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Harmful Impacts Of Heavy Metal Contamination In The Environment

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Abstract: The contaminated soil with heavy metals has become concern for agricultural scientists because of the progress made in agricultural product safety. Heavy metals are metalloids with the biological toxicity. The most common are arsenic, cadmium, chromium, copper, mercury, lead and zinc. These metals exist throughout the terrestrial environment and produced from the anthropogenic and natural activities. Recently, landfills have been reported as persecutor to soil contamination, but still, there is not promising way proposed for the waste disposal management in some developing countries. This is a biggest threat to the soil, crops, and the communities living around the dumpsites. Soil polluted with heavy metals result in the human health risks, groundwater pollution, plant phytotoxicity and decline in crop and soil production. The absorption of heavy metals through plant roots is major pathway in which heavy metals penetrate the food chain and their successive crowding along the food chain is a critical threat to the animal and human health. The previous findings reported that soil, vegetables, and other food crops around dumpsites are contaminated with the heavy metals. Therefore, there is an urgent need for continuous monitoring of the heavy metals in different open dumpsites. The necessary measures to reduce the high concentration of the heavy metals in the soil and crops should be put in place. This paper aimed to review harmful impacts of heavy metals contamination to soil and crops grown in vicinity of the dumpsites, but also several techniques treating heavy metals pollution in the soil were discussed in this review.

KEY WORDS: Heavy Metals, Soil contamination, Disposal site.

1. INTRODUCTION

The waste disposal is a serious global environmental issue resulting in heavy metal pollution of soil, water and crops. The most common environmental heavy metals are Cu, Ni, Cr, Pb, Cd, Hg, Fe and As. Some heavy metals, such as Fe and Ni are essential to the survival of all forms of life at low concentrations. However, heavy metals like Pb, Cd, and Hg are toxic to living organisms not only in the high concentration but also in low concentrations. They are contributors of metabolic abnormalities to the organisms especially consumers of food from plants and other crops grown from contaminated soil [**1**]. Generally, heavy metals are naturally occurring components of the earth's crust with large differences in the concentrations. However, the pollution from human activities has contributed to high occurrence heavy metals into the ecosystem [**2**]. The concern of environmental pollution from the heavy metals mostly came from different sources such as urban-industrial aerosols, solid and liquid wastes, mining activities, industries, and agriculture chemicals [**3**]. Concentrations of heavy metals in the soil around waste dumpsites are influenced by the some factors including types of wastes, topography, runoff, and level of scavenging [**4**]. The disposal of waste has been observed as a serious implication of the modernization [**5**]. Due to the demographic growth, lifestyle change and rapid urbanization, waste is on the rise in cities of the developing countries [**6, 7, 8**]. This has resulted in the environmental pollution, specifically in the developing countries where important efforts towards developed waste management and disposal practices have not been made at a high level [**9**]. Similarly, with a rising influence of the advanced technology in the developed countries, more municipal solid wastes and wastewaters are being produced and need treatment and proper disposal. Healthy environment is associated with good a human health. Some disposed materials containing heavy metals in the open dumpsites are of concern and pose dangers to people in contact with the soil and plants contaminated by the heavy mental from bad waste disposal management [**10**]. Waste generation and disposals have been noticed as one of the driving forces of heavy metals contamination in the soil. Generally, waste in the landfills is from different sources, composed of the different materials, and are disposed randomly in these dumpsites. There are not guidelines proposed for waste disposal, which cause the mixture of the waste and create leachate that relocates into soil and groundwater [**11**]. The decomposition of organic matter in the municipal solid waste by micro-organisms results in the hazardous liquids called leachate that consists of organic matter, macro-inorganic components and heavy metals polluting both soil and aquatic environment [**12**]. Besides, the most landfills are located near the settlements and some wastes are dumped recklessly without paying attention to environmental implications. Moreover, in the some dumpsites, wastes are burnt at the sites, and results to unhealthy environment [**13**]. Heavy metals pile persistently exists in the waste disposal at the environmentally threatening level. This results in unhealthy conditions and environmental problems due to the poisoning effects of heavy metals in plants and potential health implications to humans and animals consuming such vegetables [**14**]. There is an increasing concern about likelihood of soil contamination resulting in the introduction of dangerous elements in the food chains through uptake by the plants and thereby affecting food safety [**15**]. Heavy metals accumulation in the soil and plants have a negative influence to the physiological activities of the plants such as photosynthesis, gaseous exchange, and nutrient absorption which result in the plant growth reduction and

