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The Devastating Impact of Heavy Metal Contamination on Plant Growth and Development: Unveiling Phytotoxicity and Exploring Remediation Strategies

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Abstract

Heavy metal contamination poses a significant threat to plant growth and development, leading to reduced crop yields, impaired ecosystem functioning, and potential human health risks. This review provides a comprehensive overview of the phytotoxic effects of heavy metals on plant species, highlighting the mechanisms of uptake, transport, and accumulation. We explore the devastating impacts on plant morphology, physiology, and biochemistry, including altered root architecture, reduced photosynthesis, and impaired reproductive development. This review highlights the urgent need for effective remediation approaches to mitigate the phytotoxic effects of heavy metals and ensure sustainable ecosystem functioning. We identify knowledge gaps and future research directions, emphasizing the importance of interdisciplinary collaboration to address this critical environmental issue.

Keywords: Heavy Metal, Phytotoxicity, Phytoextraction, Phytostabilization, Phytoextraction

Introduction

The majority of metals that are classified as heavy have high densities, atomic weights, or atomic numbers. Heavy metals are classified according to densities in metallurgy, atomic numbers in physics, and chemical behavior in chemistry. According to Lewis's acid (electron pair acceptor) performance of the ions in aqueous solutions, heavy metals are described in biochemistry.

Earth naturally contains heavy metals. Human-caused activities concentrate them, and they can enter the tissues of plants, animals, and even humans through ingestion, food, and manual handling. Then, they have the ability to attach themselves to essential cellular components and prevent them from working properly.

Some of the earliest known metals are iron (Fe), copper (Cu), tin (Sn), and other elements metals like silver (Ag), gold (Au), and platinum. Other heavy metals are also necessary nutrients like iron, cobalt, and zinc, and some relatively less hazardous like ruthenium, silver, and indium, but they can be toxic in larger amounts or in their specific form. Then, some of the specific heavy metals like cadmium, mercury, and lead are extremely toxic.

Heavy metal contamination refers to the presence of high levels of heavy metals in the environment, including soil, water (rivers), air (atmosphere), and other places. Each heavy metal has a unique composition, physical characteristics, and chemical structure. Heavy metals are undoubtedly hazardous and toxic, and handling them is necessary. Some heavy metals are highly reactive, while others are less reactive; these are considered to be toxic or highly destructive to the environment, degrading the quality of air, water, and soil and causing health problems for people, animals, and plants. Some toxic elements are also considered beneficial, but only in small amounts for human health. Examples of these elements are vanadium, manganese, cupper, iron, zinc, strontium, molybdenum, and so on. It is detrimental and could make one more vulnerable to heavy metal toxicity if certain metals are lacking. The human body is dangerously affected by the chronic absorption of toxic or heavy metals and the effects do not become apparent for several years after exposure.

Importance of Plants in the Ecosystem

According to Kramer et al. (2019), plants are the foundation of ecosystems because they produce oxygen through photosynthesis, which is essential for life on Earth. controlling water cycles to avoid droughts and floods. sustaining both herbivores and predators by acting as main producers (Lindeman, 1942). supplying different species with a home, a habitat, and breeding grounds (Gibson *et al.*, 2011). Maintaining ecosystem fertility through cycling nutrients, acting as suppliers of food, medicine, and other necessities.

Sources of Heavy Metals contamination

The main sources of heavy metal contamination were mining activities that caused heavy metals to runoff into surrounding rivers and lakes and industrial discharges that frequently released heavy metals like arsenic, cadmium, mercury, and lead into water bodies through waste effluents. Agricultural runoff that carried metals from metropolitan areas, such as those from vehicle emissions and construction activities, pesticides and fertilizers used in agriculture into water bodies, Contamination may result from batteries, electronic garbage, and other products containing heavy metals being disposed of improperly. Even at low quantities, aquatic creatures are harmful to heavy metals. They have a variety of negative impacts, such as mortality, poor reproductive outcomes, and aberrant development. Over time, they build up in aquatic species' tissues, which causes larger concentrations in predators—including humans—through the foodchain (Abubakar, M. Y.,*et al.,* 2024). Both natural and human activities have the potential to accumulate heavy metals in the bios phere (Fig. 1). Although the primary natural source of heavy metal pollution in the environ ment is the weathering of rocks, anthropogenic sources include mining, smelting, and agric ultural practices (Herawati *et al.,* 2000).

