6 Soil Deterioration and Risk Assessment of Heavy Metal Contamination

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Abstract

Soils establish an understructure of ecological processes such as nutrient cycling, primary production, climate variables, biophysical habitats, species interaction, etc. Such an important part is vulnerable to various kinds of pollution, and one of them is heavy metal contamination. Soil gets contaminated with heavy metals through natural as well as anthropogenic sources. The former one includes weathering, volcanoes, wind, soil erosion, and wind storms, while the latter one includes mining, dumping of waste having heavy metals into landfills, fertilizer and pesticide application, coal combustion, sewage sludge, and petrochemicals. Almost 80% of heavy metal wastes in India are contributed by Gujarat, Andhra Pradesh, and Maharashtra. Heavy metals such as Fe, Zn, Cu, Mn, and Co are essential for improving soil health, but their excess amount could lead to contamination which affects soil hydrology, chemistry, and biota. Factors such as geoaccumulation index methods, ecological risk index (RI), and contamination factor (CF) are used to assess the anthropogenic influence of heavy metals on the soil. Physicochemical parameters such as pH, TOC, and texture govern the mobility and retention of heavy metals into agricultural soils. Phytoextraction is proven to be a realistic approach for mining heavy metals from soil. For instance, alkalinity decreases mobility and retention of heavy metals in soil, while loamy soils show better drainage and lower retention of heavy metals than clay soils. This chapter aims to yield decision-making information regarding agricultural soil quality in relation to risks associated with human health and the environment.

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R. P. Singh et al. (eds.), *Heavy Metal Toxicity: Environmental Concerns, Remediation and Opportunities*, https://doi.org/10.1007/978-981-99-0397-9_6

Keywords

Agricultural soil · Pesticides · Ecological risk · Health risk

6.1 Introduction

The development of a man-made world comes at the cost of the degradation of environmental matrices. The air we breathe, the water we drink, and the Earth on which we live are immensely contaminated with heavy metals. Soil is characterized as nonrenewable resources that socialize ground, water, and air. Most of the soil is heavily contaminated with heavy metals that led to an increase in metal concentration in the environment (Cocârță et al. 2016). Agricultural soil contamination with heavy metals (Ennaji et al. 2020) has become a notable issue that needs not only our attention but a solution to work upon. The chemical way of defining heavy metal pollution is as follows: metal and metalloids that have an atomic mass more than 20 and specific gravity more than 5 are referred to as heavy metals, e.g., chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb). On the other hand, in the perspective of biologists, heavy metals refer to those metals that are toxic for animals and plants when present even in less concentration (Li et al. 2019).

Heavy metals originate from anthropogenic as well as geogenic activities (Gayathri et al. 2021). Anthropogenic activities such as mining of gold, nickel, and copper, tailing, and dumping of wastes from mines have generated significant effects on ecology and human health (Hadzi et al. 2019). Detailed discussions on heavy metal contamination due to anthropogenic activities are covered in forthcoming sections. Natural sources of heavy metal pollution, despite being the primary source in soil, are less important when compared with anthropogenic sources (Li et al. 2019) as anthropogenic activities contribute more to metal pollution in soil (Zhuang et al. 2013). Natural sources arise from parent rock material which weathers and contributes to heavy metal pollution in soil. It is a slow geogenic process. Their efficiently persistent nature, irreversible quality, toxic characteristics, and tendency to bioaccumulate make them of utmost importance (Huang et al. 2017). The ability to persist in the environment for a long time is supported by their ability to resist biodegradation and thermodegradation (Kumar et al. 2019). Soil acts as the main sink for heavy metal accumulation (Yadav et al. 2018) which makes it the important matrix to be researched for remedial approaches and health risk assessment. Soil can hold heavy metals up to 1000 long years (Baharani et al. 2022). Soil matrix contaminated with heavy metals was studied for remediation using physical, chemical, and biological methods which is discussed in detail in later sections. Adults and children are exposed to soil dust from which heavy metals can accumulate into their tissues via ingestion, dermal contact, and inhalation (Ihedioha et al. 2017). Crops growing on such contaminated soil can be one of the major routes through which heavy metals can lead their way into the human intestine and result in fatal diseases (Fig. 6.1).