dry matter accumulation. The heavy metals' environmental pollution and associated health effects are among the leading cause of the health concerns all over the world. For example, bioaccumulation of lead in the human body interferes with the functioning of mitochondria, thereby impairing respiration, and also causes constipation, swelling of brain, paralysis and eventual death [**16, 17**]. The situation is very critical in the developing countries where research towards environmental monitoring was not prioritized by stakeholders [**18**]. Industrial growth have led to the increased production of domestic, municipal, and industrial wastes, which are indiscriminately dumped in the landfills and water bodies without treatment. The presence of heavy metals in the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains, and non-biodegradability which is responsible for their accumulation in a biosphere [**19**]. Soil is a vital natural resource for sustaining human needs of the quality food supply and quality environment. Once plants are grown in the land polluted with municipal, domestic or industrial wastes can absorb heavy metals in the form of mobile ions from the soil solution through their roots or foliar absorption. The absorbed metals get bio-accumulated in the roots, stems, fruits, grains and leaves of the plants. Some heavy metals like As, Cd, Hg, and Pb are particularly hazardous to the plants, animals, and humans. In dumpsites, the municipal wastes contains heavy metals such as As, Cd, Co, Cu, Fe, Hg, Mn, Pb, Ni, and Zn which end up in the soil as sink when they are leached out from dumpsites [**20**]. The vegetables cultivated in contaminated soil uptake heavy metals in high amounts to cause potential effects to the agricultural products, and result in adverse health outcomes to consumers. The investigation of heavy metals is very essential since slight changes in their concentration above acceptable levels, whether due to the natural or anthropogenic factors, can result in the serious environmental and subsequent health problems. To understand the heavy metals situation and their impacts to soil and crops, present study will investigate the harmful effects of heavy metals concentration in soil and the crops grown in a vicinity of the landfill and explore their sources and remediation methods to deal with the overabundance of these metals' contamination in soils.

2. Sources of heavy metals in the environment

Heavy metals are everywhere in environment as the result of both natural and anthropogenic activities. People are exposed to them in the different ways [**1**]. Heavy metals are ever-lasting environmental pollutants and enter the body through food, air, water and accumulated biologically over the period of time. The presence of heavy metals in the environment even at low concentrations is still an environmental issue because their toxicity. The slight changes in their concentration above the acceptable level, whether due to natural or anthropogenic factors is a great concern since they result to serious environmental and subsequent health problems. It can be seen in that anthropogenic sources of heavy metals pollution involve agricultural activities, such as application of the pesticides and herbicides, contaminated irrigation water, utilization of municipal waste for the fertilization purposes [**21**]. Additionally, the anthropogenic source also includes waste disposal in the farmland, mining activities, smoking, traffic emissions and discharge of the sewage and building materials like the paints [**22**]. The previous findings from studies carried out in Indonesia