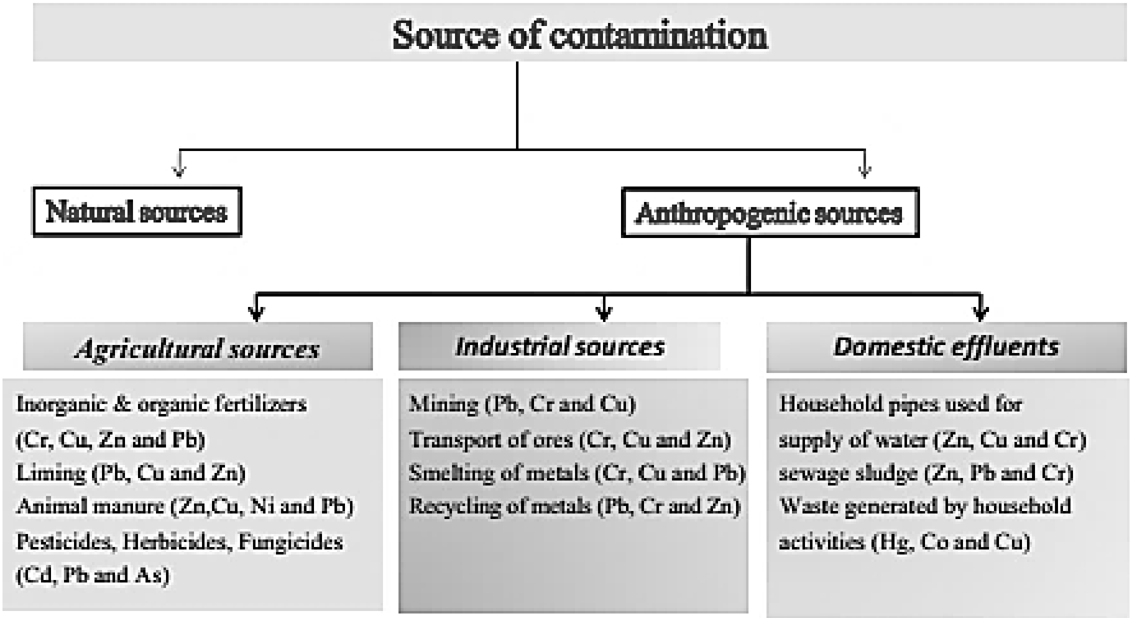

Fig. 1 Natural and anthropogenic sources of heavy metals and their composition (D. Goyal · A. Yadav *et al.,* 2020)

Heavy Metal Contamination Natural Sources Rocks Weathering

The "lithogenic" component is made up of heavy metals extracted from geological sources. The concentration and makeup of heavy metals that occur in soil are dependent on the typ e of parent rock. Mn,Co, Ni, Fe,Crand Zn are the principal heavy metal contaminants that parent rock helps to carry. Significant amounts of heavy elements are produced by weatheri ng of volcanic rocks, such as hornblende, olivine, and augite; sedimentary rocks only contri bute a minor portion of these elements (Nagajyoti et al. 2010).

Additional Natural Sources

In addition to rocks, other naturally occurring sources of heavy metals include volcanoes, wind-blown dusts and storms, natural forests, sea sprays, and aerosols (in coastal locations) (Seaward and Richardson 1990). Significant air hazardous wastes and contaminants have been brought to light by geothermal sources and volcanic eruptions (Eshleman et al. 1971).

Anthropogenic Sources

Agricultural Sources

Varying concentrations of Ni,
Cr, Zn, Cd, Pb, and other heavy metals can be found in manure, limes, insecticides, inorganic and organic fertilizers, and other agricultural products (Nriagu 1989; Yanqun et al. 2005). Similarly, Cu, Mn, Hg, Pb, or Zn are present in the majority of widely used chemical pesticides, such as lead arsenate and Bordeaux mixture. A common source of heavy metals in soi, aside from these, is the irrigation of municipal and industrial effluent.

Industrial Sources

Vanadium (V), Titanium (Ti), and Mn are mostly obtained from activities related to oil and coal, whereas Cr and Ni are primarily produced by industrial operations such as mining, smelting, and metal processing (Guan et al. 2018). While gold mining raises the amount of mercury in the environment, coal mining also releases significant amounts of As, Cd, and Fe. Typically, heavy metals are produced as vapor and particle forms, which combine with atmospheric water to form aerosols. Aerosols contaminate soil and water bodies when they are dispersed by the wind (dry deposition) or deposited during rainfall (wet deposition) (Nagajyoti et al. 2010). Additionally, nuclear power plants and the burning of coal and petroleum produce heavy metals includingSe, Cd, B, Cu, Cs, Zn, and Ni to the atmosphere. Heavy metal toxicity to the environment is also caused by the production of plastics, microelectronics, wood preservation, textiles, and paper (Tchounwou et al. 2012).

