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Effect of heavy metal concentrations in roadside soils: A review

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Abstract

Heavy metals make up to an important class of pollutants in the environment. For they do not degrade, heavy metals undergo accumulation and bio-magnifications in the environment and often regarded as chemical time-bomb. Roadside soil is a definite indicator of vehicular pollution from where the high degree of contamination, is expected. Contamination of roadside soil and farmland with heavy metals due to traffic activities is an environmental hazard causing pollution, thereby affecting the eco-system. The risk posed by heavy metals to food safety and the environment is of great concern to governments and society in many countries. Heavy metal pollution in agricultural soil is becoming serious with rapid industrialization and urbanization in developing countries and it is also influenced by the continuous increase in traffic of vehicles on the highways as observed in the soils across NH-4. The cumulative contamination effect of long-term exposure to traffic activities cannot be neglected, more importantly the road-side farmland soil, which is associated with the food chain and public health. Today, Indian cities are considered as some of the most polluted in the world and the single most important factor responsible is the ever increasing number of automobiles. Very few studies have been carried out in India and reports on heavy metal pollution in plants are extremely scarce. This article reviews the work done on heavy metal concentrations in roadside soils in India.

Keywords: heavy metals, contamination, automobiles, pollution

Introduction

The human population is growing tremendously across the globe which indicates the need of higher production to ensure food security. This has resulted in unbalanced use of inputs *i.e.*, pesticides, fertilizers, and organic amendments which might be a potential source of soil alteration and might contaminates the soil with trace toxic elements (Li *et al.*, 2020) [23]. Trace toxic elements in the polluted soil can be transferred to food products which results in significant health hazards (Qiuguo *et al.*, 2020) [30] particularly because of their persistence, non biodegradability and irreversible nature of contamination (El Rasafi *et al.*, 2020) [14]. The evaluation of the health risks connected to contaminated agricultural soils in China (Zhang *et al.*, 2013; Eziz *et al.*, 2018; Hu *et al.*, 2019) [38, 15, 17], in Egypt (Khalifa and Gad 2018) [19], in India (Bhatti *et al.*, 2018; Adimalla *et al.*, 2019) [1, 8], and in Tunisia (Chabbi *et al.*, 2020) [10] have shown high contamination with various heavy metals and metalloids such as Cu, Zn, Fe, Cr, Ni, Cd, Pb, and As.

Vehicular traffic is broadly accepted to be a major and increasing source of air and soil pollution along roads. Vehicular pollution is thought to be more harmful than other sources of air pollution because humans most often stay near vehicular exhaust (e.g., near major roadways), and thus these pollutants are more readily respired and contacted. Pollution of natural environment due to release of heavy metals from various sources is a widespread problem throughout the world. Owing to the increasing traffic volume pressures in urban areas, the environments that are closer to the highways are subjecting to pollution from traffic emissions. Public motor roads affects natural environment to a large extent because automobile act as line sources of heavy metal pollutants. These metals are contributed mainly through industrial effluents, sewage and sludge, vehicular emission, diesel generators and application of pesticides in agriculture. This loading of heavy metals often leads to degradation of soil health and contamination of food chain mainly through the vegetables grown on such soils. Environmental pollution of heavy metals from automobiles has attained much attention in the recent past. The majority of the heavy metals are toxic to the living organisms and even those considered as essential can be toxic if present in excess.

Soils fall among the most valuable non-renewable natural resources. They are vulnerable and hard to recover from environmental pollution since, despite the operation of slow auto-remediation processes, fast dispersal and dilution mechanisms meet functional limitations in soils.

In terrestrial ecosystems, the soil is a very important "ecological crossroad" where many kinds of interactions take place between solids, liquids, gases, and the biota (Giannakopoulou *et al*., 2012) [16]. Soil degradation, the result of human practices and/or natural processes, is a rather slow procedure, but its impacts are long lasting and, most often, practically irreversible in the time scale of man's life. The concern over heavy metal pollution of soils is based on many reasons (Sharma., 2016) [33]. First as a result of human activity heavy metals may accumulate in the soil environment to a point where their levels are toxic to plants. Second their off-site movement either to surface water or to ground water has the potential for contamination of drinking water resources. Thirdly heavy metal might accumulate in the food-chain and affect the health of people who eat food grown on metal contaminated soils. Studies showed that decreasing heavy metal concentration with increasing distance from the road (Sharma., 2016) [33]. The uptake of these heavy metals by plants results in bioaccumulation of these elements cause a serious risk to human health when plant – based food stuff are consumed.

