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Lead and Chromium transport in ecosystem and their impact on plants

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Abstract

Major environmental contaminants include heavy metals like lead and chromium, especially in areas with significant anthropogenic pressure.Utilizing these heavy metals excessively may result in growth suppression and decrease.The numerous sources of heavy metals include mining, residential wastewater, industry, and agriculture. Heavy metals frequently cause reduced plant development, including leaf chlorosis, necrosis, and turgor loss. They can also slow down seed germination and damage the photosynthetic process.Plants that are exposed to high concentrations of lead and chromium exhibit a variety of symptoms, including chlorosis, growth suppression, reduction in transpiration rate, inhibit seed germination, DNA damage, decreased chlorophyll, inhibit shoot growth. This review focuses on sources and negative impacts on pants. In the present review various roots of Pb and Cr transport in ecosystem has been summarised. Also a systematic review of toxicity of these heavy metals has been mentioned.

Keywords: Heavy metals; Anthropogenic activities; lead toxicity; chromium toxicity.

1. INTRODUCTION.

The term "heavy metal" can refer to any toxic metal, regardless of its atomic mass or density.(Singh*et al* 2011).This group contains approximately 40 elements. Because they are poisonous, persistent, and non-degradable, heavy metals (HM) are among the most harmful pollutants in the aquatic environment (Venkateswarlu and Venkatrayulu 2020).In addition to wreaking havoc on the availability of natural resources, anthropogenic biosphere disturbances have

led to serious and widespread pollution of vital elements of life on the planet. These manifestations include accelerated industrial growth, intensive agriculture, and extensive mining, coupled with a burgeoning population and rapid urbanisation..An important concern for ecological, dietary, and environmental reasons is the increasing buildup of heavy metals, one of the effects of human-caused disturbance of natural biogeochemical cycles (P. C. Nagajyoti*et al.* 2010; H. Ali *et al.* 2013).Heavy metals, which affect and contaminate food chains, soil, irrigation or potable water, aquifers, and the surrounding environment, are nonbiodegradable, persistent inorganic chemical constituents with an atomic mass greater than 20 and a density greater than 5 gcm3. They have cytotoxic, genotoxic, and mutagenic effects on people, animals, and plants. (S. J. S. Flora *et al* .2008; A. Cirlakova .2009; N. Rascio*et al*.2011; R. A. Wuana*et al* .2011).Fe, Mn, Zn, Cu, Mg, Mo, and Ni are important micronutrients for healthy plant growth. Cd, Sb, Cr, Pb, As, Co, Ag, Se, and Hg are non-essential elements with unidentified biological and physiological activities (N. Rascio*et al.*, 2011; A. Schutzendubel*et al.*, 2002; B. V. Tangahu*et al.*,2014).Six heavy metals were evaluated according to their potential ecological harm, and Cd was at the top, followed by Cu, Pb, Ni, Zn, and V. Zn, Pb, V, and Ni have a low potential ecological danger, whereas Cd and Cu have high and medium potential ecological risks, respectively.(Tang *et al.*, 2022).Plantsonunderground and aboveground surfaces can receive HMs (M. Patra *et al* 2004).The essential elements are critical components in the structure of enzymes and proteins. However, the concentration of both essential and non-essential metals is one particular important factor in the developing process of plants, thus their presence in excess can result in growth inhibition and decrease. Plants need them in trace levels for growth, metabolism, and development. (F. K. Zengin and O. Munzuroglu .,2005).Heavy metal toxicity is the term for substances that are naturally occurring in the earth's crust but have accumulated due to human activity. These substances can enter plant, animal, and human tissues through inhalation, diet, and manual handling. They can also bind to and impair the function of essential cellular components.. Heavy metals were major environmental pollutants, and their toxicity is becoming more of a concern for ecological, evolutionary, nutritional, and environmental reasons (Lenntech 2004).

