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Review Article

Current Advances in Agriculture, Environment, and Chemistry with Technological Applications

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Abstract

Soil contaminated with heavy metals has a negative impact on plant development and survival. On the other hand, plants have developed intricate physiological mechanisms to resist these kinds of environmental stimuli. Anthropogenic sources of emissions are the many industrial point sources, including transporters, smelters and foundries, present and former mining sites, and combustion byproducts. Mercury is released via the degassing of the earth's crust, whereas lead is emitted during its mining and smelting operations, from automotive exhausts by burning petroleum fuels coated with tetraethyl lead antiknock, and from old lead paints. The process of refining zinc releases cadmium as a byproduct and occasionally lead. Emissions are generally released during the mining and processing of metals. Stress from heavy metals affects plants absorb nutrients through interactions with other essential elements. Chromium restricts the quantity of nutrients the soil may absorb by forming insoluble compounds. An intriguing method for managing plastic waste, particularly micro/nano plastics, is photocatalysis. Through the use of suitable light energy, nanostructured semiconductors are excited, producing exciton pairs that react with surrounding water or moisture to produce highly reactive species like superoxide's and hydroxyl radicals that can effectively oxidize organic species, including polymers. Climate variability affects the sustainability of human and environmental health together with other man-made and natural stresses.

Keywords: Anthropogenic sources, lead paints, Cr stress, negative effects, sunflower seedlings.

INTRODUCTION

Heavy metals and metalloids can play extremely important roles in plant development as micronutrients e.g., Fe, Co, Cu, Mn, Zn, and Mo and by participating in metabolic processes [1, 2]. When their concentrations are above their threshold, they are considered detrimental to plant development. The true for elements such as arsenic (As), cadmium (Cd), lead (Pb), and chromium (Cr) [3]. The characteristics of other metallic elements, such as nickel (Ni), antimony (Sb), aluminum (Al), and mercury (Hg), have also been studied. Chlorosis, browning of the roots, stunted growth, or even death are possible symptoms in plants and inhibit a number of metabolic processes that are essential to the growth and survival of plants. But metal hyperaccumulator plants and certain halophytes may be able to withstand metal toxicity by restricting their absorption, segregating into vacuoles, producing phytochelatins, metallothioneins, hormones, enzymatic and non-enzymatic antioxidants, etc. Transcriptomics, proteomics, metabolomics, and miRNA omics are among the omics technologies that have yielded a plethora of information on plant molecular and metabolic regulators associated with metal tolerance. These specific genes are being identified as crucial regulators of plant metal tolerance pathways. The naturally occurring plants with extraordinary salt content in salinized soil [4, 5].

The atmosphere is exposed to both elemental and compound organic and inorganic forms of heavy metals. Anthropogenic sources of emissions are the many industrial point sources, including transporters, smelters and foundries, present and former mining sites, and combustion byproducts [5,6]. Mercury is released via the degassing of the earth's crust, whereas lead is emitted during its mining and smelting operations, from automotive exhausts by burning petroleum fuels coated with tetraethyl lead antiknock, and from old lead paints. The process of refining zinc releases cadmium as a byproduct and occasionally lead. Emissions are generally released during the mining and processing of metals. Plant chromium (Cr) toxicity is a complex phenomenon that impacts the machinery involved in photosynthetic processes, oxidative stressors, enzyme function, plant growth, and seed germination [7, 8]. Keeping in mind the potential beneficial role of various bacteria and nanoparticles in reducing Cr stress in plants, beneficial role of cerium dioxide (CeO2) nanoparticles and a bacteria called *Staphylococcus aureus* in reducing the negative effects of Cr-toxicity in sunflower seedlings. The results applying *S. aureus* and CeO2 nanoparticles significantly reduced the negative effects of Cr on sunflower plants [2, 5, 7].