Domestic Effluents

The primary cause of heavy metal pollution in aquatic bodies is domestic wastewater. Waste materials are sent through sewage outfalls and untreated wastewater materials may be included in domestic effluents that are filtered through biological treatment plants. According to Angina et al. (1970), the majority of commonly used enzymatic detergents have trace levels of elements including Fe, Mn, Co, Zn, Sr, Cr, and B. This leads to heavy metal contamination.

Impacts of Heavy Metal Toxicity on Plants

Since plants are the base of the ecological pyramid and are primary producers, heavy metals that enter their bodies pass through the trophic levels of the food chain one after another. The issue is compounded by heavy metals that are bioaccumulative, meaning that plants cannot readily metabolize them or break them down in the environment. Indeed, many plant species that are tolerant of heavy metals, such as B. napus and B. Juncea, possess an innate capacity to collect heavy metals within their bodies, which poses a risk to the contamination of food webs. (Mourato et al. 2015; Gall *et al.,* 2015.)

Heavy Metals Functioned as Micronutrients

Certain heavy metals, including as Mn, Fe, Co, the mo, Ni, and Zn, serve as micronutrients that are necessary for significant physiological processes in plants in modest amounts (less than 1 pound per acre) (Misra and Mani 1991). Table 1 lists the necessary concentrations of these heavy metals together with their functions in plant development. In the same way that deficiency symptoms arise from a lack of these minerals, high amounts of these nutrients in soil also have hazardous effects.

Table 1 Range and functional roles of a few environmentally important heavy metals in plants (D. Goyal • A. Yadav *et al.,* 2020)

Elements	Land plants (µg/g dry wt)	Role in plants
Mn	15-100	Required for photosynthesis during splitting of water, cofactor of malic dehydrogenase, oxalosuccinic dehydrogenase
Fe	140	Component of hemoglobin, myoglobin, and cytochromes
Co	0.05-0.5	Found in the form of vitamin B_{12}
Ni	1	Fixes nitrogen in legumes, main component of urease enzyme
Cu	4.15	Required for photosynthesis, acts as cofactor of superoxide dismutase, ascorbate oxidase
Zn	8-100	Main player of replication and transcription, cofactor of carbonic anhydrase, alcohol dehydrogenase

Non-Vital Heavy Metals for Plant Growth

Other heavy metals like lead, arsenic, manganese, and cadmium are highly deleterious to plants. Table 2 shows a comparative toxicity effect of different heavy metals on plants, which varies with different species.

Table 2 The range of metal toxicity in several plant species (D. Goyal • A. Yadav *et al.,* 2020)

Plant species	Range of metal toxicity
Hordeum vulgare	Hg > Pb > Cu > Cd > Cr > Ni > Zn
Lolium perenne	Cu > Ni > Mn > Pb > Cd > Zn > Al > Hg > Cr > Fe
Phaseolus sp	Hg^2 ≈ Cr
Triticum aestivum	Cu > Cr > Ni > Zn > Pb ≈ Cd > Al > Fe
Vicia faba	Cd > Ni > Zn ≈ Co
Zea mays	Cu ≈ Tl > Ag > Cd > Hg > Co > Zn > Pb or Tl3+ > Cu2+ > Ag+ > Hg2+ ≈ Cd2+ > Ni2+ > Zn2+ ≈ Pb2+ ≈ Co2+ > Sr2+

Phytotoxicity of heavy metals

Phytotoxicity refers to the harmful or toxic effects of substances, such as heavy metals, pollutants, or other chemicals, on plants. These substances can damage or kill plants, impair their growth, or alter their physiology and biochemistry. Phytotoxicity can manifest in various ways, including**:** Morphological changes (e.g., stunted growth, leaf curling)**,** Physiological disruptions (e.g., impaired photosynthesis, water relations)**,** Biochemical alterations (e.g., enzyme inhibition, pigment degradation)**,** Growth inhibition or reduction**,** Cell death or necrosis.

Specific Heavy Metals and Their Distinct Effects on Plants.

- *Lead:* inhibits root growth, alters cell wall composition
- *Mercury:* disrupts photosynthesis, causes oxidative stress
- *Arsenic:* reduces root growth, alters nutrient uptake
- *Cadmium:* impairs photosynthesis, causes oxidative stress

These effects can vary depending on factors like metal concentration, plant species, and growth conditions.

Mechanisms of Heavy Metal uptake and transport in plants

Heavy metal uptake and transport in plants involves several mechanisms, including:

- *Root uptake:* Heavy metals are absorbed by plant roots through various transporters and channels (Kramer *et al.,* 2019).
- *Xylem transport:* Heavy metals are transported upward through the xylem, driven by transpiration stream (Lux *et al.,* 2011).
- *Vacuolar sequestration:* Heavy metals are stored in vacuoles, reducing their toxicity (Verbruggen *et al.,* 2009).
- *Chelation:* Heavy metals are bound to organic ligands, enhancing their mobility and tolerance (Cohen *et al.,* 2017).
- *Antioxidant defense:* Plants activate antioxidant systems to counteract heavy metal-induced oxidative stress (Anjum *et al.,* 2015).

