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Review Article

An Empirical Review on the Impact of Heavy Metal-Polluted Soil on Soil Enzyme Activities

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ABSTRACT
Environmental contamination by heavy metals is an issue of global concern. Human activities, the release of various organic and inorganic contaminants have continued to rise. Some of these activities include industrialization, faming activities, and vehicular emissions amongst others. Heavy metals have been identified as one of the major groups of pollution because they pose deleterious effects on plants, animals and the environment. Heavy metals are not biodegraded by microbial activities; rather they persist and are transmitted along the food chain with a high degree of bioaccumulation. Heavy metals in soil have continued to increase, since the soil acts as a natural reservoir of these metals in the environment. Hence metals from other parts of the environment usually are found within the soil. This review provides details information on effects of heavy metals on soil enzyme activities. The review indicates that the heavy metals in such high concentrations inhibit the activity of enzyme secreting flora and fauna in soil, as excessive amounts of heavy metals disrupt the homeostasis of soil by interfering with the control mechanisms at genetic level. Thus, the decline in soil enzyme activity reflects the soil degradation potential of the heavy metals released into the soil. Therefore, it is crucial to take adequate remediation measure in order to protect the health of soil flora and fauna in these areas.

Keywords: Effects; Enzymes; Heavy metals; Pollutions; Soil

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INTRODUCTION

Heavy metals are a group of elements with metallic properties that include transition metals, metalloids, lanthanides, and actinides (Li *et al.,* 2019).Heavy metals are unbreakable, and most of them are poisonous to animals and people. Metals are particularly concerning among environmental contaminants since they are less apparent, have extensive effects on ecosystems, are poisonous, and bioaccumulate in ecosystems, biological tissues, and organs (Nontobeko*et al.,* 2022).Heavy metals are chemical element materials with relatively high densities that exist naturally in numerous amounts in the environment. Most heavy metals are poisonous even in low quantities, and their accumulation in bodily tissues over time may be harmful to human health (Titilawo*et al.,* 2020). Some metals are carcinogenic, genotoxic, or cause genetic mutations in humans and animals depending on the amount and duration of exposure; these include As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, and Zn (Agoro*et al.,* 2020).Soil health refers to the healthy balance of organisms and their surrounding environment inside the soil ecosystem.

Every disruption to the soil caused by the negative impacts of pollutants on soil biochemical activity affects soil health and functions (Nyika*et al.,* 2019). Soil enzymes are derived mainly from microbes, with some originating from plant or animal wastes. Enzymes accumulate in the soil as free enzymes or enzymes stabilized on clay surfaces and soil organic materials. Most enzymes are often employed to assess the impact of pollutants, such as dehydrogenase (DH), phosphatase (PHO), and urease (UR) (Lee *et al.,* 2020).

Soil enzymes are well-known for accurately reflecting the degree of deterioration of soil quality caused by soil pollution and diagnosing the functional recovery process of polluted soil (Nontobeko *et al.,* 2022). So far, contaminated site rehabilitation has mainly focused on pollutant removal, which presents expenses and secondary ecological disturbance in the repair process. Sustainable soil remediation aims to save costs, restore soil health, minimize environmental disruption, and maintain its effects. Insufficient enzyme activity can result in an accumulation of chemicals that are harmful to the environment; some of these chemicals may further inhibit soil enzyme activity. Pollutant concentrations and soil enzyme activity have a negative connection in general (Nontobeko *et al.,* 2022).

Table 1a: Effects of heavy metal pollution on soil enzyme activities

S/N	References	Title of the paper	Findings
1	Adam, 2025	Impact of manganese, iron , and cobalt fraction on soil enzymes activities	Metal fraction associated with organic matter had the greatest impact on the activities of the studied enzymes.
2	Aporite et *al*., 2020	Mata –analysis of heavy metal on soil enzyme activities	Heavy metal contamination inhibits arylsulfatsase activities and dehydrogenase acticities by 72% and 64% respectively. The mata analysis showed a clear decrease in the activities of all enzymes in response to heavy metal contamination
3	Botang *et al.,* 2022	Effect of heavy metals on microorganism and emzymes in soils of lead-zinc tailing pond	The potential ecological risk index of six heavy metl was ranked as C> Cu >Pb >Ni > Zn. *V. catalase*, cellulose, sucrose and neutral phosphatase activity had negative correlation with the content of six heavy metal. Higher heavy metal level lead to the decrease of enzyme activities
4	Xiany *et al* 2015	Quantitative assessment on soil enzyme activities of heavy metal contaminated soils with various soil properties	Arylsulfatase was the most sensitive soil enzyme and could be used as an indicator to study the enzymatic toxicity of heavy metal under various soil properties. Soil properties had significant effects on the activities of soil born enzymes in heavy metal polluted soil.

Table 1b: Effects of heavy metal pollution on soil enzyme activities

S/N	Authors	Research topic	Findings
6	Sakn et al, 2023	Enzyme activities and heavy metal interaction in calcareous soil under different land uses.	Dehydrogenase, catalase, and urease activity decrease rapidly with heavy metal concentration. High level of heavy metals can decrease some enzyme activity in the soil
7	Mohammed-Haroon *et al.,* 2023	Influence of biofertilizers on heavy metal bioremediation and enzyme activities in the soil to revealing the potential for sustainable soil restoration	Soil enzyme activity was negatively correlated to heavy metals at significant level. Biofertilize application reduces heavy metal level and increased soil enzyme.
8	Justice and Guangyu, 2021	Effect of heavy metal contamination on soil enzyme activity	The activities of catalase, urease and dhydrogenase were all affected by Cd contamination. The order sensitivity. Soil enzyme activity might be used as a metrics to measure the impact of heavy metals on biological activity in the soil
9	Naoval *et al.,* 2023	Heavy metal effect on agricultural viral soil enzymes activity to fez, Morocco	Pearson correlation showed significant positive correlation between studied soil enzyme and between these enzyme activity and heavy metal (Cu, Pb and Zinc). And significant negative correlation between enzyme activity and heavy metal (Cr and Ni).
10	Masoumeh *et al*, 2014	Effect of heavy metals on enzyme activity and microbial biomass of the soil around the waste disposal site (case study, of Savana-Iran	The correlations between total concentration of metals and bioavailable fractions with microbial quotient, urease, and alkaline phosphatase activity were moderate.