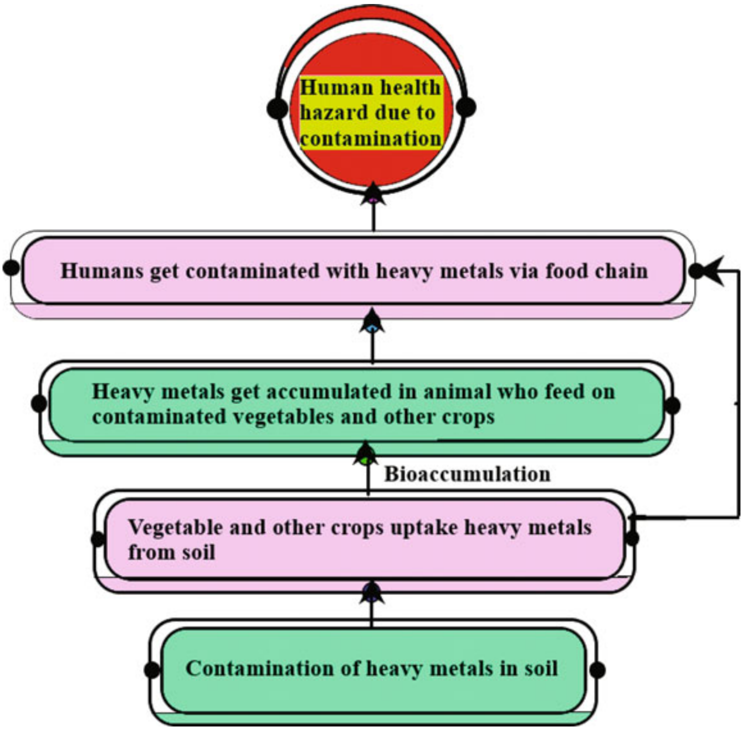

Fig. 6.1 Bottom-up approach showing the impact of heavy metals on food chain

6.2 Source of Heavy Metal in Agricultural Soils

Soils and plants need some of the essential nutrients for their steady growth. Nutrients like Zn, Cu, Fe, Mn, and Ni are referred to as essential micronutrients (Fageria et al. 2009). Hence, these nutrients when present in excess level impart their toxic characteristics. A few toxic characteristics such as growth suppression, cutback in crop yield, quality degradation, and health risk to humans and animals (Seth 2012) arise due to the accumulation of such metals in larger quantities. The entry of heavy metals in agricultural soils refers to both natural and anthropogenic origins (Fig. 6.2).

6.2.1 Natural Source

Earth's crust is made up of 95% igneous rocks and the rest 5% constitutes of sedimentary rocks. Igneous rocks are further divided into two types, that is, intrusive and extrusive igneous rocks. Intrusive igneous rocks encompass loads of heavy metals such as Ni, Cu, Zn, Cd, and Co (Sarwar et al. 2017; Li et al. 2019). Sedimentary rock mainly constitutes heavy metals such as Mn, Cu, Zn, Pd, and