Morphology: Reduced root growth and biomass, stunted stem and leaf growth, altered leaf morphology and anatomy, reduced fruit and flower production

Physiology: Disrupted water relations and transpiration**,** impaired photosynthesis and respiration**,** altered nutrient uptake and transport**,** increased oxidative stress and antioxidant defenses

Biochemistry: Changes in protein expression and activity**,** disrupted enzyme activity and metabolism**,** altered pigment composition and chlorophyll content**,** increased production of stress-related hormones and signaling molecules

Effects of Heavy Metals on Plants Growth and Development.

Plants uptake heavy metals from the soil mainly through their roots. The uptake process is facilitated by some transport proteins, chelating agents produced in the rhizosphere, and plant-induced pH changes (Heavy metal accumulation in soil has been rapidly increased due to various natural processes and anthropogenic (industrial) activities. As heavy metals are non-biodegradable, they persist in the environment, have potential to enter the food chain through crop plants, and eventually may accumulate in the human body through biomagnification. Owing to their toxic nature, heavy metal contamination has posed a serious threat to human health and the ecosystem. Therefore, remediation of land contamination is of paramount importance. Phytoremediation, phytoextraction and Phyto stabilization, soil amendment and fertilizer, microbial assisted remediation and genetic engineering or biotechnology are some of the eco-friendly approach that could be a successful mitigation measure to revegetate heavy metal-polluted soil in a cost-effective way. A better understanding of the mechanisms underlying heavy metal accumulation and tolerance in plant is indispensable. In this review,We focus on the strategies applied to improve the efficiency of Phyto stabilization and phytoextraction, including the application of genetic engineering, microbe-assisted and chelate-assisted approach. Heavy metals are also absorbed directly through the leaves because of particles accumulated on the foliar surfaces of leaves.Heavy metals basically cause formation of reactive oxygen species (ROS) and free radicals that lead to uncontrolled oxidation and radical chain reactions, ulti-mately damaging the cellular biomolecules like nucleic acids, lipids, and proteins (Phaniendra *et al.,* 2015). Plants, being primary producers, form the base of ecological pyramid; thus, the heavy metals entering the plant body make their way through successive trophic levels of the food chain. This problem gets exacerbated for the heavy metals that are bio accumulative, that is, they are neither degraded in the environment nor easily metabolized by plants. In fact, some of the heavy metal tolerant plant species like B. napus, B. Juncea have intrinsic ability to accumulate heavy metals in their body, thereby, threatening the contamination of food webs (Gall *et al.* 2015; Mourato *et al.* 2015). Some examples Heavy Metals that Function as Micronutrients are Cu, Fe, Mn, Mo, and Zn, function as micronutrients; that is, these are required in small quantities (less than 1 pound per acre) for important physiological functions of plants (Misra and Mani 1991). The optimum concentration of these heavy metals and their role(s) in plant development have been mentioned, Just as lack of these nutrients results in deficiency symptoms, their elevated levels in soil also lead to toxicity effects, while elements like As, Cd, Pb, Cr, Mn, Zn, Co, Sr, and B, thereby contributing toward heavy metal pollution.Heavy metals are also absorbed directly through the leaves because of particles accumulated on the foliar surfaces of leaves.Heavy metals basically cause formation of reactive oxygen species (ROS) and free radicals that lead to uncontrolled oxidation and radical chain reactions, ulti-mately damaging the cellular biomolecules like nucleic acids, lipids, and proteins (Phaniendra et al,. 2015). Plants, being primary producers, form the base of ecological pyramid; thus, the heavy metals entering the plant body make their way through successive trophic levels of the food chain. This problem gets exacerbated for the heavy metals that are bioaccumulative, that is, they are neither degraded in the environment nor easily metabolized by plants. In fact, some of the heavy metaltolerant plant species like B. napus, B. Juncea have intrinsic ability to accumulate heavy metals in their body, thereby, threatening the contamination of food webs (Gall *et-al.,* 2015; Mourato *et al.,* 2015).

Zinc

Zinc (Zn) is an essential micronutrient for many metabolic processes of plants. However, beyond its optimum range (15–60ppm), it adversely affects roots, shoots, seed germination, and flowering responses in French marigold (Choi *etal.*, 1996). Elevated levels of Zn in soil cause decline in the level of chlorophyll pigments leading to chlorosis in younger leaves. Zn toxicity promotes senescence and causes reduction in plant biomass (Mirshekali *et-al.,* 2012). Moreover, it also acts as genotoxic pollutant by causing structural and numerical aberrations in chromosome of plants, thus affecting cell division (Sharma and Talukdar 1987).

