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Assessment, Accumulation, Toxicity and Importance of Heavy Metals in Agricultural Soil and Living System - Review

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Abstract: Heavy or toxic metals are metals which are harmful beyond the permissible level to human health and are heavier in density than water by more than five times. Living organisms require varying amounts of heavy metals. Heavy metals like copper, manganese, cobalt, iron, zinc and molybdenum are required by living organisms in a small amount. Soil is a crucial component of rural and urban environments, and in both places land management is the key to soil quality. This paper review was aimed to touch the accumulation, assessment and importance of some heavy metals in agricultural soils and to understand the present situation and the impact of heavy metal contamination of soils in the world, in this review, compare and analyze the contamination of various cities/countries, and explore background, impact and remediation methods of heavy metal contamination of soils. Their accumulation in crops and pollution to soil can decrease crop yield, quality and cause detrimental effect to human health through food chain. Heavy metals can enter to human through inhalation, ingestion, body contact and skin absorption. In recent years, with the development of the global economy, both type and content of heavy metals in the soil caused by human activities have gradually increased, resulting in the deterioration of the environment.

Keywords: Heavy Metal, Soil, Contamination, Anthropogenic, Pollution

1. Introduction

Heavy metals are natural constituents of earth crust and they are generally found in low concentration. These metal elements, are lead (Pb), cadmium (Cd), arsenic (As), they have toxic effects on human health at higher concentration. Anthropogenic activities have also increased metals concentration in the environment. Due to the increment growth of population, high industrialization, urbanization and expansion of agricultural practices environmental pollution is also raising [1]. Heavy metals are distributed by atmosphere within a distance and transported up to several kilometers away from their sources and transferred to the soil through wet or dry deposition [2]. Heavy metals in soils have been considered as powerful tracers for monitoring impact of anthropogenic activity such as industrial emission (cement plant, fossil fuel and coal combustion chemical plants), vehicular emission, and atmospheric deposited. These lead to emission of heavy metals into the air and their subsequent deposition into soils [3]. Toxic metals can accumulate persistently in the body over a lifetime. Heavy metals are metallic and semi-metallic (metalloids) chemical elements of high density (> 5 g/cm^3) with most of them toxic and carcinogenic even at low concentrations. There are elevated levels of heavy metal in soils in many areas of the world, especially in developing countries and regions. Widely known heavy metals are mercury, cadmium, arsenic and chromium [4]. Heavy metals are naturally occurring elements in the soil environment due to pedogenic process of rock weathering, and are generally present at trace levels. One of the most important sources of air pollution is vehicle emission. Metals such as Fe, Cu and Zn are essential components of many alloy, pipes, wires and tires in motor vehicles and are released into the roadside environment as a result of mechanical abrasion [5].

2. Literature Review

2.1. Heavy Metal Persistence in Soil and Living Organisms

Soil is composed of mineral constituents, organic matter, living organisms, air and water, and it regulates the natural cycles of these components. Some lists of them are Fe, Mn, Ni, Co, Zn, Cu, Cr, V, Ti, Cd, Hg, Mo and other trace metals as well as As, Se and F occur naturally in soils, which are formed by geological processes. Heavy metals enter the surroundings and into the living system by natural means and through human activities. Heavy metals are impossible or difficult to destroy biologically in a living system, but they can be transformed from very toxic form to less toxic one [6]. Heavy metals can be readily taken up by vegetable roots, and can be accumulated at high levels in the edible parts of vegetables, even heavy metal in soil at low levels. Moreover, heavy metals enter food chains from polluted soil, water and air, and consequently cause food contamination, thus posing a threat to human and animal health.

2.2. Importance of Heavy Metals

Some heavy metals exist in the environment with different oxidation states and their toxicity has a great relation with their oxidation number and they are beneficial for ecosystem. These heavy metals are mostly derived from many sources and inhibit the whole ecosystem [7]. Industrial waste contain high concentrations of heavy metals, when added to water bodies and dispersed in irrigation water caused serious type of environmental pollution, causing bad effects on whole biota and ultimately causing a threat to the human being. Some heavy metals are biologically essential even then in excess they become toxic strongly, such type of metals pollution causes inhibition of plants growth and it is highly toxic to plants cells and cause death. Some heavy metals are essential to microbial functions in soil at an acceptable levels and conversely at toxic levels [8].