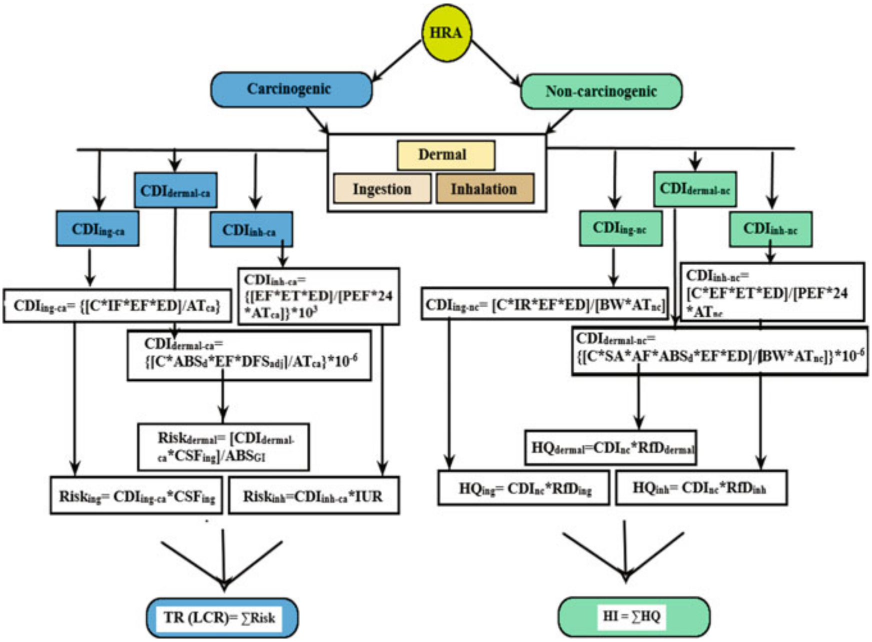

Fig. 6.2 Schematic representation of approaches followed in health risk assessment (HRA) C = metal concentration (mg/kg); IF = intake factor (mgyr/kg/d); EF = exposure frequency (d/yr); ED = exposure duration (yr); AT_{ca} = average time for carcinogens (d); IR = ingestion rate (kg/d); BW = body weight (kg); ET = exposure time (h/d); PEF = particulate emission factor ($m^3 kg^{-1}$); ABS_d = dermal absorption factor (no unit); DFS_{adj} = soil dermal contact, age-adjusted (mgyr/kg/d); SA = skin's surface area ($cm^2 event^{-1}$); AF = soil-skin adherence factor (mg/cm^2); CSF_{ing} = chronic oral slope factor; IUR = inhalation unit risk; ABS_{GI} = gastrointestinal absorption factor; HQ = hazard quotient; nc = noncarcinogenic; ca = carcinogenic; RfD = reference dose (mg/kgday); TR = total risk; LCR = lifetime cancer risk; HI = hazard index

Cd. Hence, soil when formed from igneous and sedimentary parent material constitutes a larger fraction of these metals. The movement of heavy metals from parent rock to soil felicitates through natural phenomena such as biogenic, meteoric, terrestrial, volcanic processes, wind, erosion, and leaching (Li et al. 2019). However, these processes occur very slowly in nature which got disturbed by anthropogenic activities as discussed in the next section.

6.2.2 Anthropogenic Source

Increased level of heavy metal contamination in soils is the result of upgradation in human lifestyle. The current lifestyle of rural as well as urban people, younger as well as older generation, demands advancement in the industrial and agricultural sector. These advancements lead to heavy metal contamination. Some anthropogenic sources are as follows:

6.2.2.1 Mining

Mining and connected smelting processes are major sources of heavy metals in soil. Extensive mine waste piles generated from milling accumulate on the ground surface. Particles of soil loaded with heavy metal have the tendency to move over 20 km from the starting point (Beattie et al. 2018). Sometimes, tailing may contaminate the surrounding soil through wind and water disposal as it contains metals (Hadzi et al. 2019). Other mining processes such as grinding and concentration of ores also release chunks of heavy metals into the atmosphere which pave their way to soil. Mining of gold through artisanal and small-scale gold mining releases more than 30% of mercury across the globe (Fernandez-F et al. 2022).

6.2.2.2 Sewage Irrigation

Urban sewage is a house to the majority of industrial and household discharges. These wastes are loaded with chemical and organic residues. The sewage coming out of industries and households is further utilized for irrigation of agricultural lands. The chemical and organic pollutants present in water used for irrigation infer with agricultural activities. This interference leads to yield reduction (Dorak 2020). Sewage coming out of stainless industries has a major content of Cr and Ni. Thus, paving their way to agricultural fields through sewage irrigation, these metals get concentrated in agricultural soil (Su et al. 2022). Zn, Al, Cr, and Fe residues were identified in the wastewater coming out of tannery industries (Appiah-Brempong et al. 2022). Therefore, agricultural land when irrigated with such wastewater tends to get contaminated with heavy metals.

6.2.2.3 Application of Pesticides

Organic fertilizer contains large amounts of copper (Su et al. 2022) and Zn (Ennaji et al. 2020). Application of fertilizer throughout the year has led to the accumulation of heavy metals such as Cd, As, and Pb, as these fertilizers contain heavy metals (Yokel and Delistraty 2003).

6.2.2.4 Traffic Emission

Heavy metals such as Pb enter the soil through vehicular emissions (Mielke et al. 2010). Fuel combustion in automobiles that run on the road along with the wearing of tires that produce cadmium powder moves toward soil causing heavy metal pollution in soil (Turer et al. 2001). The movement of heavy metal emission from road toward soil is supported via rainfall runoff.

6.2.2.5 Waste Dumping

Dumping of waste in India has no control. Wastes containing heavy metals are dumped so carelessly without any segregation. The expansion of cities has left no gap between these dumpsites, agricultural areas, and residential societies. The leachate from these dumpsites can travel via geological process carrying loads of heavy metals in it to agricultural areas contaminating the soil. Dumped stainless steel, rechargeable batteries, fabrics, leathers, electrical appliances, paint materials, gasoline, and discarded mechanical parts contribute to heavy metal contamination released from wasteyards (Ihedioha et al. 2017).