Table 1c: Effects of heavy metal pollution on soil enzyme activities

S/N	Authors	Research topic	Findings
11	Ofuegbu *et al.,* 2013	Effect of heavy metal on soil enzymatic activities in Ishiagu mining area of Ebonyl State, Nigeria.	The activities of dehydrogenase, polyphenol oxidase, hydrogen peroxidase,alkaline and acid phosphatases and urease showed significant negative correlation at $p<0.05$ with heavy metal contents except for Zn against dehydrogenase activity and Cd against hydrogen peroxidae and urase activities that were though negative
12	Sahoo *et al.*, 2014	Effect of heavy metals on enzyme activities in sponge iron industry polluted soil	Amylase, invertase, cellulose, dehydrogenase and urease activity in the experimental site were significantly low when compared to the controlled site in both season. With the increase in distance from the stack of the industry, the heavy metal contents decreased and the enzyme activities increase
13	Marta *et al.*, 2016	Assessment of heavy metals contamination and enzymatic activity in pine forest soils under different levels of anthropogenic stress	The lowest activity or soil enzymes (acid phosphatase, and in particular B-glucosidase was found in the site with the highest levels of heavy metal.
14	Radina *et al.*, 2023	Enzyme activities in soils under heavy metal pollution: a case	The result showed that there was enzyme functional redundancy between soils. Soil

		study from the surroundings of a non- ferrous metal plant in Bulgaria	enzyme showed a relatively high capacity to tolerate long term heavy metal pollution.

Table 1d: Effects of heavy metal pollution on soil enzyme activities

S/N	Authors	Research topic	Findings
15	Marta *et al.,* 2021	The influence of heavy metals on biological soil quality assessments in the Vaccinium myrtillus L. rhizosphere under different field conditions.	The B-glucosidase and ureaseactivity in the soil correlated most negatively with the examined metals. The study showed that rhizophere soil is more sensitive and could be used in the monitoring and assessment of forest ecosystem
16	Liugen *et al,* 2019	The inhibitory effect of cadmium and/ or mercury on soil enzyme activity, basal repiration , and microbial community structure in coal mine – affected agricultural soil	Heavy metal inhibit soil enzymes activities. Both Cd and Hg decreased 25.52-34.89% of the soil catalase activity and the highest level of Hg (30 mg kg-1) decreased 76.50-89.88% of the soil urease activity and 85.60-92.92% of the soil dehydrogenase activity and the soil acid phosphatase activity significantly decreased. Soils containing the highest level of Cd and Hg exhibited the lowest soil enzyme activities
17	Gang *et al.,* 2017	Interactive effect of radioactive and heavy- metal contamination on soil enzyme activity in a former Uranim mine	The invertase and –glucosidase activities were significantly lower in the core mining areas than the control areas ($p<0.05$). Activities of the two enzymes decreased with increasing metal concentrations and radioactivity.

Table 1e: Effects of heavy metal pollution on soil enzyme activities

S/N	Authors	Research topic	Findings
18	Adam and Dorota, 2018	Influence of Zn, Cd and Cu fractions on enzymatic activity of arable soils.	Activity of micro organism. Protease activity was influenced by f2 fraction. Protease and dehydrogenase activities were significantly differenciated between sampling dates.
19	Agata et al.,2020	Assessment of selected heavy metal and enzyme activity in soils within the zone of influence of various tree species	Correlation analysis showed a significant relationship between total Pb content and nitrate reductase. Nitrate reductase activity also correlated positively with bioavailable Cu content. The study found no heavy metals content to be in excess of permissible levels. This indicates their natural accumulation in the soil, which did not inhibit the tested enzymes.
20	Sonia and Saksham, 2015	Response of soil enzymes to different heavy metals	The study showed that addition of Cd and Zn negatively inhibited soil enzymes activities. with regards to the four enzyme, urease is the most sensitive to combined poluution of Cd and Zn with a significant negative correlation between urease activity. It is considered that heavy metals mainly inhibit enhibit enztmatic reactions either their complexing with substrate or blocking the functional groups of enzymes or reacting with complex enzyme-substrate.

21	Linchuan *et al.*,2017	Proper land use for heavy metal-polluted based on enzyme activity analysis around a Pb-Zn mine in Feng County, China	urease was the most sensitive enzymes to Pd and Cd in the farm land, and catalaseand phoshatase were the most sensitive enzymes to Pb, Zn, and Cd. Wood land might be optimum land use choice in relieving heavy metal pollution..

CONCLUSION

Heavy metal toxicity in the soil is one of the problems of remarkable priority in the world. Heavy metals are toxic to plants, the soil, as well as human health at high concentrations. It is therefore paramount to continually monitor the contents of heavy metals in various environmental matrices, most especially the soil since the soil is the natural storeroom for various environmental contaminants.

RECOMMENDATIONS

The decline in soil enzyme activity reflects the soil degradation potential of the heavy metals released into the soil. Therefore, it is highly essential to take immediate remediation measure in order to protect the health of soil flora and fauna in these areas.

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