Arsenic

Arsenate (Ar) is an analog of phosphate and a toxic metalloid. It is widely distributed in the environment due to various natural and anthropogenic activities such as mining and fossil fuel combustion (Bhattacharyya *etal.,* 2003). High concentration of As causes detrimental effects on plant growth by causing cell necrosis, chlorosis, and electrolyte leakage from cell membranes (Singh *etal*,. 2006). The toxicity of as also leads to formation of ROS that can damage nucleic acids, proteins, and cause peroxidation of lipids present in membrane (Moller *et al.*, 2007). Chinese brake fern (Pterisvitatta) was found to be the worst hyperaccumulator of this heavy metal, and today, this species is currently being used as a potent as tolerant and the potential of tolerance is up to 1500 ppm in soil (Shen*etal.,* 2014).

Cadmium

Cadmium (Cd), like Hg, Co, Pb, and As, is a nonessential element for plants. The impacts of Cd toxicity can be seen on the activity of enzymes involved in photosynthesis and nitrogen metabolism (Alcantara *etal*,. 1994). Cd also adversely affects stomatal opening, mineral uptake, and water balance in plants. Cd accumulation reduces ATPase activity of plasma membrane and alters membrane permeability and metal ion homeostasis. High Cd levels have been reported to reduce the level of osmoprotectants, mainly proline, and alter the genetic stability in Solanumnigrum. Plant Defense Mechanisms Adopted by Plants Against Heavy Metal StressAs mentioned earlier, heavy metals interact with biomolecules likewise nuclear proteins and DNA and cause production of ROS. This causes morphological, metabolic, and physiological abnormalities in plants (Manara 2012)

Potential Remediation Strategies

Remediation of Heavy Metals Heavy metal toxicity imposed on plants is the most challenging problem in most countries. Removal of heavy metals from a contaminated site is known as remediation (Khan *et al.,* 2000). Some of the conventional methods for remediation include dredging (physical removal of the contaminated sediment layers), capping (covering the contaminated sediment surface with clean material, thus isolating the sediments), and incineration (waste treatment technology that involves the combustion of organic substances contained in waste materials) (Azubuike*et al.,* 2016).Bioremediation, that is, the use of living organisms (mainly microbes) for the removal of pollutants from contaminated site, has gained immense popularity in recent years . Some microbes are unique in producing enzymes that degrade organic contaminants into nontoxic compounds. The remediation techniques of heavy metals could be classified into four major types depending upon the type of microorganism used: cyanoremediation, bioremediation, mycoremediation, and phytoremediation; these remediation strategies have been discussed below.

Cyanoremediation

Cyanoremediationis the use of algae for the removal of organic and inorganic pollutants from the contaminated site. Some algae such as Chlorella, Spirulina, Spirogyra, Oedogonium have been used for phycoremediation purposes. Deng *et al.* (2007) reported the use of Cladophorafascicularis as an effective material, which absorbs Pb (II). In another study, observed the biosorption capacity of Cladophora and Spirogyra, for copper ($Cu2+$) and lead ($Pb2+$), respectively. In recent years, the focus on algae for remediation has increased due to their wide occurrence, central role in carbon dioxide fixation, and potential source of biofuel (Chekroun*etal.,* 2013).

Bioremediation

In bioremediation living organisms are used to degrade environmental contami-nants into less toxic forms. In bioremediation, microbes enzymatically attack the pollutants and convert them to harmless products. Some of the widely used microorganisms in bioremediation are Pseudomonas putida, Dechloromonasaromatica, Deinococcusradiodurans, Methylibiumpetroleiphilum, and Alcanivoraxborkumensis (Mani and Kumar 2014). Apart from being a cost-effective process, bioremediation involves minimal site disruption, and the possibility of simultaneous treatments. Although this approach is commonly used.

Microbial–assisted remediation

MycoremediationBesides the use of bacteria, fungal species such as Aspergillusniger, Aureobasidiumpullulans, Ganodermalucidum, and Cladosporiumresinae are found to be capable of mycoremediation (Mani and Kumar 2014). Fungi secrete more potent enzymes even in nutrient-decient conditions, which act on a broad category of natural chemicals. Remediation through fungus may proceed faster than bacterial degrada-tion because of their large lament surface area. Some fungal species are reported to metabolize hydrocarbons and hence, used in mycoremediation of oil-polluted regions. These are many fungi being used for mycoremediation purpose such as Acremonium, Aspergillus, Aureobasidium, Candida, Cephalosporium, Cladosporium, Cunninghamella, Fusarium, Geotrichum, Gliocladium, Graphium, Hansenula, and Mortierella. Some fungi, such as Trichoderma, act as biocontrol agents as well as remediate agricultural waste. Lentinusedodes, the gourmet mush-room, has the potential of remediating more than 60% of pentachlorophenol from soil. Such a potent fungus is being used as a boon in oil industries and refineries. Phanerochaetechrysosporium and other white rot fungi degrade some xenobiotics like DDT and lindane (Kirk *et-al.,* 1992). Mycoremediation is a very efficient method of remediation that produces fewer toxic chemicals as by-products.