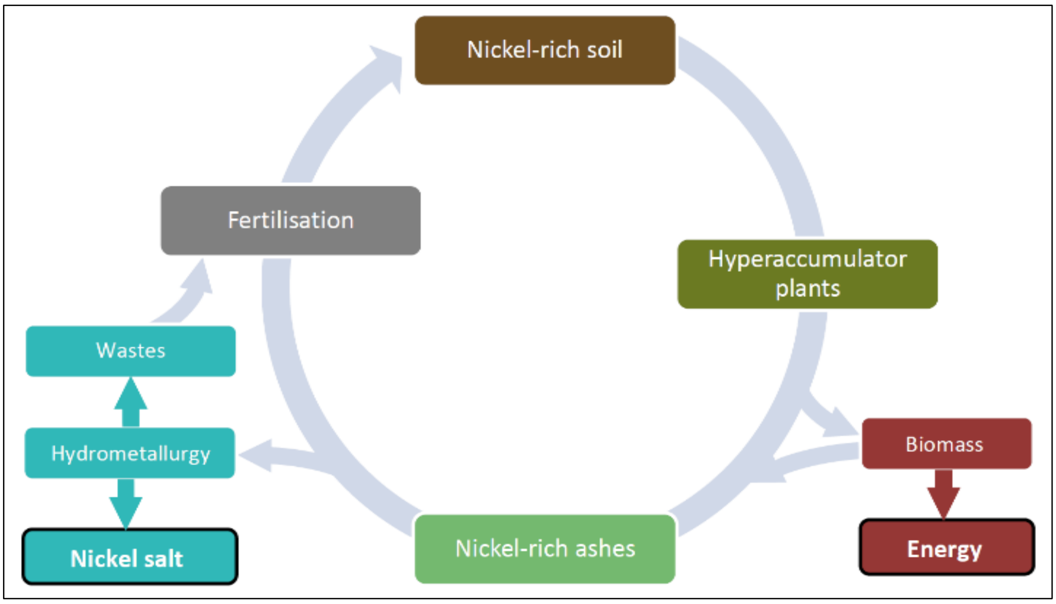

Fig-1: Shows various metals toxicity and effective mechanisms

Current advances in plant sciences/agriculture, environment, and chemistry

Soil contaminated with heavy metals has a negative impact on plant development and survival. On the other hand, plants have developed intricate physiological mechanisms to resist these kinds of environmental stimuli. Many plant cultivars that are more resistant to the harmful effects of metals have been created by transgenic and molecular breeding techniques [7, 8]. Plants, like all other living things, have evolved special defensive systems to limit their exposure to heavy metals that are not necessary and to maintain physiological concentrations of important metal ions. Some systems have a large distribution because they need total metal homeostasis. Furthermore, they lessen the damage that high levels of heavy metals in plants cause by detoxifying the plant, giving it resilience to heavy metal stress. Certain plants possess different defense systems against the build-up of certain metals. These processes target metal ions and can include keeping some metals out of the intracellular milieu or confining hazardous ions within compartments to keep them away from delicate cellular components [9, 10].

Table-1: Shows various metals toxicity and their effects

Metal type	Effects	Agricultural /ecological aspects	Factors
Nickle	It can cause nutrient imbalance	It can interfere the biochemical process.	Environmental and soil
Chromium	It can cause inhibition in seed germination	Disrupt the chemical events	Uptake and cause agricultural land affected
Arsenic	It can cause the risk of microbial infections	Crops and cultivating areas	Environmental and soil
Lead	It comes from the plastics and other pollutants	It can cause the metal toxicity by affecting the plants organs	Soil

Heavy metals effects in agriculture/industries affecting crops

Stress from heavy metals affects the plants absorb nutrients through interactions with other essential elements. Chromium restricts the quantity of nutrients the soil may absorb by forming insoluble compounds. As a result, metal toxicity prevents the body from absorbing nutrients, especially when the metal concentration is higher than permitted [11, 12]. For instance, it has been observed that elevated Cr levels might prevent the body from absorbing essential minerals including magnesium (Mg), phosphorus (P), calcium (Ca), and iron (Fe) by obstructing the sorption sites and forming insoluble complexes. However, Cr transport to other Citrullus plant parts increased, leading to reduced leaf concentrations of sulfur (S), copper (Cu), zinc (Zn), and iron (Fe), and greater concentrations of manganese (Mn) and P. This suggests that Cr impacts the. Cr represented a lag in root development, elongation, and cell division. According to research on Arabidopsis seedlings, higher concentrations of Cr suppress root development, but lower concentrations (20–40 μM) enhance it. The primary causes of the decrease in root development under Cr (VI) toxicity were the inhibition of root cell elongation and the decrease in tissue absorption of water and nutrients [13, 14].

Fig-2: The various principles of cleaning the environment.

However, the role of metal-specific chitinase may shed some light on how plants remove chromium from their bodies. It found differential expression of dehydrin (DHN), mitochondrial processing peptidase-like (MPP), adenine phosphoribosyl transferase, superoxide dismutase, and mitochondrial malate dehydrogenase (MDH) in plants under chromium stress. These proteins further subdivided into four categories according to their functions in energy metabolism, RNA binding, metabolism, and the stress response. Heat shock protein 90 (Hsp90), glyoxalase I (glyoxalase I), protein-glycosylated peptides which reversibly increase the expression of glycosylated polypeptides; RGP, S-adenosyl-methionine synthetase (SAMS), glutamine synthetase (glutamine synthetase), and other proteins among those found to be upregulated in rice [15, 16]. Cr represented a lag in root development, elongation, and cell division. The higher concentrations of Cr suppress root development, but lower concentrations enhance it. The loss of cell division and primordial formation caused of Cr significantly hindered root development. The primary causes of the decrease in root development under Cr (VI) toxicity were the inhibition of root cell elongation and the decrease in tissue absorption of water and nutrients. According to earlier reports, a significant amount of Cr remains in the cell walls of plant roots [16, 17].