2.3. Accumulation of Heavy Metal in Soil

Soil is of major importance for life since it represents a source of both water and nutrients for plants and soil-living microorganisms and animals. Soil is a crucial component of rural and urban environments, and in both places land management is the key to soil quality. The concentration of heavy metals in soil is influenced by various physicochemical characteristics of soil such as pH, particle size distribution, organic matter, cation exchange capacity, and moisture content of the soil [9]. Mining, manufacturing, and the use of synthetic products (e.g. pesticides, paints, batteries, industrial waste, and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils. Heavy metals also occur naturally, but rarely at toxic levels. Excess heavy metal accumulation in soils is toxic to humans and other living organisms. Acute/immediate poisoning from heavy metals is rare through ingestion or dermal contact, but is possible. Preventing heavy metal pollution is critical because cleaning contaminated soils is extremely expensive and difficult. Heavy metal accumulation in soil is of concern in many countries due to the impact this can have on food quality and soil health [10]. It does not explicitly damage the environment in a short period once the soil suffers from heavy metal contamination; it is difficult to be remediated. If the air and water are polluted, the pollution problem can be reversed certainly by dilution and self-purification after switching off the sources of pollution. But, it is difficult to use dilution or self-purification techniques to eliminate heavy metal contamination and to get soils improved [11]. Heavy metals are currently of much environmental concern. They are harmful to humans, animals and are susceptible to bioaccumulation in the food chain. Soil pH is a major determinant of metal mobility in the soil, as pH decreases the solubility of the metal cation increases due to desorption from soil minerals such as carbonates, metal oxides and hydroxides [12]. Industrialization movement and population increment, deforestation results in changes in the composition and quantity of heavy metals in the soil and food chain system which adversely affects human health.

Mostly anthropogenic activities and in less amount natural process increases the accumulation of heavy metals which involves emission of different toxic metals from industries, disposal of sewages and municipal solids, petrochemical spillage, application of different fertilizers, and pesticides, coal combustion and processes that takes place in different garages. Soil contamination occurs as a result of pesticide use/production, leakage of hazardous chemicals to the environment from industries, mining, petroleum exploration and storage which indicates their accumulation/concentration is beyond the permissible level that leads to threatening of human and other organisms' health [13]. Heavy metals contamination of soils becomes a severe issue around the world as a result of anthropogenic activities that been emitted into atmosphere as aerosols and distributed in soil [14].

Fertilizer is used to increase production and income of the producers to sustain the economic development, currently, fertilizer application became a mandatory to increase productivity, which contains some impurities. As a typical example, phosphorus fertilisers contain other impurities such as arsenic, chromium, strontium, uranium and zinc [15]. There is a high risk that these heavy metals may be released to food chain via plant uptake over a time and harm human health. Compared with inhalation of soil particles, drinking water, and dermal contact, food consumption has been identified as the major pathway for human exposure to toxic metals particles, drinking water, and dermal contact, food consumption has been identified as the major pathway for human exposure to toxic metals [16].

Formal limits for maximum heavy metals concentration in soil are relevant to agricultural land use, because they are one of the uptake parameter that represents total heavy metal concentration.

2.4. Cadmium (Cd)

Cadmium is a soil contaminant that is naturally present in phosphate fertiliser and this element has built up in soil with time. Chronic Cd exposure can cause acute toxicity to the liver and lungs, induce nephrotoxicity and osteotoxicity, and impair function of the immune system [17].