Phytoextraction

It is the best approach to remove contamination primarily from soil and isolate it, without destroying the soil structure and fertility. It is also referred as phytoacumulation. As the plant absorb, concentrate and precipitate toxic metals and radionuclide from contaminated soils into the biomass, it is best suited for the remediation and superficially several approaches have been used but the two basic strategies of phyto-extraction, which have finally develop are (Rulkens *et al.,* 1998) Chelate assisted phyto-extraction or induced phytoextraction, in which artificial chelates are added to increase the mobility and uptake of metal contaminant and Continuous phyto-extraction in this the removal of metals depends on the natural ability of the plant to remediate The removed heavy metal can be recycled form the contaminated plant biomass. Factors such as growth rate, elements selectivity, resistance to disease, method of harvesting, are also important, Baker *et al.,* 1994). However, slow growth, shallow root system, small biomass production, final disposal limit the use of hyperaccumulator species.

Phytostabilization: it is mostly used for the remediation of soil, sediment and sludges and depends on roots stability to limit contaminant mobility and bioavailability in the soil phytostabilisationan occur through the sorption, perception, complexation or metal valence reduction. The plants primary purpose is to decrease the amount of water percolating through the soil matrix which may result in the formation of hazardous leachate and prevent soil erosion and distribution of the toxic metal to other areas. A dense root system stabilizes the soil and prevent erosion Berti W.R and Cuningham S.D 2000) it is very effective when rapid immobilization is needed to preserve ground and surface water and disposal of biomass is not required. However, major disadvantage is that, the contaminant remains in soil as it is and therefore requires regular monitoring.

Genetic Engineering and biotechnology

To breed plants having superior phytoremediation potential with high biomass production can be an alternative to improve phytoremediation. General plant productivity is controlled by many genes and difficult to promote by single gene insertion. Genetic engineering techniques to implant more efficient accumulator gene into other plant have been suggested by (Chaney *et al.,* 2000). Implementing more efficient accumulator genes into other plants that are taller than natural plant increases the final biomass. Zhu *et al.,* 1999 genetically engineered Brassica Juncea to investigate rate limiting factors for glutathione and phytochelatin production; they introduced the Escherichia coli-gshl-gene. The transgenic seedlings showed increased tolerance to cadmium and had higher concentration of phytochelatins, glutathione and total non proteinthiols compared to wild type seedlings. The potential of success of genetic engineering can be limited because of anatomical constraints.

Soil Amendments and Fertilizer

The commonly used amendments are natural organic materials e.g compost, sewage sludge, biochar, humic substance and plants extracts. Many amendments can immobilize heavy metals through precipitations, complexation, ion exchange and adsorption, but they have different specific characteristics and dominant remediation mechanisms (Wiszniewska*et al* 2016, when amendments are used in the remediation of contaminated agricultural fields, their effects or crop growth and heavy metal accumulation are taken into account. Hydroxyl group enhances soil PH diminishing the solubility of heavy metal and forming chelate or precipitate substances to change heavy metals bioavailability ,reduce phytotoxicity. fertilizer can improve soil quality and enhance crop production. Organic fertilizer have advantages such as low cost and abundant sources. Manure can also reduce heavy metal toxicity through complexation and adsorption (Jiang *et al.,* 2017). Functional group such as carboxyl group and hydroxyl groups, which combine with heavy metals to form organic metal complexes, altering the migration and availability of heavy metals (Tang *et al.,* 2013).Cattle manure generally decrease Pb and Cal concentrations in tobacco plant tissues but increases the total uptake of Pb and Cd due to the greater plant biomass.

Effects of Heavy Metal on Plant Growth and Development

Root growth and architecture:- heavy metals are non-biodegradable and can accumulate in the body, they can accumulate in the soil for a long period of time, the source of heavy metals such as fe, cu, Co, zn, As, Ni and Hg can be from sewage disposal at industrial waste (Ashaf*et al.,* 2017). Some of these heavy metals are important for plant growth and development in small quantity they are considered as micronutrients, however many can have serious effect and may affects the metabolism, senescence, physiology and growth.