6.3 Current Status of Heavy Metal Contamination in Different Land Use Pattern

Soil is heavily polluted with heavy metals. All the above sources contribute to soil pollution at a global scale. The extent of the abovementioned activities is increasing continuously. The quality of the soil once degraded cannot regain its original strength. However, there are solutions available for reclamation of such degraded land through remediation approaches (Prathap et al. 2022). The soil from the coal mine dumpsite area was found to be heavily contaminated with heavy metals such as Fe, Mn, Zn, and Ni. The researchers are now trying to find out the removal strategies of over-dumped soil via plant management. Some of the plants that showed positive results are *C. dactylon*, *E. binata*, *L. indica*, and *C. oblongifolius* (Prathap et al. 2022). The agricultural soil irrigated with river water was found to be contaminated with heavy metals such as Fe, Mn, Zn, Cu, and Ni, but their concentrations were below the standard limit prescribed by regulatory bodies (Singh et al. 2021). However, metals such as As, Cr, and Pb were found to exceed their threshold in the hazardous waste disposal sites of Hyderabad (Parth et al. 2011). According to other reported studies, Pb makes one of the most potent toxic elements among other heavy metals such as Cd, Ni, Cr, Zn, and Cu. Pb has exceeded the permissible limits set by WHP/FAO 2007 and Indian standard in soil (Devi and Yadav 2018; Sonu et al. 2019). The kinds of research work that are published now are significantly different from the ones that used to be published 10 years ago. There is a huge sense of responsibility that can be seen in current research papers as they are not only monitoring the concentration levels but also adapting new approaches for remediation of contaminated sites. A study from agricultural soils in Kerala found elevated concentration of Pb in the soil and with their research work provided some of the plant species that could assist in the lead accumulation such as *D. chinensis* L., *C. indicum* L., *L. camara* L., and *R. simplex* C. (Arathi et al. 2021). Several other studies also worked on monitoring and remediation of heavy metals from soil (Adimalla et al. 2020; Bhat et al. 2021; Yadav et al. 2021; Vasudhevan et al. 2022). The concentrations of heavy metals in major parts of the country that are well researched are shown in Table 6.1.

Part of the lands located outside India has been well researched with the contamination of heavy metals (Table 6.2). The soils of the dumpsite were mentioned to be largely contaminated with Fe and Zn (Ihedioha et al. 2017). Agricultural soils were found to be contaminated with Cu and Zn because of the pesticide uses (Li et al. 2009; Ennaji et al. 2020). Urban soil showed extremely high concentration of Pb in Malaysia (Praveena et al. 2015). Agricultural soil of Romania region was found to have high concentration of Cd, whereas in Nigeria agricultural soils were found to have very less Cd concentration (Cocârță et al. 2016; Ogunlade and Agbeniyi 2011). This implies that the concentration of heavy metals varies from region to region

Table 6.1 Heavy metal contamination in soil from India (mg/kg)

Location	Soil type	Fe	Mn	Cu	Ni	Pb	Zn	Cd	As	Cr	Co	Hg	References
Bokaro, Jharkhand	Coal mine dumpsite	17817.8	278.513	–	8.37	4.6	38.07	–	5.76	–	-	–	Prathap et al. (2022)
Kali River, Uttar Pradesh	Agricultural	86.45	53.65	33.95	22.1	12.53	75.68	0.75	–	9.54	-	–	Singh et al. (2021)
Kazipalli, Hyderabad	Waste dumpsite	–	–	35.2	48	206.4	122.3	–	51.7	127.9	-	–	Parth et al. (2011)
Kopargaon area, Maharashtra	Agricultural	3.929	6.76	2.284	0.595	1.328	0.936	0.682	–	–	-	–	Patil et al. (2022)
Kozhikode, Kerala	Agricultural	–	–	–	–	0.19	–	–	–	–	-	BDL	Arathi et al. (2021)
Ludhiana, Punjab	Agricultural	19.6	8.61	1.16	0.61	5.72	4.36	0.2	–	0.39	0.23	–	Dhaliwal et al. (2021)
Patna, Bihar	Agricultural	–	417.73	49.604	–	24.454	136.952	–	–	–	–	0.445	Sonu et al. (2019)
Patna, Bihar	Roadside			143	165	984	713	9.50	–	55.5	–	–	Devi and Yadav (2018)
Ranga Reddy, Telangana	Urban	-	–	40.64	7.55	47.48	34.68	–	–	43.24	16.54	–	Adimalla et al. (2020)
Salem, Tamil Nadu	Agricultural	28.69	8.45	2.79	1.28	1.99	1.59	0.12	–	–	–	–	Vasudhevan et al. (2022)
Shahjahanpur, Uttar Pradesh	Agricultural	6.388	8.77	0.3	–	–	0.633	–	–	–	–	–	Yadav et al. (2021)
South Kashmir	Agricultural	–	–	29.46	41.46	22.6	82.87	0.128	8.99	110.06	18.71	–	Bhat et al. (2021)

