Heavy Metal Contamination of Roadside Topsoil in North East Jordan

Sura Taha Al-harahsheh
Institute of Earth and Environmental Science, Al - albayt University, Al-Mafraq, Jordan
Email: surah_h71@yahoo.com

Abstract:
Environmental pollution of heavy metals from automobiles has attained much attention in the recent past, a study of heavy metals in roadside soils is critical in assessing the potential environmental impacts of automobile emission on soil. The present research was conducted to study heavy metals contamination in roadside soils of Mafraq-Zarqa highway in Jordan. The soil samples were collected and analyzed for the levels of Mn, Ni, Cu, Pb, Cd and Zn using flam atomic absorption spectrophotometer (AAS). The results showed that all heavy metals except Mn are lower than other studies. The results indicate the decreasing order of the average total metals content for the studied metals: Mn> Zn > Cu > Ni> Pb> Cd, higher levels of heavy metals east of the roadside were due to the westerly prevailing wind at the sampling site. The contamination decreased with distance from off the edge of the roadside and dropped to background level at about 60m west, also the contamination of the top soil was higher than the lower soil, finally the levels of heavy metals increased with increasing traffic densities and furthermore, they reached elevated levels in urban areas.
Keywords: Roadside, Soil, Heavy Metal, Mafraq ,Zarqa, Jordan.

1. Introduction

Soils receive potentially toxic elements from both natural and a wide range of anthropogenic sources, including the weathering of primary minerals, mining, fossil fuel, combustion from the transportation and many industries. The transportation sector is one of the major sources of pollution worldwide, emitting various types of pollutants including heavy metals which are known for their persistence in the environment. The surge of vehicle and population in Jordan had increased over the last decade due to natural population growth and mass migration from neighboring countries namely, Iraq and Syria. Currently, the number of automobiles have increased rapidly as there are more than 3 million automobiles deteriorating urban air quality and public health. Automobiles contribute largely to air and soil pollution. The emitted pollutants from automobiles resettle in the surrounding areas. Therefore, roadside soils always contain high concentrations of metallic contamination. The pollution of soils by heave metals from automobile sources is a serious environmental issue.

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. The heavy metals can impair important biochemical processes posing a threat to human health, plant growth and animal life. (Jarup 2003, Michalke 2003, Silva et al 2005). Roadside soils are the most contaminated areas, this contamination comes from various operations of road transport such as vehicle exhaust, fluid leakage, waste disposal, component wear and corrosion of metals. Studies have shown that such pollutant can be harmful to the roadside vegetation, wild life, and the neighboring human settlements (Turner and Maynard 2003) (Iqbal et al 1994), (Jaradat et al 1998). The distribution of heavy metals (Mn, Ni, Pb, Zn, Cd and Cu) in the roadside soils is strongly but inversely correlated with the increase in the distance from road.

Developed countries with long histories of industrialization and interest in environmental health have rich literature on roadside soils pollution, consequently, many improvements have been made to automobiles industry to reduce the amount of pollution caused by automobiles such as the use of unleaded gasoline, the improvement of corporate average fuel economy, and recently the manufacturing of what are called hybrid cars that are powered by a combination of gasoline engine and electric motor.

The knowledge of the variation of the level of heavy metals with distance is crucial. Therefore, the current study investigates the effect of traffic density and distance from the highway on the levels of heavy metals (Mn, Ni, Cu, Pd, Cd and Zn) contamination in the top soil in the governorate of Mafraq on a major traffic highway that connects Mafraq city with other major cities in the country as well as to Iraq, Syria and Saudia Arabia.

2. Materials and Methods

2.1 Study Area:

The study area is located in the governorate of Mafraq, in the north of the country, the study area has arid and semi-arid climate with temperature ranging from 25 to 38C° and annual mean precipitation less than 100mm (department of meteorology, Open files, 2014).

Mafraq city is slightly industrialized, therefore vehicular emission is one of the major sources of heavy metals contamination in the environment of the city.

The study area is a major traffic highway that connects Mafraq city to cities of Irbid, Zarqa, and Amman at the domestic level, and connects Jordan at the national level to countries of Syria, Iraq and Saudia Arabia (figure. 1).