2. Source of Contamination

Heavy metals in the environment can come from a variety of sources, including atmospheric sources, natural, agricultural, industrial, home wastewater, and other sources.Large portions of the world, including Japan, Indonesia, and China, have been polluted by heavy metals including Cd, Cu, and Zn by mining and smelting activities as well as agriculture. (Herawati*et al*., 2000).Both natural and human-made mechanisms result in the entry of heavy metals into the agro-ecosystem..According to several studies, compared to anthropogenic activity, natural sources of heavy metals in the environment are often negligible. (Dixit *et al*., 2015).Heavy metals are only naturally present in soil as a result of weathering since they are generated deep below the Earth's crust. Several factors contribute to excessive levels of heavy metals in soil, including atmospheric deposition, sewage irrigation, poor industrial solid waste storage, mining operations, and the use of pesticides and fertilisers. (Zhang *et al.,* 2011).Heavy metals are the fertilisers pollutants that are most frequently reported..Fertilizers with nitrogen and potash have modest amounts of heavy metals, but those with phosphoric fertiliser frequently contain large concentrations of harmful heavy metals.. The primary sources of heavy metals in compound fertilisers are master materials and production techniques. Here is a list of the heavy metals that are present in fertilisers: fertilisers made of phosphoric acid, compounds, potash, and nitrogen (Boyd, 2010).

3.Transport Pathways Of Heavy metals

3.1.Pathway from atmosphere towards the soil

The primary sources of heavy metals in the atmosphere are gases and dust created by the production of energy, transportation, metallurgy, and building materials..With the exception of mercury, most heavy metals enter the atmosphere as aerosols and settle and precipitate naturally, depositing in the soil. Take lead contamination as an illustration. (Lin, 1998)Central Sweden's downtown was claimed to have an urban industrial copper plant, a sulfuric acid plant, a paint factory, and a significant quantity of garbage from the mining and chemical sectorsHeavy metals from both point sources (such as thermal power plants and coal mines, as well as chlor-alkali chemical industries like goldmines, smelting, electroplating, textiles, and e-waste processing) and non-point sources (such as soil/sediment erosion, agricultural runoff, and open freight storage) can

seriously harm food crops..In addition to having an adverse effect on human health, heavy metals also have an adverse effect on soil biota through microbial processes and soil-microbe interactions. (Gadd, 2010; *Gall et al*., 2015; Rai, 2018a). Beneficial soil invertebrates, small and big animals, and beneficial soil insects have all suffered injury. (Gall *et al.,* 2015; Bartrons and Peuelas, 2017; Rai *et al.,* 2018).

3.2.Pathway from Sewage towards the soil.

Sewage sludge is one of the main causes of heavy metal pollution in the soil. (Ross, 1994)Farmersutilise wastewater for irrigation in an effort to transform it into a rich source of nutrients and reduce their reliance on fertiliser. (Lone *et al*.,2008).Continuous wastewater irrigation may cause soils to become too heavy with metals for crops to tolerate. (Rusan MJM *etal*.,2007)..Waste water harms soil and cannot be utilised in agricultural practises because of salt and sodicity problems, which harm plant seedlings. (Ansari and Malik .,2007).People who consume plants produced in tainted soils or irrigated with sewage from local municipalities may get diarrhoea, mental retardation, and liver and kidney damage. (Uzair *et al*.,2009).

3.3.Pathway from Solid wastes towards the soil.

The characteristics and quality of soil may suffer from an overabundance of trash discharged by industry, municipal agencies, homes, and agriculture. (Soffianian*et al*., 2014).These wastes degrade soil quality and have an impact on long-term development.Poor waste management and open disposal pose various risks to the health of city inhabitants, especially those who live close to disposal sites since garbage has the ability to contaminate water, food supplies, soil, air, and vegetables. (Hunachew and Sandip, 2011).One of the biggest problems that many nations throughout the world are currently experiencing is the correct disposal of solid wastes that contain heavy metals. This trash is hazardous to human health and the environment because it contains heavy metals. (Larios *et al.*, 2012; Wu *et al.,* 2018; Zhao *et al*., 2021).

3.4.Pathway from Agricultural supplies towards soil.