2.5. Copper (Cu)

Copper is a naturally occurring metal in soil that can also be introduced by human activities. Mining activities, metal production, wood production, phosphate fertiliser production and use of agrochemicals in horticultural soils are human-influenced sources of copper in agricultural soils. Most copper compounds complexes strongly with organic matter and water-soluble species pose a threat to the environment [18]. Metal elements such as copper (Cu) and zinc (Zn) are important nutrients for humans, but excessive ingestion can also have adverse effects on human health [19]. Copper surplus can cause acute stomach and intestine aches, and liver damage, and Zn can reduce immune function and levels of high-density lipoproteins.

2.6. Lead (Pb)

Lead is usually scarce but occurs naturally in the environment or through industry and transportation combustion processes [18]. Human can be exposed to lead through food (such as vegetables, meats, grains, seafood, soft drinks and wine), water and air (especially cigarette smoke) and it is extremely toxic metal that can damage human health. Pb can adversely influence the intelligence development of children, cause excessive lead in blood, and induce hypertension, nephropathy and cardiovascular disease [20].

Table 1. *Ranges of Heavy metals in New Zealand farmed (pastoral) and non-farmed soils at 0 – 100mm (Edmeades, D.C. (2013). The Taranaki landfarms; are they "fit for purpose". A report commissioned by Taranaki Regional Council. 24pp).*

Element	Farmed soils	Non-farmed soils
	mg/kg	
As	3-9	3-5
Cd	0.1-0.8	0.1-0.14
Cr	8-18	8-12
Cu	10-20	10-16
Pb	6-16	9-16
Ni	4-14	4-14
Zn	7-79	28-66
Hg	0.07-0.20	0.11-0.19

From the study it was reported higher concentrations of arsenic in farmed soils than other land use; higher cadmium and copper concentration in horticultural soil than other land uses which could be as a result of applied fertilizer impurities while lead concentrations were generally higher in horticultural soils followed by orchard, vineyards, market gardens, with pastoral soils having the lowest concentration [21]. This excessive accumulation of heavy metals in agricultural soil due to anthropogenic and natural processes can lead to elevated heavy metal uptake by food crops and hence a risk to human health via food crop consumption

Table 2. *Heavy metal concentrations (mg/kg) Pollution index (PI) of soil.*

Heavy metal	No. of samples	Concentration			Pollution index values		
		Min	Max	Mean	Min	Max	Mean
Cu	18	26.7	0.38	240.59	22.42	0.01	9.01
Pb	18	19.4	0.39	27.47	2.58	0.02	1.40
Cd	18	0.12	ND	0.63	0.06	ND	5.25
Cr	18	49.3	0.64	3.92	1.43	0.01	0.08
Ni	18	26.6	0.69	2.40	1.57	0.03	0.09

ND – not detected, CNEMC, 1990. CNEMC (China National Environmental Monitoring Centre) (1990). The background values of Chinese soils, Environmental Science Press of China, Beijing.

As indicated in the above Table, eighteen soil samples collected from whole Perlis state were analyzed for Cu, Cr, Ni, Cd and Pb. Cr, Ni and Pb concentrations in soil were lower than allowable limit, whereas Cu and Cd concentration exceeded their corresponding values. Heavy metal concentrations were assessed using pollution index (PI). In respect of Pollution index only Cu (11%) and Cd (6%) were classes as heavily contaminated. From this result, found that level of heavy metal in soil near centralized Chuping industrial areas give maximum value compared with other location in Perlis. Results of combined heavy metal concentration and heavy metal assessment indicate that industrial activities and traffic emission represent most important sources for Cu, Cd and Pb whereas Cr, Ni mainly from natural sources.

3. Conclusion

The concentration of heavy metal in soil influence by various sources such as anthropogenic and naturally. Consequently, it is imperative to continually assess and monitor the levels of heavy metals in the environment due to anthropogenic activities for evaluation of human exposure and for sustainable environment. Increasing of human activities influences on the environment, typically, pollution have caused negative changes in natural ecosystems, decreased biodiversity, simplified structure and lowered productivity. The level of heavy metal concentration in the soil in different areas of the World differs as the source of each metal and the amount at each places vary and the methods, instruments, some reagents used to analyze these metals also differs. Accumulation of heavy metals often results in soil/water degradation and ecosystem malfunction

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