reported that heavy metals released into the environment by the human activities in Indonesia cities are mainly from Industrialization, waste disposals and agricultural activities, reported that coastal area of Indonesia is polluted by the metals from direct discharge of the about 1,100 tons of solid wastes. This massive discharge of the pollutants is embarrassing water safety and aquatic life since it contributes to death of the aquatic animals such as the death of coral reefs on the large scale [**23**]. Humans and animals are also contaminated by the toxic heavy metals via inhalation of the dusty soil. Heavy metals pollutants such as Cu, Pb and Zn from additives used in the gasoline and lubricating oils are also deposited in the highway soils and vegetation [**24**]. From Table 1, each of the discussed heavy metals have its source and pathway to the reach soil. Regardless the differences in origin, heavy metals follow general biogeochemical cycle after entering the environment, although their transportation, residence time and fate differ from the certain environments. Regional pollution occurs in the overpopulated areas, factory zones, motor vehicles and municipal waste locations [**1**]. All the metals mentioned have the similar anthropogenic source such as the waste disposal and incineration, mining activities and fertilizer. Municipal solid waste incineration, application of pesticides, herbicides and fungicides; industrial waste storage, and the production of metals and alloys have increased heavy metals concentration in soil [**25**], which implies their significant contribution to occurrence of the heavy metals in environment. The study reported that 25,000-125,000 tones/year of mercury enters the environment naturally. Meanwhile, only 10,000 tons per year enters the environment through mining and smelting and this has been increasing with annual rate of 2% since 1973. Furthermore, Luoma and Rainbow [**31**] reported that the anthropogenic contamination of Cadmium was approximately 31 times higher than that of the natural origin. Worldwide, 5.6-38×106 kg of Cd year^{-1} was introduced in a soil via human activity.

3. Harmful impacts of heavy metals on soil and crops

3.1 The impacts of heavy metals on soil

Heavy metals are considered one of important sources of the soil pollution. Heavy metals contamination in the soil is caused by the various types of the metals, mainly Cu, Ni, Cd, Zn, Cr, and Pb [**32**]. The human activities such as the waste generation and disposal in the landfills and dumpsites have been observed as the major source of soil pollution by heavy metals. The concentrations of the heavy metals in the soil around waste dumps are influenced by the various factors such as the types of wastes, topography, run-off, and level of the scavenging [**33**]. The improper waste disposal can result in the contamination of both soil and groundwater. Municipal solid waste contains paper, food waste, metal scraps, glass, ceramics and ashes. The decomposition or oxidation process releases heavy metal form the wastes to nearby soil [**34**]. Heavy metals in the soil result to changes in the soil quality and fertility, groundwater contamination, bio magnification and ultimately irreparable damage of soil biota [**35**]. The historically, soil systems were subjected to the physical stress by the ingestion of foreign substances, such as the heavy metals, when heavy metals are abundant in the soil results to the unhealthy ecology which affects the entire health of the living organisms (Table 1). Table 1 discussed the harmful impacts of the heavy metals. Table 1 shows lead is a toxic metal with very low mobility but the high bioavailability. On the soil surface, lead persists for the long time [**36**].

Cadmium and its compounds can move through the soil, but its portability depends on several factors including soil pH and the amount of organic matter, which depends on the local environment [**37**]. Besides, cadmium binds tightly to organic material, and becomes immobile in the soil and absorbed by the plants, and eventually enters the food chain [**38**]. The soil contaminated with heavy metals is associated with excessive concentration in the heavy metals, insufficient nutrient, and organic content, low water retention capacity and low cation exchange the capacity [**16**]. The heavy metals indirectly affect soil enzyme activities by the altering the microbial community synthesizing enzymes [**37**]. Pollution of the heavy metals causes a decrease in a specific adsorption of other cations by the increase in the saturation or super saturation of the cation exchange sites by the heavy metals cations, which displaces the protons in soil solution and result in the lower pH. Heavy metals contamination in soil inhibits enzymatic activity and cause the attenuation of the SOM mineralization and nutrient cycle [**1**]. It also can be seen from the Table 1 that heavy metals like cadmium reported as the harmful metal to the activities of enzymes. The findings of the study conducted [**37**], reported that the concentration of the Cd at 10 µg g-1 in the soil did not have any significant change in the soil enzyme, while the addition of Cd at 50 µg g-1 resulted to the reduction of soil enzyme activity. This study reported that the greatest effects of Cd on enzyme activities were higher in sandy loam compared in loam or clay loam soils [**39**]. Also found that the activities of urease were completely disappeared with 2,000 µg of heavy metals like (Cu2 + and Zn2+) g^{-1}.