Table 6.2 Heavy metal contamination in soil elsewhere in the world (mg/kg)

Location	Soil type	Fe	Mn	Cu	Ni	Pb	Zn	Cd	As	Cr	Co	Be	References
Akwa Ibom, Nigeria	Dumpsite	1804	91.2		11.82	11.8	146	12.2	–	4.05	–	–	Ihedioha et al. (2017)
Bahr El-Baqar, Egypt	–	–	–	122.96	67.83	43.096	133.25	12.702	–	111.57	–	–	Omran and Abd El Razek (2012)
Central Romania	Agriculture	–	–	–	50.68	704.22	–	23,083	–	27.29	–	0.15	Cocârță et al. (2016)
Cross River State, Nigeria	Agriculture	–	–		0.42	0.86	–	0.05	0.02	1.22	0.61	–	Ogunlade and Agbeniyi (2011)
Hunan Province, China		–	–	25.07	27.63	802.58	689.66	6.13	84.85	–	–	–	Huang et al. (2017)
Jilin Province, China	Metal dump, coal gangue	–	–	21.563	–	20.97	65.5	0.153	–	69.68	–	–	Jiang et al. (2014)
Nepal	Urban soil	1190	1870	277	121	137	1020	1.1	4.5	309	46	–	Yadav et al. (2018)
Neyshabur, Iran	Industrial	–	–		15.77	57.33	–	1.9	8.84	37.66	–	–	Mohammadi et al. (2020)
Seri Kembangan, Malaysia	Urban soil	–	–	–	–	2668.8	–	47.5	13.57	74	–	–	Praveena et al. (2015)
Shenyang, China	Agriculture	–	–	18.47	–	29.81	110.27	1.99	–	–	–	–	Li et al. (2009)
Tadla plain, Morocco	Agriculture	19249.3	–	138.1	–	31.72	162.11	0.92	–	32.0.72	–	–	Ennaji et al. (2020)

despite the same type of soil. A meta-analysis of heavy metal pollution in China showed the higher trend in southeast China whereas the lower trend in northwest China. The concentrations of Cd, Hg, Zn, Cu, and Pb were higher in vegetable and paddy sites (Huang et al. 2019).

6.4 Health Risk Assessment of Heavy Metals

Soil when contaminated with heavy metals has a high chance to pass it to higher organisms present at trophic level. Humans constitute the highest group of trophic level; hence, being the last repository, there is a maximum chance to get affected by harmful effects of heavy metals. Metals such as Cr, Cu, Pb, and Zn are known to cause detrimental health issues (Karim and Qureshi 2014). The severity of these issues can only be determined by performing the health risk assessment for available metals in the environment. Health risk assessment of humans can be defined as a process involving mathematical calculations that help in the estimation of likelihood of damages incurred to populations that had been exposed to pollution (Oves et al. 2012). In this process, the ways by which the population gets exposed to pollution and harmful effects of pollutants are assessed. The health risk assessment is an important parameter for decision-makers as it helps them give a new perspective for defining new policies or refining the existing ones. Now, different researchers followed different approaches for the assessment of health risks, but the parameters of calculating the risk is the same in every research article (Karim and Qureshi 2014; Qu et al. 2012; Adimalla and Wang 2018; Baltas et al. 2020; Kacholi and Sahu 2018). For assessing the human health risk of heavy metals in soil, four steps can be followed: the first one is to identify the hazard followed by dose-response assessment. The next step is the assessment of exposure, and the last is to characterize the risk (Koki et al. 2015). In most of the study, the population is exposed to heavy metals present in the soil through skin or dermal contact, inhalation, and ingestion of soil, dust, or agricultural crops and vegetables (Ma et al. 2018; Mohammadi et al. 2020; Praveena et al. 2015; Zheng et al. 2020). The human health risk assessment is divided into two pathways, carcinogenic and noncarcinogenic pathways. These two approaches are connected with the exposure pathways such as dermal, inhalation, and oral exposures. The schematic representation of calculating health risk is presented in Fig. 6.2.

