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Research Article

Effects of Heavy Metals on Soil Properties and their Biological Remediation

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ABSTRACT

Such elements have an atomic density of more than 4g/cm^3 or 5 times or more than water is heavy metals, i.e. Nical (Ni), silver (Ag), cobalt (Co), iron (Fe), manganese (Mn), lead (Pb), arsenic (As) and cadmium (Cd). In these, some are essential, i.e. iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo) and Nical (Ni). Rapid increments in industry, agriculture, and urbanization produce non-degradable toxic materials, i.e. heavy metals. Heavy metals are also produced by natural resources but higher values reflect anthropogenic accumulation. Soil is one of the valuable, essential, non-regenerative resources. Many soil properties, i.e. pH, organic contents, ion exchange capacity, texture, microbial growth, microbial density or metabolic processes, are deteriorated by the heavy metals accumulation. Heavy metals are a non-degradable part of the soil environment. Soil remediation is necessary due to high productive pressure with food security concerns. Different Physico-chemical and biological practices are in practice to remediate the soil environment. Mainly use of amendments (liming material, organic contents and adequate fertilizer rate) and plants (phytoremediation and phytodegration) are the most economical cost-effective and environmentally well-sounded techniques for cleanup of the soil environment. Amendments help to reclaim the soil's Physico-chemical properties, microbial community establishment and bond different heavy metals to reduce their mobility. Prevention of the entry of heavy metals into the food chain is a major goal of phytoremediation. Physical with genetic engineering approaches must be practiced to make new genetically controlled plants used in future prospects to remediate the soil.

Keywords: *Heavy metals, remediation, Physico-chemical, non-degradable, genetic engineering.*

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INTRODUCTION

Soil is one of the most valuable and essential resources for agricultural crop production. Different biotic and abiotic stresses are the main hindrances to soil quality improvement, plant growth and development. Biotic stresses occur mainly due to pathogens attack and abiotic stress, including salinity, heavy metals toxicity, high temperature, and high oxidative stress conditions are responsible for major crop production loss across the world. Heavy metals accumulation badly deteriorates the soil quality and plant growth. Heavy metals are groups of elements having atomic density more than 4g/cm^3 or 5 times or more than water (Hawkes, 1997), i.e. Nical (Ni), silver(Ag), cobalt(Co), iron (Fe), manganese (Mn), lead (Pb), arsenic (As) and cadmium (Cd). Rapid increment in industrial production with greater use pesticides and fertilizers results in the production of lot of harmful pollutants such as heavy metals.

Mainly heavy metals accumulated in soil through natural and anthropogenic processes. Generic processes mainly include parent material decomposition and atmospheric addition, while anthropogenic include industrial or sewage waste or sewage sludge and indiscriminate use of pesticides with fertilizers. Yang et al. 2018 study show that heavy metals accumulation in soils is mainly due to industrial activity. Anthropogenic activities show higher contents in soil. Human activities, i.e. industrial emission, municipal waste disposal, and indiscriminate use of pesticide and fertilizer results in the accumulation of heavy metals in soil (Chen et al., 2015; & Lee et al., 2019).

Lian et al. 2019 usually considered that soil is a final sink for pollutants in terrestrial environmental. Nour et al. 2019 reported that threats posed by the heavy metals and there results show that sediments are highly contaminated with Sr, Cd, Pb and Zn. Heavy metals pose serious threats towards soil quality, plant growth and needs attention of researches towards sources, accumulations and their hazardousness. Macronutrients unavailability and soil pH towards acidity are the major effects of heavy metals accumulations. Mainly accumulated metals rendered the seed germination, growth and production of plants. Heavy metals toxicity above the permissible limits is the main hindrances towards agriculture sustainability and crop production.

WHO, 1996 modified the permissible limits for heavy metals concentration in soil and plant

Heavy metals	Concentration in soil mg/kg	Concentration in Plants mg/kg
Lead (Pb)	85	2
Copper (Cu)	36	10
Zinc (Zn)	50	0.6
Cadmium (Cd)	0.8	0.02

During the past decades, pollution cleanup from soil environment is a major concern due to attain sustainability, soil quality and ecological health improvement. Two types of remediation strategies are applicable to remove heavy metals 1) uses of amendments such as lime, organic matter and adequate fertilizers 2) uses of plants such as phytoextraction or phytodegradation (Hamlin & Barker, 2008).