Heavy Metals

Heavy metals are defined as a metallic element with a density between 4-5 g/cm^3 (Nagajyoti *et al*., 2010) [26]. Commonly found toxic heavy metals include lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu) (Wuana and Okieimen, 2011) [37]. In toxic concentrations heavy metals can cause damage to the ecology, environmental, nutritional and evolutionary characteristics of the polluted areas (Babula *et al*., 2008) [7]. Soils are heavy metals sinks, heavy metals originate from the earth's crustal rock and are released through weathering processes through its anthropogenic sources such as, ferti lizers, mine tailings, pesticides, sewage sludge and smelting, causing unnaturally high contamination (Wuana and Okieimen, 2011) [37]. Concentration of heavy metals persists as they are not degraded by microbial activity or chemicals, like the organic compounds, reducing soil quality (Lasat, 2000) [22]. Prolonged contamination of soils severely reduces the soil quality (Oliviera and Pampulha 2006) [26], however, changes to chemical form are possible (Wuana and Okieimen, 2011) [37]. According to some studies carried out in India, China, England and Iran, the traffic activities, industrial activities, agricultural activities, atmospheric precipitations, wastewater sludge, erosion of buildings and pavement surface are the main sources of heavy metals in the soil (Kumar *et al*., 2018) [20].

Impact of heavy metals in roadside soils

Heavy metals at trace levels are ubiquitous in natural water, air, dust, soil and sediment (Brown *et al*., 1990) [9]. Many of these heavy metals are considered toxic to living organisms and even trace metals considered essential for life can be toxic when present at excessive levels that impair important biochemical processes and pose a threat to human health, plant growth and animal life (Morrison *et al*., 1990) [25]. Pollution of roadside soils by heavy metals presents serious concern throughout the world and, specifically, in India, due to the increasing traffic and anthropogenic activities (Kumar *et al*., 2019) [21].

Zhao *et al*. (2018) [39] while working on roadside soils in Sydney reported that rainfall, distance to the road and soil types are the major factors responsible for HMs pollution. Alexakis and Gamvroula (2014) [3] in their study on potentially toxic elements of Oropos-Kalamos Basin, Attica, Greece, reported that natural sources like lithogenic factors were responsible for contamination of the studied area.

The pollution of soils by heavy metals from automobile sources is a serious environmental issue. These metals are released during different operations of the road transport such as combustion, component wear, fluid leakage and corrosion of metals. Lead, cadmium, copper, and zinc are the major metal pollutants of the roadside environments and are released from fuel burning, wear out of tyres, leakage of oils, and corrosion of batteries and metallic parts such as radiators etc (Dolan *et al*., 2006) [12]. Road-side heavy metal concentration is influenced by multiple factors, including traffic properties, highway characteristics, road-side terrain, road-side distance, rainfall and wind direction, etc. The distribution of these metals in the roadside soils is strongly but inversely correlated with the increase in the distance from road (Aksoy, 1996) [2].

A higher level of lead in roadside environment is often associated with the traffic density (Arslan, 2001) [5]. The levels of copper, cadmium and zinc are also reported to correlate with vehicular traffic (Narin and Soylack, 1999) [27]. Vehicular emissions along the busy roadways contain high levels of lead which are present in fuel as anti - knock agents (Atayese *et al*., 2009) [6]. Along with lead, other heavy metals such as cadmium, copper and zinc are associated with the vehicular activity; since they are included in petrol, engines, tyres, lubricant oils and galvanized parts of the vehicles.

In agricultural areas, intake of heavy metals through the soil, crop system could play a predominant role in human exposure to heavy metals. In general, heavy metals with a high concentration in the environment result in health problem adversely affecting the nervous, cardiovascular, renal and reproductive systems. The entrance of heavy metal in the food chain is the major route of heavy metal exposure to human (Uddin *et al*., 2019) [36]. The consequences of heavy metal pollution include reduced intelligence, attention deficit and behavioural abnormality as well as contributing to cardiovascular diseases in adult. However, it is not easy to remove heavy metals from the soils because of their irreversible immobilization within different soil components.

Contamination of agricultural soil by heavy metals has become a critical environmental concern because of their adverse effects. Such toxic elements are called as soil pollutants because of their widespread occurrence and their acute and toxic impact on plants growing in such soils. The regulatory limit of cadmium in agricultural soils is 100 mg/kg soil (Salt *et al*., 1995) [32] which is exceeding over the years thanks to anthropogenic activities. Cadmium exhibits several negative effects on plants *i.e.,* reduction in photosynthesis, water as well as nutrient uptake and other injury symptoms like chlorosis, growth inhibition, browning of root tips which eventually leads to death (Mohanpuria *et al*., 2007) [24].