Table 1: Heavy metals effects on soil

Heavy metals	Effects on soil	References
Lead (Pb)	Shortage of soil macronutrients like Phoosphorus	**[20, 37]**
Cadmium (Cd)	Abnormalities in the metabolic function of organisms.	**[36, 37]**
Zinc (Zn)	Phytotoxic and can directly affect soil fertility	**[40, 43]**
Copper (Cu)	Reduced the availability of soil N and S for crop production Inhibit the activity of β-glycosidase more than the activity of cellulose	**[37]**
Mercury (Hg)	Abnormalities in the metabolic function of organism	**[36]**

3.2 The harmful effects of heavy metals on Plants

The plants growing in the Municipal Solid Waste landfill and its surroundings are associated with heavy metals contamination that can affect food chain [**44**]. Heavy metals can affect the plants in so many ways (Table 2). Heavy metals are indestructible and have global environmental impact. Heavy metals are one of the major types of the pollutants that are found on the surface and in the tissues of the fresh vegetables [**42**]. Some heavy metals can function as the plant nutrients depending on their concentration in the environment, others like Hg, Pb, Cd, Ag and Cr distributed by the human activities and contributes to the toxic effects

even at low concentrations [**45**], documented that the uptake and accumulation of the heavy metals in the plant tissue depend on various factors, such as a temperature, humidity, organic matter, pH and nutrient availability. This study reported that the absorption and accumulation of the some metals like Cd, Zn, Cr and Mn in the spinach were found higher during the summer, while Cu, Ni and Pb accumulated more during the winter. It is estimated that rate of the decomposition of the organic matter during the summer was most likely to release heavy metals into soil solution for the possible plant uptake. The higher assimilation of the heavy metals like Cd, Zn, Cr and Mn in summer was expected to be caused by a high sweating while in the winter heavy metals accumulation rate expectation is due to the high ambient temperature and low humidity [**41**].

Table 2: Heavy metals effects on crops/plant

Heavy metals	Effects on crops	References
Lead (Pb)	Seed germination by gradually slowing down the seed germination	**[48]**
Cadmium (Cd)	Poisoning the soil and this affects the production of phytochelatins due to obstruction of the transporter/channel for loading other elements and an imbalance of plant nutrients	**[50]**
Zinc (Zn)	Phytotoxic and can directly affect crop yield, Affects the growth of pea plants	**[42]**
Copper (Cu)	Reduced the availability of soil N and S for crop production, Inhibit the activity of β-glycosidase more than the activity of cellulose	**[1, 37]**

The heavy metals uptake by the plants and their subsequent accumulation in food chains is a risk to animals and human health. In this case, mobile heavy metals cause serious pollution problems because of their easy absorption by the plants and enter food chains or contaminate groundwater [**46**]. Some of the factors influencing the uptake of the heavy metals by the plants are metals species and plant species. As documented by several earlier scientists, vegetables, especially leafy vegetables grown in the soil contaminated with heavy metals accumulate the high amounts of the metals through their leaves [**47**]. Heavy metals at the excessive level are harmful to the plant growth, they can cause oxidative stress in the plants and damage cell structure by a replacing defective elements with toxic heavy metals and inhibiting photosynthetic reactions in the plant cells. Furthermore, heavy metals affect seed germination and reduce the possibility of the harvest production. Heavy metals cause the detrimental effect on the plant growth compared to the other environmental stresses. Some enzymatic activities like have been delayed due to the Nickel toxicity and therefore affect the plant germination and plant growth. Nickel can result to the plant height reduction, roots length reduction, the decrease of the chlorophyll content, reduction of the photosynthetic pigments and accumulation of Na+, K+, and Ca2+ in the plant. Heavy metal potential toxic effects and phytotoxicity in the plants lead to chlorosis, poor plants growth and plant depression but also

associated with the reduced nutrients uptakes, plant metabolism disturbance and reduced ability to the repair molecular nitrogen in the leguminous plants [**16**]. The main harmful impacts of the heavy metals on the plant are discussed in Table 2.