Many of heavy metals are accumulated in the root cells of plants because cell walls may trap them, accumulation of heavy metals in plant tissues may directly or indirectly impairs several morphological biochemical and physiological functions. Heavy metal such as Cd, Pb, Hg can translocate from the soil to all the plant parts they can inhibit roots growth and development, cause roots tip browning (Li *et al.,* 2021), it can also reduce transpiration rate, chlorophyll, increase in Co_2 content. According to sidhu *et al.,* (2017) increasing levels of Pb caused a gradual decline in the activities of all hydrolytic enzymes (α-, β-anylase and protease) in both roots shoot. Heavy metal toxicity have provoked excessive production of reactive oxygen species (ROS) that damages different cellular components such as nucleic acids, proteins, membrane, lips, causing perturbation of many physiological, biochemical and molecular processes in plants.

Stem and Leaf development

Stem and leaf development is reduced by heavy metals through induction of harmful effects to different physiological functions in plants. Heavy metals such as Cd, Mn, o causes leaf chlorosis, nutritional imbalance, inhibits roots and shoots growth and biomass, induce root tips browning, disrupted respiration and hampered nucleic acid synthesis. Heavy metal like Cd reduced root length, leaf length and area (Waheead*et al.,* 2021). The presence of heavy metal can interrupt important metabolic processes that leads to leaf necrosis and ultimately hampers the growth. A comprehensive microscopic analysis on soy bean leaf exposed to different Pb levels was studied by (Alamri*et al.,* 2018). He observed a reduction in cotyledons and leaf blades. Heavy metals exicity induces leaf epidermal alterations such as reduced guard cell size, increased wax coating, number of stomata and trichrome per unit area, reduced leaf blade thickness, xylem and phloem area.

Photosynthesis and pigment content

Anthropogenic activities causes soil contamination with different heavy metals which is a growing ecological concern. Heavy metal such as Cd, Pb, Hg are known to be highly toxic and have becomes significant pollutant in the environment. Plants can translocate heavy metal to the aerial parts such as stem, leaves, flowers, and fruits and can cause phototoxic symptoms such as reduction in photosynthesis and chlorophyll biosynthesis (GUO *et al* 2017). The loss of chlorophyll pigment is one of the most extensively reported manifestations of heavy metal toxicity in plants, it has been reported that Cd stead can alter the process of chlorophyll synthesis via interacting with the thiol groups of denzymes 5-Aminolevulinic acid synthesis and protochlorophyllidereductase complex or elevated ROS generation (Wu *et al.,* 2019).

Cd stress causes reduction in net photosynthesis rate, (Pn) stomatal conductance, transpiration rate, chlorophyll a,b and total chlorophyll content and increase in Co_2 concentration. Significant reduction in chlorophyll pigments of lemon balm plants under Hg toxicity was reported by (Safari *et al.,* 2019) was due to the Hg induced oxidative stress, disturbed mineral content uptake and replacement of metal ions by Hg in photosynthesis pigments.

Seed Production

Some anthropogenic activities such as application of herbicides or pesticides, coal burning timber, preservatives can contribute to heavy metal contamination in the environmental may modulates several metabolic processed in plants resulting to reduction in seed germination, growth and seed production. (Wu *et al* 2020). Heavy metals has a deleterious impact on plant physiological, biochemistry, growth and yield by interacting with other essential nutrients, causing nutritional imbalance.

Heavy metal contamination in vegetables

Heavy metal is a potential threat to human and animals health because of bioaccumulation through the food chain, from urbanization, industrialization, chemical applications etc. absorption and accumulation of heavy metals in plants tissues depends on some factors such as temperature, PH, Organic matter and nutrient availability, this study is aimed at reviewing some literatures on concentration of heavy meatals in some crop planted in northern Nigeria Audu A.A. and Lawal A.O (2005) Study metal content of irrigated vegetables farms in Kano metropolis, it was found out that it follows Fe>Zn>Mn>Cu>Ni>Pb>Co>Cr. The update of these metals is by plants roots. Another study was carried out by John O.J and Kakulu S.E 2012. On heavy metal bioaccumulation in spinach cabbage and tomatoes in farms within kaduna state revealed that the concentration of some heavy metals like Cd and Lead were higher than Permissive limite but lower for Ni and Cr this of Cd and Pb toxicity. Another study by (Omono A.M and Kakulu S.E 2012) was carried out in Itakpe Kogi state, the result obtained was that all the heavy metals were below the WHO/FAO limit for food, high level of zinc and copper in the plants indicates that agrochemicals contributed to the concentration.