Heavy metals concentrations in soil samples along highway which surrounded Baghdad city took the following order Ni > Zn > Pb > Cd and the direction of the prevailing wind played a major role in the transport of heavy metals concentrations towards the east of the highway (AL- jibury and Essa, 2016) [4]. Levels of heavy metals (Pb & Cd) contamination in soil are decreased to background levels with distance on either side of the highway and the decrease of elemental concentrations with distance from highway would indicate aerial deposition of metal particulates in road side environment from extraneous sources and not a function of soil type. The concentrations of Pb, especially in soil, exhibited a larger variation with distance from the road than those of Cd (Dutta and Sisodia, 2014) [13].

vehicular traffic and industrial emission represents the most important metal contamination source in the Anand city (Gujarat). Metal concentrations in street dusts from five major roadways indicated that roadside dust contained elevated levels of heavy metals. Cu concentration ranged from 52-130 mg/kg, Ni from 5771 mg/kg, Pb from 66- 105 mg/kg and Zn from 44- 93 mg/kg in street dust samples. The extent of metal pollution in street dust was influenced more by heavy traffic than by industrial activities (Tanushree *et al*., 2011) [35].

Distribution of heavy metals such as Ni, Pb, Cr, Zn, Cu, and Cd from the roadside soil of Zheng zhou Putian section of Longxi-Haizhou Railroad, China. The soil samples were collected at a distance of 0, 10, 20, 30, 50, 100, 200, 300 and 500 m from the railroad edge. The contents of Pb and Cd were estimated by graphite furnace atomic absorption spectrometry (GF-AAS), while contents of Cu, Zn, Cr and Ni were estimated by flame atomic absorption spectrometry (F-AAS). The maximum concentration of the metals was found at distance a 10-30 m from the railroad and the content of these metals was found in order of Cr > Cd >Pb > Zn > Ni > Cu (Jian-Hua *et al*., 2009) [18].

Naser *et al*. (2012) [28] examined lead, cadmium and nickel in roadside soils and vegetables along a major highway in Gazipur, Bangladesh. The soil samples were collected at various distances *viz*., 0, 50, 100 and 1000 m from the road. Both soil and plant samples were analyzed for heavy metals using atomic absorption spectrometry. It was observed that there were significant differences in the concentrations of lead, cadmium and nickel for different plant species and soil sample at various distances. The order of accumulation of heavy metals was found to be nickel > lead > cadmium.

Experimental Findings

Table 1: Concentration of heavy metals in roadside soil on either side of highway at different distances (range in ppm).

Sampling site distance from road	Titanium	Manganese	Iron	Zinc	Strontium	Zirconium
10 m	1541-5186	115-488	11019-36078	34-248	40-247	111-574
200 m	1899-7044	0-464	16047-45200	25-68	30-190	112-1974
Mean	3378.8	268.86	26308.07	52.6225	116.37	411.83

(Sripathy *et al*., 2015) [34].

The concentration range of six heavy metals in roadside soils, taken from 35 sites, at 10m and 200m distance from the main road is presented in Table-1. The results indicate considerable heavy metal accumulations in the soils at 10m and 200m from the edge of the road on both sides and these accumulations could be from engine wear, bearings or bushings and from vehicular emissions. The soils across the highway have shown significant differences in the concentration of all the heavy metals studied.

The typical elements, including Titanium, Manganese, Iron, Zinc, Strontium and Zirconium in roadside soils coming from traffic activity, can be transported through the food chain into the human body and thus be very toxic to people.

Table 2: Heavy metal concentration on point A (50 cm- 1m) away from the roadside (mg kg^{-1})

Sampling points	Cu	Cr	Fe	Pb	Zn	Mn
1	6.5	40.2	22.2	45.3	7.12	41.12
2	17.1	31.6	18.6	36.4	6.15	38.2
3	24.6	29.3	20.2	38.6	4.26	27.65
4	22.7	37.4	15.3	28.2	5.25	28.8
5	20.4	42.8	10.6	33.4	5.16	55.16
6	16.8	38.8	18.4	22.8	5.21	42.62
7	12.9	28.3	14.8	25.4	4.24	32.52
8	26.8	27.2	9.5	39.6	6.28	17.46
9	21.5	33.2	11.5	31.1	7.23	31.84
10	16.6	41.5	15.3	48.2	5.18	25.16
11	19.2	27.3	12.6	40.6	6.24	30.42
12	23.3	34.8	18.4	23.5	6.32	19.42
Mean	19.03	34.36	15.61	34.425	5.72	32.53

(Sharma, 2016) [33].