6.4.1 Carcinogenic Risk

Carcinogenic risk is the risk associated with possible carcinogens that may lead to development of cancer in an individual exposed to it for an entire lifetime. The carcinogenic risk assessment can be calculated by multiplying chronic daily intake (CDI) with the individual metal's slope factor. Cumulative risks by dermal, inhalation, and ingestion exposure will result in lifetime cancer risk (LCR). The formula for calculation of CDI for each exposure phase is represented in Fig. 6.2.

6.4.2 Noncarcinogenic Risk

The noncarcinogenic risk is represented by hazard quotient (HQ). HQ is calculated by dividing chronic daily intake (CDI) (Fig. 6.2) by RfD of a specific chemical exposure. HQ can only be estimated for individual chemical exposure. But in the real environment, more than one exposure factor is responsible for the impact such as inhalation, ingestion, and dermal exposure. Therefore, concentration for single chemical exposure may be low within prescribed limits. But when two or more chemical's exposure combined together, the strength (impact in this case) increases. Hence, by combining individual HQ values, HI would be determined. If the overall value for HI is smaller than 1, this implies that the risk is not substantial, but if this value is greater than 1, it implies the occurrence of noncarcinogenic risk.

6.5 Ecological Risk Assessment of Heavy Metals

Ecological risk assessment is calculated to evaluate the affected biological communities in heavy metal-polluted areas (Kumar et al. 2019). The ecological risks imposed by heavy metals on soil and biological communities can be assessed by indices such as CF (contamination factor), EF (enrichment factor), and *I*geo (geoaccumulation) (Keshavarzi and Kumar 2020), P_N (Nemerow composite) and PERI (potential ecological risk indexes) (Cui et al. 2021), and PLI (pollution load index) and (bioconcentration factor) (Liu et al. 2014b). The indices mentioned above assess the extent by which the pollution level of heavy metals is spread over an area (Yahaya et al. 2021). These indices have different levels of classification according to their level of pollution and risk (Liu et al. 2014b; Mohseni-Bandpei et al. 2017; Olatunde et al. 2020; Cui et al. 2021) which is represented in Table 6.3. These indices are explained one by one in the following subsections.

6.5.1 Contamination Factor

The contamination factor is generally denoted by CF. CF is the measure of the pollution level of individual metal. It is the ratio of concentration of metal in the soil to the background concentration (concentration of metal in unpolluted soil) (Olatunde et al. 2020). CF value >1 indicates the contamination, and <1 indicates pollution of heavy metals (Yahaya et al. 2021):

$$\mathrm{CF} = \frac{Concentration\ of\ metal\ in\ soil}{Background\ concentration}$$

Table 6.3 Ecological risk assessment indices and their grades with the level of classification

Indices	Grades	Pollution level or risk level	References
Contamination factor	0	None polluted	Liu et al. (2014b)
	1	None to moderately polluted	
	2	Moderately pollution	
	3	Moderate to strongly polluted	
	4	Strongly polluted	
	5	Strong to very strongly polluted	
	6	Very strongly polluted	
Contamination factor	<1	Low risk	Mohseni-Bandpei et al. (2017)
	1–3	Moderate risk	
	3–6	Considerable risk	
	>6	High risk	
PLI (pollution load index)	<1	No pollution	Liu et al. (2014b)
	1–2	Moderate pollution	
	2–3	Heavy pollution	
	>3	Extremely heavy pollution	
Enrichment factor	<40	Low risk	Mohseni-Bandpei et al. (2017)
	40–80	Moderate risk	
	80–160	Considerable risk	
	160–320	High risk	
	>320	Very high risk	
PER (potential ecological risk index)	<65	Low risk	Mohseni-Bandpei et al. (2017)
	65–130	Moderate risk	
	130–260	Considerable risk	
	>260	High risk	
P_N index	<0.7	Safety state	Cui et al. (2021)
	0.7–1.0	Warning state	
	1.0–2.0	Slight pollution	
	2.0–3.0	Moderate pollution	
	>3.0	Heavy pollution	
I_{geo}	<0	Unpolluted	Olatunde et al. (2020)
	0–1	Unpolluted to moderately polluted	
	1–2	Moderately polluted	
	2–3	Moderately to strongly polluted	
	3–4	Strongly polluted	
	4–5	Strongly to very strongly polluted	
	≥5	Very strongly polluted	