Mulch, insecticides, and fertilisers are crucial agricultural inputs for the development of crops. (Zhang and Zhang, 2007; Zhang *et al*., 2011).However, prolonged excessive application has led to

heavy metal pollution of the soil. With a few pure minerals or organic-inorganic compounds tossed in for good measure, pesticides are primarily composed of organic molecules.Some pesticides also contain heavy metals like mercury, arsenic, copper, zinc, and other heavy metals (Arao*et al.*, 2010).Several typical insecticides with a long history of usage in horticulture and agriculture had significant metal contentFor instance, nearly 10% of the substances recently licenced for use as fungicides and insecticides in the UK were based on substances containing Cu, Hg, Mn, Pb, or Zn. These insecticides include copper-containing fungicidal sprays like Bordeaux mixture (copper sulphate) and copper oxychloride. (L. H. P. Jones and S. C. Jarvis, 1981.)

4. Effects of heavy metals on plants

Within a limited range, low concentrations of soil heavy metals have little impact on plant development, whether they are useful or detrimental to plants. However, if the concentration is too high, the plant will get poisoned and may even die since the quantity of heavy metals it has enriched will be too much for it to handle.Heavy metals affect plants in the rhizosphere, which is where metalliferous minerals and chemicals interact with root exudates. (Cabala and Teper.,2007).The properties of Zn-Pb mining-related rhizosphere soil pollution and its detrimental effects on plant roots were looked into. Heavy metal exposure causes a range of physiological and metabolic alterations in plants. (Dubey, 2011; Villiers *et al.*, 2011).The most typical visible indicator of heavy metal poisoning is a reduction in plant development, including leaf chlorosis, necrosis, turgor loss, a drop in the rate of seed germination, and a compromised photosynthetic machinery. (Sharma and Dubey, 2007). This is frequently linked to developing senescence processes or plant death. (Dalcarso et al., 2010; Carrier *et al.*, 2003).These impacts are all connected to the molecular, biochemical, and ultrastructural alterations caused by heavy metals in plant tissues and cells. (Gamalero*et al.*, 2009).Because plants may store vital metals as well as non-essential elements, heavy metals in excess can be hazardous to them. (Djingova and Kuleff.,2000).It has been discovered that soil heavy metal concentrations and soil pH decrease in a linear manner, increasing the amount of heavy metals in crops and fruits. (Junhe*et al.*,2017 and Y. Yang *et al.*,2018)Heavy metals prevent some plant components or the entire plant from growing. (Shafiq and Iqbal 2005; Shanker *etal*. 2005).Direct contact with polluted soil causes quick and delicate alterations in the development pattern of plant roots. (Baker and Walker.,1989)Vegetables

grown in greenhouses are significantly more polluted with heavy metals than those grown outdoors, probably as a result of inadequate sunlight. (Li *et al.*, 2017).

4.1.Sources and Contamination of Heavy metals (Lead, Chromium) in plants.

4.1.1. LEAD

One of the most prevalent and pervasive hazardous minerals in soil is lead (Pb). The periodic table's group IV and period 6 metal, lead, has an atomic mass of 207.2, an atomic number of 82, a density of 11.4g/cm3, a melting point of 327.4^{o}C(Wuana and Okieimen.,2011).

Sources

It can originate from a number of places, such as paint, mining, and vehicle exhaust. The primary causes of Pb pollution include gasoline, industrial chimneys, storage battery effluents, industrial mining and smelting of Pb ores, metal plating and finishing processes, fertiliser pesticides, and additives in pigments. (Eick*et al*.,1999).

Effect

Pb poisoning symptoms are comparable to those of other heavy metals, including growth suppression, chlorosis, and (in the most extreme instances) death. In maize, Pb disturbs the microtubule network in the root meristem, causing a shorter branching zone and more compact lateral roots to emerge closer to the root tips(Eun*et al*.,2000).High Pb levels lead to a water deficit, which slows transpiration and alters the osmotic pressure of the cell sap and the water potential of the xylem. These results lead to a change in the plant's water status that is detrimental. (Parys *et al*. 1998).Lead is known to inhibit the germination of Spartiana alterniflora and Pinus helipensis seeds. (Morzck and Funicclli.,1982).Lead inhibited early seedling growth in soya bean, rice (Huang *et al.*,1974),barley, tomato, and some legumes (Sudhakar *et al.*,1992).Pb is a protoplasmic poison that has a cumulative, slow-acting, and subtle effect. Pb-contaminated soils drastically lower agricultural production, creating significant issues for agriculture. (Johnsons and Ealton,1980).SThe majority of the risk, even at soil levels exceeding 300 ppm, comes from lead-contaminated soil or dust deposits on plants, not from the plants absorbing lead. (Rosen *et al.*,

2002). The effects of Pb toxicity on plants can be seen in the reduction of nutrient uptake and the deactivation of cell memberene permeability (Ashraf *etal.*,2015).Plants that have accumulated Pb have physiological problems such DNA damage and the deterioration of their root and shoot systems. (Gichner*et al*. 2008), as well as affecting enzymatic activity (Reddy *et al.*,2005).