4. Remediation technics of soil contaminated with heavy metals

The heavy metals are unspoiled and if introduced in the soil, they overstay. Soil is a biochemical and geochemical heterogeneous complex material or composition [**20**], therefore it holds heavy metals longer than air or water [**51**]. There are various techniques available for the restoring contaminated soil by the heavy metals. Remediation technologies usually involve physical, chemical and biological processes as discussed. It is shown in Table 4 that the first technique in the remediation is engineering remediation. In engineering remediation, the method is by the adding a huge number of clean soils to cover the polluted soil and to blend with the latter [**52**]. The soil removal and isolation are by the involving the removal of the polluted soil and renewing it with clean soil, this method is necessary for the seriously contaminated soil with the small area. The next method is by the soil electro kinetic remediation, which involves the DC-voltage to produce the electric field gradient on all sides of the electrolytic tank which holds the polluted soil and works well in the low permeability soil [**53**]. Other method is by involving cleaning of the contaminated soil with certain reagents thereby remove heavy metals complexes and dissolved Fe adsorbed on solid-phase particles. The last method is by the fixation or adsorption by the clay minerals for example bentonite, zeolite or so forth [**54**]. Table 4 also shows the bioremediation technique which involves phytoremediation or microbial remediation. The phytoremediation involves the growing of the particular plants in the contaminated soil for the example cruciferae plants such as the genus Brassica and Alyssums etc [**55**]. These types of the plants must have certainty hyper accumulation capacity for the contaminants in the soil, where most important key here is to found the plants with strong capability to accumulate or tolerate heavy metals [**30**]. The mechanism of the phytoremediation is by the plant resistance of the producing proteins and expressing the detoxifying enzyme or nucleic acid, the mechanism is integrated with the plant protection against injury [**49**]. Another mechanism is by the production of the phytochelatins by the plants which binding the heavy metals and sequestering the compounds inside the cell so the heavy metals cannot disturb cell metabolism [**52**]. On the other hand, microbial remediation involves the use of the several microorganisms to carry out the absorption, deposition, oxidation or reductions of the heavy metals in the soil with main bio-remediator are bacteria, archaea or fungi [**56**]. Many ions in the microbial cell surface functional groups such as the nitrogen, oxygen, sulfur or phosphorus can be substituted with the metal ions called as the coordination atoms [**52**]. Heavy metals pass through the cell membrane wall of the microbial remediation microorganism which are negatively charged or carry the cationic group [**36**].

CONCLUSION

This narrative overview discussed the harmful effects of the heavy metals concentrations in the soil or crops grown around landfills. The excessive increase in the waste entering landfills the accumulation of the heavy metals in landfills seep toward the surrounding area, contaminating the soil or absorbed by the plants. Heavy metals reaching in the soil result to the soil quality deterioration or decrease the soil fertility contaminate groundwater and irreparable damage of soil biota. The high concentration of the heavy metals in the soils is reflected by the concentrations of metals in plants, water, animal and human bodies. The soil contamination around the landfill implies the food contamination harming the human health. This is a serious issue that requires emergency attention or action. Since slight changes in their concentration above the acceptable levels result in the serious environmental and subsequent health problems. The regular monitoring or awareness are needed to the ensure separation of the waste before dumping to reduce elevated levels of pollution. Besides, it is advised to stop the continuous cultivation of consumable crops in the vicinity of dumpsites before implementing the necessary techniques to reduce the heavy mental pollutants in the soil.

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