Effects of heavy metal toxicity on soil

Heavy metal affects physico-chemical properties of soil i.e. pH, organic matter, ion exchange capacity, texture, microbial growth, microbial density or metabolic processes. Hu et al., 2018 reported that heavy metal accumulation and mobility in soil is mainly influenced by pH and organic content of soil. Heavy metals accumulation in soil increases the capacity to move within the environment. Lead exists in the many forms naturally and accumulation across the world. Lead is a one of the hazardous metal effects by the reduction in soil fertility, nutrient availability and microbial diversity (Dotaniya et al., 2020). Reduction in the microbial activity causes low organic matter decomposition rate and results in the less fertile soil. Causes of mortality and reduction in the earthworm (*Eisena fetida*) growth are mainly due to lead accumulation in soil. Lead accumulations effect the important soil parameters i.e. pH and cation exchange capacity (Vega et al., 2010). Once the contamination of the soil with heavy metals occur it's difficult to remove (reviewed in Shahzad Ali et al., 2021). Soil chromium presents in Cr (III) and Cr (VI), these are differentiated on the basis of prominent properties and their level of toxicity. Cr (III) is the micronutrient and non-toxic while Cr (VI) is highly toxic and strong oxidizing agent. Cr (VI) toxicity badly affects the growth and diversity of soil microbes (Gamier et al., 2006). In general heavy metals affects the microbes in all cases e.g. enzymes activity, respiration, and microbial growth are the main indicator of soil pollutions. The lead (Pb) contamination cause slight changes in the soil microbial concentration observed (reviewed in Singh et al., 2011).

Biological remediation strategies of contaminated soil

Heavy metals mainly flow in environment and plants due to soil pollution. Contaminated soils are found all over the world (McGrath et al., 2002). Liu et al., 2018 divide these processes into five categories such as physical, chemical, electrical, thermal and biological are known to remove the contaminants from soil. Contaminated soils are the one the concerned issue due to their adverse affects on ecological environment (Pinto et al., 2008). Commonly, biological remediation techniques are divided into two categories. In first category, remediation is done by using the amendments like liming, organic material, and adequate fertilizer rate. While in second category, remediate the soil through phytoextraction or phytoremediation means that by using the extractor plants to remove the contaminants from soil environment and use plants with their associated microbes to remediate the soil.

1. Amendments Addition

In first category, amendments are used to remediate the soil from heavy metals. In liming material different nutrients are added to soil to catalyze the remediation process.

1.1 Liming

In acidic soils, liming material is added to increase the concentration of calcium (Ca) and magnesium (Mg) supply or increase in soil pH. The liming practices increase the cation exchange capacity (CEC) rather than increasing the calcium and magnesium concentrations in soil solution. Liming material increases soil pH that reduces bioavailability of soil towards the plant uptake. In soil-plant system the heavy metals are controlled by adsorption-desorption method at particle-solution interface. Mostly heavy metals desorbed in soil when pH of soil is raised from acidic to neutral. The uptake of essential elements (Cu, Fe, Mn and Zn) by rice are reduced when the pH of rise from 4.6 to 6.8.

1.2 Increment in soil organic material

Soil organic matter content can be increase by the using animal or poultry manure, green manuring, crop residue addition, reduce tillage operation, and keeping land under the pasture. The organic matter act as store house for nutrients provides plant nutrition, water retention capacity and main source energy to microbes. Organic matters improve the soil quality and maintain the soil microbial growth or microbial diversity. Organic material act as environmental sinks for heavy metal because of the made the ligands that are stable complex compound that retards from leaching or uptake by plants (Bolton et al., 1996).

Soil organic material increases the heavy metals adsorption by increasing ion exchange capacity or soil metals sorption capacity. Organic matter accumulation is a critical factor to control soil erosion and helps to maintain the agroecolgical sustainability. The strong correlation was observed between organic matter and zinc contents of soil, which helps to retain zinc in soil. Copper have low leaching capability due to their complexes with soil organic matter (Fageria, 2009). Zinc mobility is affected due to their infinite bonding capacity with organic complexes (Codling et al., 2008).

1.3 Application of fertilizer in adequate rate

Adequate rate of fertilizer helps to reduce the mobility in soil and phytotoxicity of heavy metals towards plant growth. Mishra & Kar (1971) reported that Nical (Ni) toxicity towards plant growth can be reduced by using adequate rate of nitrogen, potassium, calcium, molybdenum and magnesium. These authors reported that lower concentration of Nical (Ni) was observed to their antagonistic relationship with molybdenum (Mo). Mo immobilized by adding suitable amount of zinc in soil. Concentration of cadmium in barley plants are observed low due to the addition of zinc fertilizers. Cadmium toxicity in plants can be reduced by using adequate rate zinc fertilizers i.e. $ZnSO_4$ (Wu & Zhang, 2002).