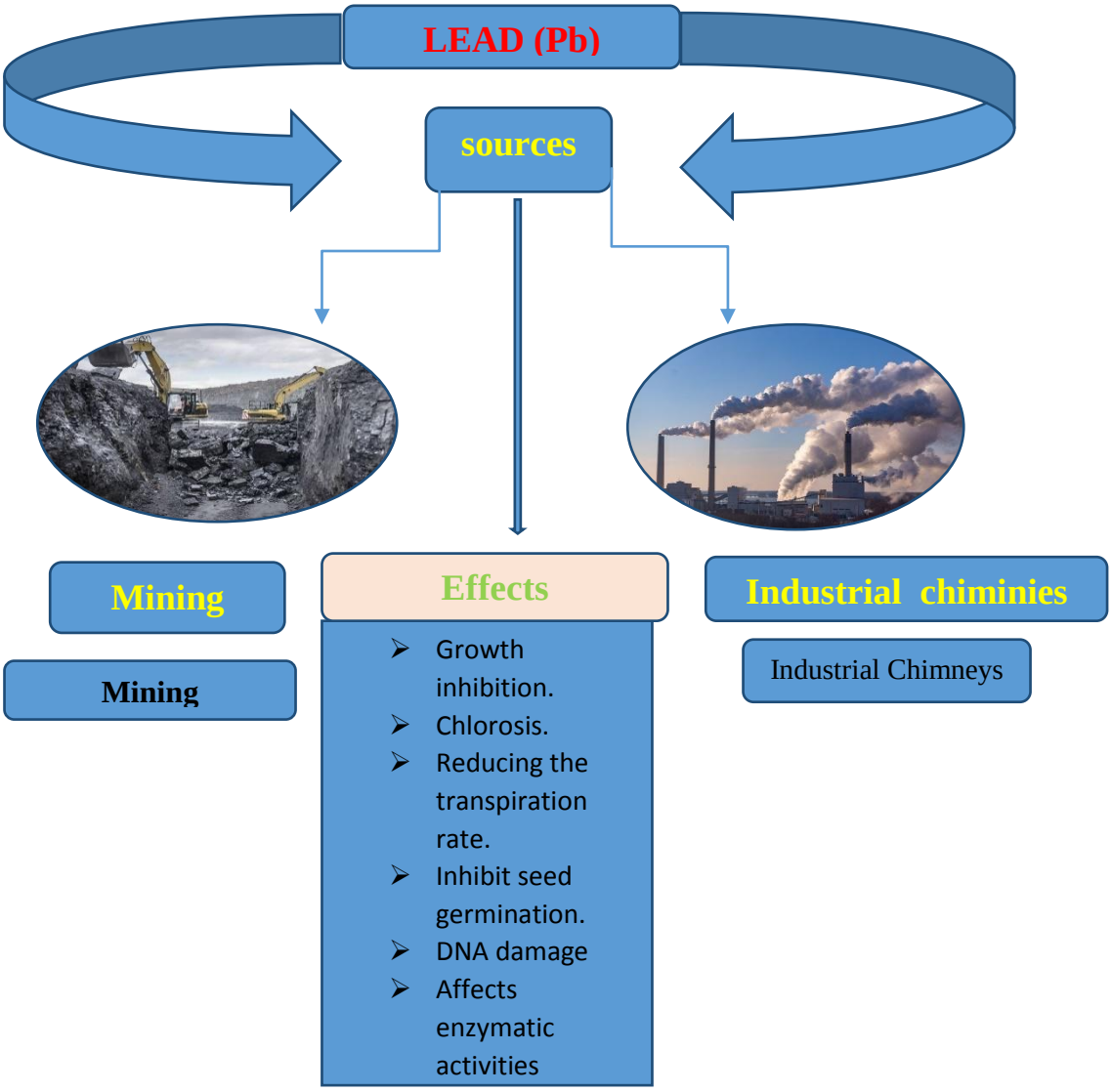

Figure 1. Different sources and effects of lead (Pb).

