nickel exposure is the kidney. Acute nickel toxicity causes Frank haematuria and kidney injury, inflammation in bronchitis, congestion in the lumen, alveolar cell hyperplasia, and alveolar congestion, carcinogenesis, chromosomal damage, mutagenesis and inhibits NK cell activity as Ni+2 acts as a tumor. Ni induces reactive oxygen species (ROS) by accretion of iron and enhancing the lipid peroxidative damage by hydroxyl radicals involving Haber-Weiss and Fenton chemistry and it also causes oxidative stress. Ni causes tightness of the chest, sweating, palpitations, vertigo, insomnia and diarrhoea. In sensitized skin, individual absorption of nickel ions through skin cause dermatitis, which shows inflammation in the skin. Sometimes it leads to skin eruptions, redness, and in extreme conditions, causes ulcers and pustules. Ni accumulates in the nucleus, mainly in nucleolar fraction, so it is a carcinogen to humans. Soluble Ni clears faster from the tissue, but insoluble Ni particles retain longer in tissue, so soluble Ni compounds are more potent carcinogens than insoluble Ni compounds [10]

3. Effects of Arsenic (As) Arsenic is toxic heavy metal for human beings.

Inorganic arsenic is known as a carcinogen. Low to moderate levels of As exposure causes diabetes, hepatic & renal dysfunction, and neurological complications. Skin is considered more susceptible to As and causes dermatitis, women; they are more prone to As induces skin disorders than men. Skin lesions – keratosis, melanosis and pigmentation are the characteristic feature of As exposure. The brain is also one of target organs.
for Arsenic toxicity. Arsenic causes neurological complications. Neurons with long axons and sensory nerves are more affected than neurons with short axons and motor nerves. Capabilities of neurons to detoxify reactive oxygen species and glutathione production decreases due to which pain, numbness in soles of feet and paresthesia occur. As causes oxidative stress, one of the major cause of neurotoxicity. Arsenic increases premature delivery, increases fetal loss in women’s and loss of conception in the uterus. As causes steatosis [10]

4. Effects of Mercury (Hg) Mercury is most toxic non-essential metal to human beings.

Hg is present in 3 forms - elemental Hg, inorganic Hg and organic Hg in the environment. Elemental Hg is mainly released as a vapor in the air in the environment. Elemental Hg vapor mainly targets the central nervous system, due to which cognitive, motor, and sensory disturbance occurs and shows symptoms like insomnia, memory loss, tremors (affecting hands & sometimes other parts of the body) and muscle twitching. Prolonged exposure to elemental Hg causes poor concentration, blurred vision and unsteady walking. High exposure to Hg, causes neurological damage and death. Harmful effects of Hg passed to fetus from mother and cause brain damage, blindness, mental retardation, and inability to speak. Exposure of Hg to high level cause pneumonia, pulmonary edema and show many symptoms of lung damage. Hg exposure to low level causes depression, tremors (shaking), skin rashes, memory loss in adults and peeling off hands & feet and redness in children. In the amalgam of a dental filling, about 50% metallic Hg has been used and from the amalgam filling, Hg is released as Hg vapors or inorganic ions through abrasion of the amalgam surface. Hg vapors in the oral cavity may be absorbed through the respiratory system and inhaled into the lungs. Metals ions are ingested in gastrointestinal tract through oral fluids and Hg vapors distributed to different body organs by the blood [11].

5. Effects of Lead (Pb) Lead is considered as a toxic heavy metal.

At low concentration, Pb causes serious effects on the body. Pb disturbs many processes such as protein folding, inter & intra cellular singling, apoptosis, enzyme regulation, and cell adhesion because Pb metal ions can replace other monovalent cations like Na+ and bivalent cations like Cl+2, Fe+2, etc. Deficiency of Pb in children in age group 0-5, causes neuro-development effects. Pb exposure to pregnant women causes serious concern because Pb reaches to children through placenta in the women’s uterus. Pb causes oxidative stress in living cells as it increases ROS and decreases antioxidants like glutathione which protect cells from free radical such as hydrogen peroxide. ROS cause stressed situation at the cellular level because it causes structural damage to proteins, cell membranes and lipids. Free radicals collect electron from lipid molecules which is present in cell membrane leads to lipid peroxidation. At picomolar concentration on the binding sites of cerebellar phosphokinase C, lead can compete with calcium for binding and affect neuronal signals [10].

III. CONCLUSION

Plants grow on heavy metal polluted soils resultant in reduction in growth due to changes in their physiological and biochemical activities especially true when the heavy metal involved does not play any beneficial role towards the growth and development of plants. The problem of heavy metal pollution is continuously worsening due to a series of human activities, leading to intensification, A major portion of heavy metals are toxic and cause environmental pollution. Heavy metals are non-biodegradable and water-soluble, so they easily enter into plants and human beings and cause adverse effects. They are mainly released from natural and anthropogenic activities in the ecosystem. In this review, all possible effects of highly toxic heavy metals like Cd, Ni, As, Hg, and Pb on plants and human beings in a easy way are presented. Heavy metals affects plants by inhibiting their growth, decreasing the plants’ functions affecting physiological and biological activities and the plants also show many types of resistance to detoxify heavy metals.

IV. REFERENCES

[3] D. A. Cataldo* and R. E. Wildung* Soil and Plant Factors Influencing the Accumulation of Heavy Metals by Plants, Environmental Health Perspectives Vol. 27, pp. 149-159, 1978


[14] Bioconcentration of heavy metals by plants Ilya Raskin, PBA Nanda Kumar, Slavik Kushenkov and David E Sal, Current Biology Ltd ISSN 0958-1669