Ni is a heavy metal and a crucial micronutrient for the development of plants. When administered in high concentrations of Ni. It turns poisonous to the plant cells formation. Cell membrane functions are destroyed by exposure to nickel. Moreover, it prevents seeds from germinating. Plant development and growth eventually slow down [18, 19]. It possesses an excess of nickel and cadmium in the metal causes the concentration of hydrogen peroxide (H2O2) to rise. Different plants may absorb minerals from their surroundings in different ways. The latest work involved the growth of wheat seedlings in hydroponic culture with concentrations of Ni. The outcome demonstrates that Ni was harmful to wheat seedlings. The more Ni present, the more it impacts the cellular processes in roots. Apart from their harmful impact on growth, heavy metals can also induce morphological alterations in plants. Subjecting to the *Triticum aestivum* leaves to NiSO4 solution reduced the mesophyll thickness, vascular bundle size, and vessel diameter in the main and lateral vascular bundles. Conversely, when NiSO47H2O is added to *Brassica oleracea* plant leaves grown on agar, the volumes of the sponge mesophyll and intercellular gaps decrease in comparison to control plants. It is well established that heavy metals reduce the malleability of cell walls, possibly by direct binding to pectin's and by inducing peroxidase activity inside the walls and between cells. Nonetheless, lignification and the connection between extension and polysaccharides containing ferulic acid depend on these peroxidases [20, 21].

However, plants have evolved complex defensive mechanisms against ROS in order to combat oxidative stress and scavenge ROS. Ascorbate peroxidase, catalase, and superoxide dismutase are examples of antioxidant enzymes; antioxidants, such as carotenoids, glutathione (GSH), polyphenols, and flavonoids; and osmolytes, such as glycine betaine, proline, soluble sugars, and total proteins, are examples of these mechanisms [20, 22]. Many plants have detrimental impacts on their physiological and metabolic processes, and various plants respond differently to nitrogen treatments; some are more susceptible than others. The level of nickel poisoning to plants depends on a number of factors, including chemical form, developmental stage, length of exposure, plant genotypes, and culture methods. Nevertheless, it can be challenging to distinguish between the direct and indirect impacts of heavy metals on enzyme activity. Ion-induced imbalances cause competitive inhibition of nutrient transport and absorption, which results in indirect effects like zinc, copper, and iron. By interacting with the SH groups of proteins, the direct actions of heavy metals block enzymes, leading to their inactivation [22, 23].

Since plastic first gained popularity, its uses have increased dramatically due to its advantages for society's health, safety, and energy. However, because plastics are long-lasting and difficult to decompose, inappropriate rubbish management has become a common problem as a result of their extensive use. Around plastic resin and fibers have been produced; more than half of that plastic was produced [23, 24]. It is estimated that plastic in circulation in the maritime environment. The weight of all people on Earth was produced in plastic. Furthermore, experts forecast. Recent advancements in nanoscience provide many approaches to alleviate concerns about eradicating contamination or reducing scarcity. For example, several filters remove contaminants from drinking water by using nano-chemistry. This technology has already impacted over 7.5 million people by 2016, the last time implementation numbers were collected. It has reduced pesticide levels from over 20 times the safety standard to concentrations significantly below it (0.5 parts per billion, or ppb, for all pesticides combined). As an additional example, it is reasonable to remove arsenic from drinking water using a nanostructured material [25, 26].