4.1.2. Chromium

Cr is a group 1 carcinogen element according to the International Agency for Research on Cancer (IARC), and it is prevalent in industrial and contaminated areas. (Wang *et al.*, 2017).It is a

transition element that is a member of group VI-B of the periodic table, having a ground-state electronic structure of Ar 3d5 4s1. The most stable forms of Cr are trivalent Cr(III) and hexavalent Cr(VI), however there are a few more valence levels that are unstable and transient in living things. The most poisonous form of Cr is Cr(VI), which is formed as the oxyanions chromate (CrO4 2) or dichromate (Cr2O7 2) in the presence of oxygen. Most commonly found attached to organic materials in soil and aquatic habitats, Cr(III) is less poisonous and less mobile. (Becquer*et al*., 2003).

Source

The production of speciality chemicals and cleaning agents like chromic acid, electroplating, wood preservation, leather processing and finishing, refractory steel manufacturing, and leather finishing all contribute to Cr pollution. The production of speciality chemicals and cleaning agents like chromic acid, electroplating, wood preservation, leather processing and finishing, refractory steel manufacturing, and leather finishing all contribute to Cr pollution.

Effect

Inhibition of enzyme activity, mutagenesis, lower yield, impacts on leaf and root development, and other manifestations of Cr toxicity in plants are only a few.Crop production is decreased by Cr toxicity, which also stunts the growth of shoots, decreases the number of leaves and their area and biomass, burns the leaf edges and tips, and produces chlorosis and necrosis in adult plants. (Sharma and Sharma 1993; Singh 2001; Jain *et al.* 2000).The quantity of root hairs and the fraction of pith and cortical tissue layers in the root increase as a result of Cr stress, which also changes the morphology of the roots. (Suseela*et al.* 2002).Plant roots cannot divide and extend due to chromium toxicity, resulting in a reduction in the length of the roots overall. (Shanker *et al.*, 2005).Cr treatment makes more Protease activity, which might be a factor in a seed's inability to germinate (Zeid, 2001).As a result of disrupting redox homeostasis and signalling, damaging membrane lipids, DNA, proteins, and enzymes, and affecting enzymatic activities related to starch synthesis and N metabolism, Cr toxicity affects plant physiological and biochemical processes such as photosynthesis, transpiration, pigment biosynthesis, root growth, and nutrient uptake. It also affects seed germination, flowering, fruit setting, crop yield loss, and deterioration of food

quality. (Del Bubba *et al*., 2013; Stambulska et al., 2018; Sharma *et al.*, 2020; Christou *et al*., 2021; Christou *et al*., 2021).All of these toxic effects of Cr may be due to an excess of reactive oxygen species (ROS), which disrupts the redox balance in plants.(Anjum *et al*.,2017).When plants of the Catharanthus roseus species were exposed to Cr, the foliar concentration of the chlorophyll pigments total chlorophyll, chlorophyll a (Chl a), and chlorophyll b (Chl b) was examined.(Rai *et al.*,2014).In terms of CO2 fixation, electron transport, photophosphorylation, and enzyme activity, chromium stress is one of the significant components that influence photosynthesis. (Clijsters and Van Assche, 1985)