6.5.2 Enrichment Factor

Not every researcher defines an enrichment factor in their research. Those who define it represent it as EF. EF is the ratio of proportion of metal in soil to the proportion of metal present in the Earth's crust (Yahaya et al. 2021):

$$\mathrm{EF} = \frac{Msample}{Resample} \Big/ \frac{Mreference}{Rereference}$$

where Msample and Resample are the contamination factors in polluted soil and Mreference and Rereference are the contamination factors in reference soil. EF assists in the estimation of potential pollution sources along with the impact of anthropogenic activities on contamination level in soil and associated human health (Kumar et al. 2019).

6.5.3 Pollution Load Index

The pollution load index, abbreviated as PLI, is used to find out the cumulative heavy metal pollution level of a particular site (Liu et al. 2014b). It is the geometric mean of CF of all the heavy metals studied for a site. Mathematically, it is expressed as:

$$\mathrm{PLI} = (CF1 * CF2 * CF3 * \ldots\ldots\ldots CFn)^{1/n}$$

where CF is the contamination factor and n is the number of metals identified for a particular site.

6.5.4 Nemerow Composite Index

Nemerow composite index also known as P_N index assesses the destruction in soil environmental quality due to heavy metal contamination (Cui et al. 2021). It is calculated using the following equation:

$$\mathrm{P_N} = \{[(Ci/Si)\max + (Ci/Si)ave]/2\}^{1/2}$$

where Ci = measured value of heavy metal i and Si = reference concentration of heavy metal i.

6.5.5 Potential Ecological Risk Index

PERI assists in environmental quality assessment. The effect of heavy metal pollution on biological communities can be assessed by potential ecological risk index and ecological risk factor (E_r). E_r is calculated for individual heavy metals, whereas PER is calculated for cumulative effect of heavy metals on soil quality (Mohseni-Bandpei et al. 2017):

$$E_r = \mathrm{T_r} \times \mathrm{CF}$$

$$\mathrm{PER} = \sum_{i}^{m} Er$$

where T_r = toxic factor for individual heavy metals and CF = contamination factor.

6.5.6 Geoaccumulation Index

This index is used to compare the present level of heavy metal contamination in soil with the past level concentrations. It is calculated for individual metal contamination (Tian et al. 2017; Yahaya et al. 2021). The geoaccumulation index represented as (I_{geo}) can be computed as:

$$I_{\mathrm{geo}} = \log_2[C_n/1.5B_n]$$

where C_n is the metal concentration in soil (mg/kg), B_n is the background concentration (mg/kg), and 1.5 is the constant that minimizes the lithogenic variation in background concentration. Anthropogenic contamination is depicted by the positive value of I_{geo}.

6.5.7 Bioconcentration Factor

Bioconcentration factor (BCF) determines the sharing amount of pollutant that the aerial part of the plant uptakes from soil. It is estimated by calculating the ratio of concentration of heavy metal present in plants to the concentration of heavy metals present in soil. Mathematically, it can be expressed as:

$$\mathrm{BCF} = C_{\mathrm{plant}}/C_{\mathrm{soil}}$$

where C_{plant} is the concentration of heavy metal in plant (mg/kg) and C_{soil} is the concentration of heavy metal in soil.

6.6 Heavy Metals and Soil Interaction

Soil is the end result of the weathering process. One of the natural sources of heavy metal is weathering of parent rock. During the soil development, a soil profile is formed which constitutes different soil layers starting with O followed by A, B, and