Table 3: Heavy metal concentration on point B (30m) away from the roadside (mg kg^{-1})

Sampling points	Cu	Cr	Fe	Pb	Zn	Mn
1	3.2	30.4	16.4	24.6	4.15	30.21
2	10.4	21.6	12.2	45.3	1.18	28.2
3	15.6	19.4	17.6	27.6	0.97	17.35
4	16.7	31.7	9.5	24.8	1.26	22.8
5	18.6	28.3	4.6	20.2	2.45	35.26
6	14.7	27.5	8.1	12.3	1.32	32.32
7	8.5	18.6	11.8	22.5	0.68	22.12
8	11.3	20.8	3.6	32.4	3.48	10.26
9	5.6	15.3	9.4	28.3	4.21	21.28
10	10.6	34.7	11.7	31.7	1.25	15.14
11	19.2	16.8	7.4	53.8	3.68	20.16
12	20.5	30.2	14.6	40.5	2.68	12.52
Mean	12.9	24.6	10.5	30.3	2.27	22.3

(Sharma, 2016) [33].

The results indicated that the heavy metals concentrations of Cu, Cr, Fe, Pb, Zn and Mn in roadside soil matrix increased at first and then decreased with the distance increases away from the roadside. The study showed elevated heavy metal concentration at 50cm-1m from the roadside. Results from the study showed that agricultural soil nearer roadside contains higher levels of heavy metals and constitute health risk to human and animal health when plants – based food stuff grown along the area consumed.

Table 4: Metal accumulation profile in road side soil

Heavy metals	Control (µg g^{-1} dry wt)	Road side soil (µg g^{-1} dry wt)	
		Range	Mean± SE
Lead	70.50	81.91-139.8	95.71±8.71
Copper	34.91	39.54-58.58	49.71±3.51
Zinc	29.84	32.29-381.54	188.3±54.28
Cadmium	2.16	1.51-2.08	2.0±0.19
Manganese	1254.1	1257.9-2051.5	1528.3±26.5
Chromium	110.41	131.9-951.2	315.54±2.46
Nickel	69.38	69.53-108.6	85.91±5.91

(Rolli *et al*., 2016) [31].

The order of increment of heavy metals in roadside soil is as follows: Mn > Cr > Zn > Pb > Ni > Cu > Cd. Soils due to their cation exchange capacity (CEC), complexing organic substances, oxides and carbonates, have high retention capacity for the heavy metals. Thus, contamination levels increase continuously as long as the nearby sources remain active. It was concluded that with an increase in the amount of heavy metals in soil and their uptake by plants also increase. The mobility of heavy metals are highly translocated from soil to plant leaves in all the sampling sites

Table 5: Concentration (mg/kg) of metals in roadside soil

	Co	Cr	Cu	Fe	Mn	Ni	Pb	Cd
Minimum	5.35	13.55	0.35	3757.5	30.65	5.7	0.7	0.075
Maximum	58.9	1098.5	161.05	28600	661.5	2660	46.65	21.25
Average	13.09±9	149.21±216	17.79±29	13984.5±29	328.08±167	165.47±503	13.00±11.34	1.94±4

(Devi *et al*., 2015) [11].

The concentration of the metals was found in the order: Fe>Mn>Cr>Ni>Cu>Co>Pb> Cd. The average concentration of Co, Cr, Cu, Cd and Ni were high as compared to background soils (soils collected from beyond 200 meters away from the highway). These metals were emitted from the exhaust as well as from wear and tear of vehicles as particulates and could have deposited on the roadside soils.

Conclusions

Heavy metals in the soil can also generate airborne particles and dust which may affect the quality of air. These lands may be used for growing ornamental and timber plants rather than leafy, root and tuber vegetables to minimize the transfer of heavy metals from soil to human beings through food chain. Inhalation of substantial quantities of heavy metal particles over period of time may add to human body and constitute health risk.

The risk posed by heavy metals to food safety and the environment is of great concern to governments and society in many countries. The cumulative contamination effect of long-term exposure to traffic activities cannot be neglected, more importantly the roadside farmland soil, which is associated with the food chain and public health.

The most probable source of these contaminants is the vehicular traffic run on this way. The results indicated that the heavy metals concentrations of Cu, Cr, Fe, Pb, Zn and Mn in roadside soil matrix increased at first and then decreased with the distance increases away from the roadside.

There is also a need for enforcement of regulations to control environmental pollution. Public participation, non-governmental organization and civic agencies of the government required collective approach towards the solution. Continuous air monitoring for one or more pollutants is an absolute necessity for completing a diagnosis of pollutant level in the air, water and soil environment. Most importantly, a network of monitoring stations throughout the country would be helpful to measure the current pollutant level. Accumulation of air monitoring data will provide the criteria needed for establishing air quality standards.

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