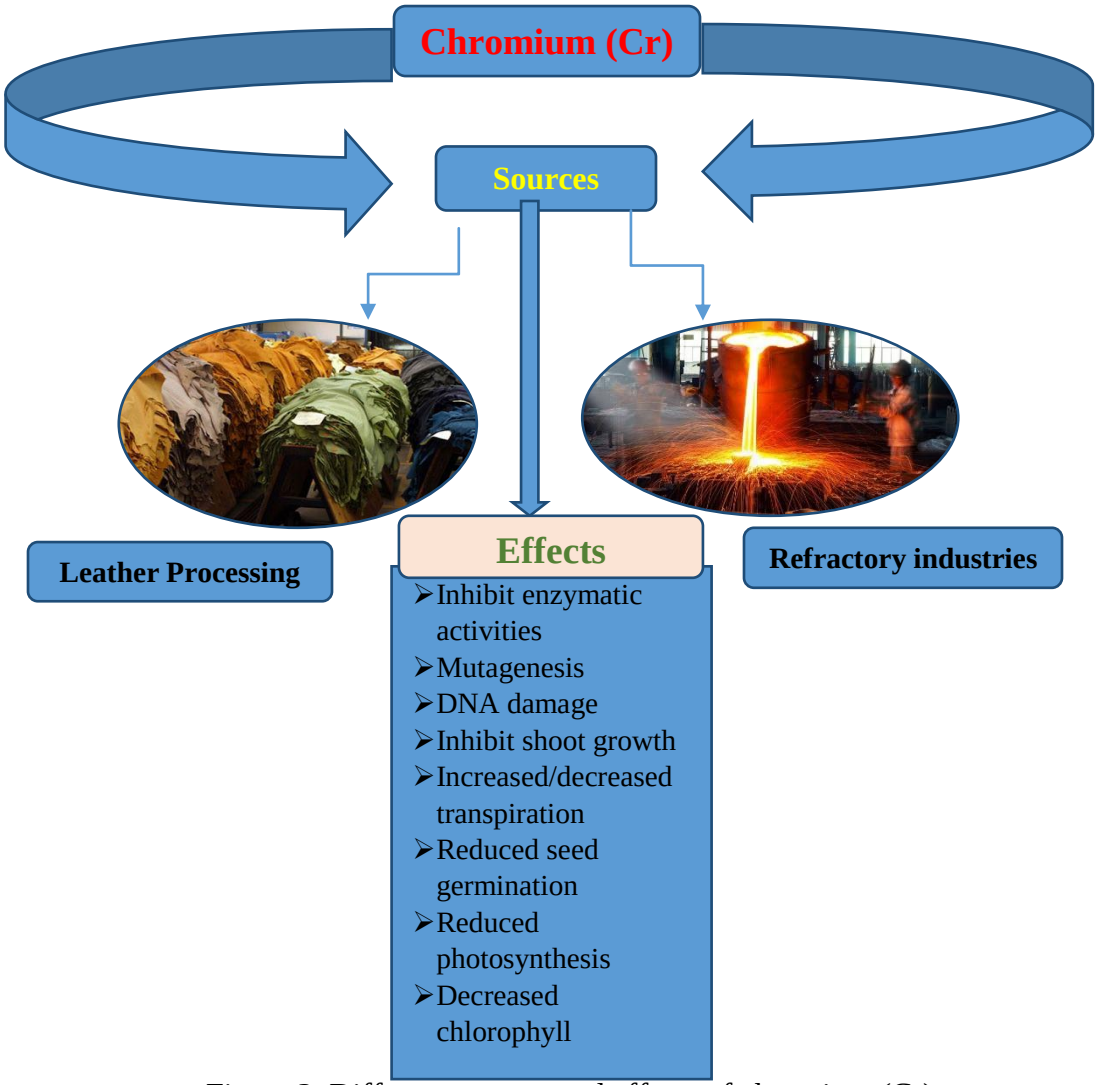

Figure 2. Different sources and effects of chromium (Cr).

Conclusion:

The review illustrates an overview of the negative impacts of heavy metals on plant growth and development. Heavy metals are transported and widely distributed in the environment through various anthropogenic activities. Plants uptake heavy metals which causes a number of toxic effects, such as necrosis, chlorosis, decrease in the rate of seed germination. Lead one of the toxic metal disrupts the root meristems. Lead slows down the rate of transpiration and also inhibits growth. Lead accumulation in plants causes DNA damage, destruction of root and shoot systems, and affects enzymatic activities. Chromium a Carcinogenic element also targets plant growth and development. Chromium toxicity inhibits shoot growth, affects physiological and biochemical processes in plants such as photosynthesis, transpiration, pigment biosynthesis, root growth and nutrient uptake, damages in membrane lipids, DNA, Proteins and enzymes. This review provides one of the most comprehensive literature reviews. Therefore, it is essential to understand strategies by which heavy metals can be reduced and their detrimental effects on the environment, especially on plants.

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