2 **Use of Extractors or Degrader**

2.1 Phytoremediation or Phytoextraction

In second category, such types of plants are used that have ability to sequester heavy metals in their roots and shoots without facing the damage in growth (Mahmood et al., 2015). Usually these plants are disposed off and safely deposited away from the contaminated soil (Hamlin & Barker, 2008). Such types of plants have enough capacity to accumulate the high concentration of contaminants in shoots by using scavenging mechanisms. If the plants are used for remediation than plants roots are excavated and disposed away properly (Pinto et al., 2015). All these techniques are used to stabilize or remove the contaminants from contaminated soil.

In last decade, remediation of soil from heavy metals is most important technique (Ali et al., 2013; & Sarwar et al., 2017). Plants are capable to grow in the metal-contaminated soils and tolerate their high concentration in soil. Barker, (1981) identified three kinds of physiological mechanized plants that have ability to grow and face high toxicity level. These are the (I) Indicator (II) Accumulator (III) Excluder plants. In case of indicator plants, soil heavy metals have linear relationship with plants uptake. In other words, Increase heavy metal concentration in soil results in the more uptakes by the plants.

Malarkodi et al. (2008) reported that *Ricinus cummunis* L. and *Tagetes erecta* M. have ability to sequester high quantity of heavy metals. The matured these plants are disposed off away from the cultivated area or water resources (Lasat, 2002).

Plants	Heavy metals	States
Turraea nilotica	Nical	Zimbabwe
Tephrosia spp.	Lead & Zinc	Australia
Ruta Latifolia	Zinc	Brazil
Silene otites	Copper	Germany
Alsine sentaceae	Mercury	Spain

2.1.1 Antonovics et al., 1971 describes the different heavy metals indicator plants with respect agro-ecological states in which some these are following

2.1.2 Balker, 1990 describes the different heavy metals accumulator plants

Plants	Heavy metals
Ipomoea alpina	Copper
Haumaniastrum robertii	Cobalt
Thlaspi retundifolium	Lead

2.1.3 Balker, 1981 describes the different heavy metals excluder's plants

Plants	Heavy metals
Armeria maritime	Zinc, Lead and Copper
Silene vulgaris	Zinc and Copper
Thlaspi alpestre	Lead

2.2 Phytodegradation

Use of plants with their associated microbes to degrade the organic pollutants in soil described in soil is known as phytodegradation. Lasat, 2002 described that several microbes have ability to alter the phyto-availability of heavy metals. Microorganisms are also used to stabilize the heavy metals. Precipitation of heavy metals can be done via microbial process and greatly decreases the bioavailability of heavy metals to plants. Xanthomonas maltophyla catalyze that process of precipitation and reduction of Cr (VI) to Cr (III) because Cr (VI) is highly toxic and reductive while Cr (III) is not toxic for plants and required in low quantity to plants for their normal growth. Same strain of this microbes can transformed the Lead (Pb^{+2}) and Mercury (Hg^{+2}) to less phyto-available forms (Lasat, 2002). Entry of heavy metals in food chain is a principle way through soil. Mishra et al. 2017 reported that certain soil microbes enhance the ability of plants to tolerate the heavy metals and growth in contaminated soil. Endo & ecto-mycorrhizal symbiosis plays a role in protecting the plants roots from toxicity. Galli et al. 1994 described those heavy metals taken up the fungal mycelium and bound with nitrogen and phosphorus indicating heavy metal-thiolate binding in metallothioneins like peptide.

CONCLUSION

In past decades, pollution cleanup from soil is in the focus of researcher due to sustainability in crop production and food security issues. Heavy metal presents everywhere in the soil, environment, and plants and in their tissues. Heavy metals are non-essential toxic as well as essential for plant growth. Addition of these essential metals is necessary for maximizing the crop yield. Unlike the organic pollutants, heavy metals are not degraded by the soil. Heavy metals badly affect the soil properties. So, remediation of soils is needed for quality production and sustainability of agro-ecological environment. Both biological remediation techniques are economically cost effective and environmentally well sounded. With biological (phytoremediation) genetic engineering approach must be practiced to produce genetically modified valuable heavy metals accumulators or excluders to clean up our soil environment.

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Conflict of Interest

There is a no conflict of interest between authors.

Author's Contribution

All authors are contributed equally and equal response is observed from all authors.

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