Heavy metals concentration in crops

A review of papers on heavy metal contamination in food crops cultivated in different part of Nigeria. Study the concentration of heavy metal in food crops grown along major high ways in lagos state Nigeria. The study showed the concentration of 0.37mg/kg of Arsenic in groundnut, 0.48mg/kg of cooper and Arsenic 0.28mg/kg in Maize grains and 0.36mg/kg of cobal, the sample on the road and dumpsites has higher metal contents which suggested possible mobility of the metals from contaminated side to farm land.

Another review was carried in Owerri Imo state Nigeria. It was reported by (42) (Orisakwe*et al.*,2012). The concentration of Lead, admine and Nickel exceed permissible limit for WHO/FAO, rice recorced the highest level of those heavy metal then Glycin max and pentabactamicrofila respectively. There is a need to monitor the danger posed by the bioaccumulation of those heavy metals on the health of both plants and animals on the areas where the concentrations are relatively high.

Heavy metal concentration in fruits

Fruit may contain toxic heavy metals such as (Cd, Cr, Pb) from the use of pesticide, application of synthetic fertilizer, waste water irrigation and transport to the market. This study is to review papers on the level of metals in fruits. Ibraheem and Abed (2017) reported high level of Cr in apples (63.8mg/kg), watermelon (53.2mg/kg) and Oranges (100mg/kg) in Irag.

Taha and Ghtani 2015 reported high amount of Pb concentration of 13mg/kg in banana at 26mg/kg in oranges (Adewale*et al.,* 2022) reported metal concentration in fruits obtained from major markets in Abeokuta metropolis Nigeria. The concentration of Heavy metal follow below pattern Ca>fe>Mn>Ni in dates coconut, bananas and coconuts respectively.

Vegetables	Heavy metals			References
	Zn	Cd	As	
Red pepper	4.14	2.02	1.23	Adam, A. B 2023
Spring Onion	1.53	0.05	1.18	Shittu, A. M., *et al.,* 2023
Carrots	1.36	0.02	1.28	Shittu, A. M., *et al.,* 2023
Crops	Zn	Cd	As	References
Rice	1.60	0.003	0.09	Luo, Y *et al.,* 2017
Maize	5.67	3.03	1.20	Adah C.A., et al 2013
Wheat	0.54	0.19	0.028	Wang, S *et al.,* 2017
Fruits	Zn	Cd	As	References
Oranges	2.15	0.03	0.54	Elbagermi, M.A *et al.,* 2012
Water melon	5.11	0.03	1.28	Elbagermi, M. A et al.,2012
Banana	6.34	0.05	1.59	Elbagermi, M. A et al.,2012

Discussion

From the results of the study it was observed that the concentration of Heavy Metals in vegetables such as Cd and As was found to be high in Red pepper, only As was high in Spring onions, while in fruits it was observed that all the heavy metals Cd, Zn and As were found to be high, then only Cdconcentration was found to higher in Maize .These heavy metals cause health issues such as Kidney disease, Lungs damage, Bone effects, Liver dysfunction and reproductive toxicity. Long term exposure to Cd and As in vegetables cause Cancer, renal damage, diabetics, Osteoporosis, negative impact on cognative development and cardiovascular diseases. In fruits when exposed to As, Cd and Znthey may cause damage to some vital organs such as Liver, Lungs and Kidney and then hampare the defects, immune system, Arsenic are known to be carcinogenic, high concentration of Zn in fruits cause birth defects, stomach cramps, nausea and vomiting, long term exposure may cause anemia,damagepancrease and decreases levels of high-density lipoprotein cholesterol.

Conclusion

Heavy metal contamination in soils, Vegetables, Crops and Fruits is one of the abiotic stresses that limit crop productivity. Genetic engineering and the recent genome editing Approachess have been used to confer heavy metal resistance in plants. One of the strategies of tackling heavy metal toxicity in plants is to target the initial step of uptake of heavy metals by plants. Research on membrane proteins like ion channels and pumps should be promoted to understand the molecular mechanism involved in the transport of heavy metals across cell membranes and within the cells. Heavy metal accumulators, such as B. napus and B. juncea, are widely used for phytoremediation due to their large biomass. A crucial, yet often neglected, aspect of phytoremediation involves recovery or disposal of heavy metals (accumulated in plants) in such a manner that the plant biomass can be properly handled and the associated environmental risks could be reduced. Further, investigations should be focused on rhizosphere and soil microbial diversity, which affect heavy metal solubility. Work could also be directed toward endophytes (non-pathogenic microbes inside the plant organs) that provide resistance against heavy metals. The role of government and environment protection agencies is imperative in initiating awareness among people and formulating stringent laws in order to check the anthropogenic production of these heavy metals. The knowledge about harmful impacts of heavy metals on plant growth is very important not only for improved plant growth and yield, but also to achieve pollution free environment and ecological harmony.

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