C. These layers are termed as horizons. The constituents of each horizon are different. For instance, O horizon consists of organic matter and other humic substances. A horizon (eluviation zone) is mainly composed of organic matter and minerals. The B horizon, often known as the alluviation zone, constitutes clay minerals. Fe oxyhydroxides are also present in the B horizon which has the ability to absorb heavy metals (Bradl 2005). C horizon is composed of weathered parent rock. Heavy metal's adsorption to the soil and its release from the soil depend upon conditions such as pH and redox (Bradl 2005). Metal sorption in the soil occurs at substantially lower pH as compared with the pH associated with metal hydroxide formation (form at pH 5.5 to 7.5). The presence of dissolved organic matter in soil helps in the sorption of heavy metals. From the soil, the metals can be moved to groundwater via leaching and to the atmosphere via erosion and colloid loss. A soluble metal-humate complex formed at high pH that lowers the metal precipitation. Carboxyl group present in the humic acid interacts with the metal cations (Spark et al. 1997). Heavy metals such as copper, chromium, cadmium, nickel, zinc, and lead are evidenced to reduce the potential of dehydrogenase enzymes present in the soil (Wyszkowska et al. 2006). The order of heavy metals according to their capability to reduce the dehydrogenase's activity in soil is highest in Cr (VI) followed by Cd; then Zn, Pb, Cu, and Ni have the weakest potential to reduce the enzyme's activity in soil. The activity of urease was reduced mostly by Cr (VI) and then Ni followed by other metals such as Cu, Cd, Zn, and Pb. All these metals when present in soil inhibit the activity of enzyme acid phosphatase. Cadmium produced the strongest harmful effect in inhibiting the activity of alkaline phosphatase, while copper produced the weakest effect, and Zn and Pb did not produce any harmful effect on this particular enzyme. The mobility of metals in the soil environment is dependent upon pH and varies from metal to metal. Low pH and CEC (cation exchange capacity) increase the mobility of heavy metal cations while decrease the anion (chromate and arsenate) mobility (Xu 2013). For instance, chromium and zinc are the most mobile heavy metals present in soil. Other metals except heavy metal reduce the adsorption of later in soil (Markiewicz-Patkowska et al. 2005). The heavy metals, when adsorbed by the soil, form complexes with organic material resulting in organomineral complexes. These complexes lead to the humic acid destruction and increase the aliphatic structures in soils (Minkina et al. 2006).

6.7 Heavy Metal and Human Interaction

Through the process of bioaccumulation, heavy metals make their way from soil to the human physiological system. All the heavy metals pose serious risks to human beings. For example, cadmium is a heavy metal that targets the liver, kidney, and vascular system of our body. Low concentration of Cd can cause Cd(II)-HSA (human serum albumin) complex and deform the original structure of HSA. Higher concentration of Cd(II) deforms the structure of protein and induces changes in size of HSA (Liu et al. 2014a). Heavy metals such as Au and Zn were proven to inhibit the activity of enzyme known as HNC (human neutrophil collagenase), which plays a substantial role in inflammatory disease by destructing tissues in human (Mallya and Van Wart 1989). Other heavy metals such as Cd(II), Cu(II), and Hg(II) also showed similar kinds of inhibition. Pb adsorption takes place in the gastrointestinal tract and then spreads into bone, soft tissue, and blood. Leads get attached with RBCs present in the blood. Being similar to calcium, lead has the tendency to mimic the pathway of calcium, while sometimes calcium also disturbs the movement of lead in the human body. Arsenic disturbs cellular respiration through inhibiting some of the important pathways such as glycolysis and gluconeogenesis. Therefore, acute exposure of arsenic is also related to the risk of diabetes (Alissa and Ferns 2011). Exposure of arsenic in deficiency of vitamin B and folic acid might impact the blood pressure by affecting the production of S-adenosylhomocysteine and homocysteine. Pb, Cd, and Ni are known carcinogens. Their chemical species such as Pb2+, Ni2+, and Cd2+ attach with dsDNA which leads to adulteration of the original structure of dsDNA. These changes make the helical structure unstable and further make the DNA vulnerable for reactions with oxidative agents (Oliveira et al. 2008).

6.8 Conclusion

Soil pollution through heavy pollution continued to be one of the major concerns to the rapidly growing human race. The increasing trend in contamination level has awakened the concern in the mind of industrialists, environmentalists, economists, and other classes of workers. The effect of heavy metal on human health, animal population, crop yield, and soil quality and land degradation has directed the researchers to think of strategies that can reduce the toxicity of metals from all our lives. The health risks and ecological risks are continuously increasing as the sources of heavy metal toxicity are vastly spread. Therefore, continuous monitoring and remediation approaches on the ground level would be one way to solve this drastically increasing problem. The uptake of metals from under the surface of soil to over the soil surface via plant uptake toward aerial parts is a growing concern that needs our attention. Hence, the monitoring of heavy metals needs to be supported by fresh threshold level and background values distinctly setup for agricultural fields.

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