One of the main drivers of the creation of novel environmental systems with appealing applications has always been the availability of new materials. These substances have the ability to dismantle obstacles to earlier procedures and, in the end, result in applications that may have worldwide advantages. Materials classified as nanoscale have features that are controllable at a smaller scale than microscale. Because of the fundamental differences between the characteristics of materials with these dimensions and sizes and normal materials, research on nanomaterials is growing daily. Colloidal and solid particles with intricate surface chemistry that have macromolecular components ranging in size [24, 26]. Depending on how they are made, nanoparticles can take the following forms. The use of polymer/inorganic hybrid nanomaterials in environmental applications has also been extensively studied; in particular, the adsorptive removal of various harmful metal ions, colors, and microorganisms from water and wastewater streams. Their chemical and thermal properties are quite stable. These hybrid materials also exhibit a notable ability for the selective sorption of heavy metals from aqueous environments. The greatest features of both materials have been combined in their creation using a range of techniques, including self-assembly protocols, sol-gel processes, and the production of nano-building blocks. Poly amidoamine or dendrimers (PAMAM) have been used to remediate water samples contaminated with metal ions, such as Cu2+. These dendritic nanopolymers contain functional groups such as hydroxamates, carboxylates, and primary amines. They may encapsulate a wide range of solutes in water, including cations (Cu2+, Ag+, Au+, Fe2+, Fe3+, Ni2+, Zn2+, and U6+). By binding with metal ions and serving as chelating agents and ultrafilters, they help filter water. These compounds have also been used as antibacterial and antiviral agents. The primary feature of dendritic nanopolymers is that they are less likely to flow through the holes than linear polymers with similar molecular weights due to their globular shape and decreased polydispersity [26-28]. It supports cost savings associated with environmental threats, compliance with environmental, and the development and maintenance of a sustainable plan for managing an organization's environmental impact [29, 30]. Reduced energy use can result in the practice of taking the environment into account while making purchases for an organization is known as "green procurement," often known as "environmentally responsible" or "sustainable procurement." It aims to lessen the environmental impact associated with the purchase of goods and services by accounting for elements like energy efficiency, resource conservation, waste reduction, pollution avoidance, and the use of eco-friendly materials or technologies. To execute green procurement, stakeholders including senior management, suppliers, sustainability teams, and procurement departments must collaborate. It means adding environmental considerations to procurement regulations, methods, and supplier selection standards, as well as carrying out ongoing monitoring and evaluation of environmental performance. Some of the essential components include the integration of environmental requirements, supplier evaluation, life cycle assessment, product certification and labeling, and supplier involvement [31, 32].

An intriguing method for managing plastic waste, particularly micro/nano plastics, is photocatalysis. Through the use of suitable light energy, nanostructured semiconductors are excited, producing exciton pairs that react with surrounding water or moisture to produce highly reactive species like superoxides and hydroxyl radicals that can effectively oxidize organic species, including polymers. This technique is a light-mediated redox process. Different photocatalysts have been employed to research the degradation of PVC, PET, PS, and PE, including titanium oxide ($TiO2$) and zinc oxide (ZnO). Numerous microorganisms, including fungi and bacteria, have been shown to have the ability to break down plastic waste, particularly microplastics. Plastics break down through microbial decomposition to produce biomass, methane, carbon dioxide, water, and other inorganic chemicals [33, 34].

A few things must be done in order to foster the growth of the green economy, including adjustments to fiscal policy, reforms, and mitigation of environmental harm; directing public investments toward important ecological sectors; and considering the environment in the scientists and policymakers working in the fields of environmental and public health are confronting novel and intricate environmental issues that have an effect on both ecological and human health [28, 29]. The need for energy has grown, and new methods and sources of energy are being used, which raises concerns about how these developments may affect the environment and public health. Land use decisions may affect the quality of the air, land, and water, and hence, human health. Land use patterns are always changing. As technology develops, agriculture and industries are also undergoing changes. Due to these developments, environmental protection is now more focused on recognizing the global implications of human activities on ecosystems and human health than just local ones [32-36].

To prevent possibly irreversible climate change, a significant worldwide shift in human behavior is required. In particular, worldwide yearly greenhouse gas emissions must be cut by 45% by 2030 if we are to keep global warming [37, 38]. Psychological well-being is based on certain socio-agricultural, socio-economic, and physical systems, terrible effects on these systems. Climate variability affects the sustainability of human and environmental health together with other man-made and natural stresses. Another worrying situation that might result in lower-quality food, more expensive food, and insufficient food delivery networks is food security. Numerous climatic conditions, including storms, droughts, flash floods, and heavy precipitation, pose a threat to global forests [37, 38]. However, their anthropogenic wiping is making them more prevalent. While it is true that different parts of the world have varying degrees of vulnerability, decision-making bodies may still benefit from adequate mitigation and adaptation strategies when creating policies to address the implications of these differences. In order to fully profit from CO2, more nitrogen and other fertilizers would undoubtedly be needed. When significant amounts of fertilizer are sprayed, any nitrogen that is not absorbed by the plants may be released into the soil, groundwater, or surface waters. Elevated nitrogen concentrations in groundwater sources have been linked to chronic diseases in humans and have an effect on marine ecosystems. These have thoroughly evaluated grain drying, cultivation, and other field operations [39-41].

CONCLUSION

With the exogenous application of various organic or inorganic compounds and their ability to lessen HM-induced toxicity in plants. The exogenously given nitric acid (NO) and salicylic acid (SA) have been shown to provide protection against the deleterious effects of heavy metals Examining the effects of heavy metals (HMs) on agricultural plants in low-input sustainable farming practices is crucial, with a particular emphasis on supplying soil with organic fertilizers.

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