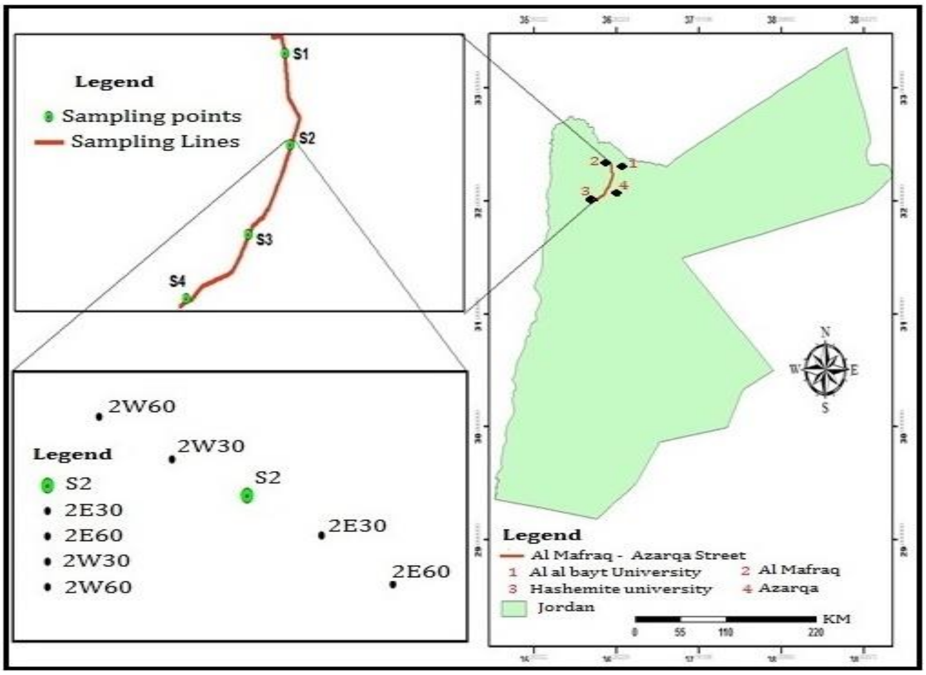


Figure (1): The location of the Study area (Mafraq- Zarqa highway)

2.2 Sampling

Soil sampling was done during summer 2014, along the highway connecting Zarqa and Mafraq cities, therefore no effect of rain on washout or leaching of metals took place. Four sampling sites were chosen for the study representing different traffic density as shown in table 1. For each site, sampling was done from two depths upper soil (0-5 cm depth) and lower soil (20-25 cm depth) at a distance of 0m, 30m and 60m from the road and at east, west sides of the highway. Sampling was done using stainless steel shovel and placed in a prewashed polyethylene bags. A control sample was collected from a remote site few kilometers from the highway at Al-albyt university where human activities and traffic density were very low. The volume of traffic for each site was estimated by visual counting of vehicles passing each sampling point at both sides of the road for 12 hour period (from 7 am to 7 pm), the results are shown in table 1.

Table (1): The average number of the motor vehicles pass through the study area, Ministry of Interior, Jordanian public security, Traffic management center, Open files 2014

Site	No. of Motor Vehicles /day
A	5780
B	4257
C	6830
D	8657

2.3 Sample preparation

Soil samples were air dried for one day, and then heated for 24 hour at 105 °C to remove any moisture exists in the samples. The oven dried samples were sieved through 2 mm mesh to remove any foreign object during sampling.

One to two grams was accurately weighted and placed in test tube containing 10 ml concentrated nitric acid of analytical grade. The digested samples were sonicated for one hour and heated in a test tube heater for another one hour at 90 C °(Hewitt and Candy 1998).

The samples were filtered through whatman filter paper no. 42 after cooling in a 25 ml volumetric flask. The final extracts diluted to the mark with 1% HNO_3.

Six heavy metals were selected for this study Mg, Ni, Cu, Cd, Pb and Zn. The standard of the metals was prepared from a stock standard by appropriate dilution with 0.1 HNO3. The soil extract was subjected to metal analysis using flame atomic absorption spectrophotometer (Spectra AA 800 Varian).

3. Results and Discussion:

The concentration of heavy metals collected from different sites and at different distances from the highway connecting Mafraq to Zarqa city is summarized in table 2 and table 3. The results of all heavy metals showed a decrease of concentrations with distance indicating that traffic is the major source of these metals in the investigated area. However, the concentrations of all metals were higher at the eastern side of the highway than the western side which is due to the westerly prevailing wind direction in the study area. The higher concentration of upper layer than the lower layers is due to the weak leaching of these metals under alkaline pH conditions which enhances precipitation rather than dissolution. The highest concentration of all metals was found at site D which had the highest traffic density and the lowest at site B which showed the lowest traffic density.

Manganese was the highest among the analyzed heavy metals as its mean concentrations ranged from 16.68 to 26.17 ppm in the top soil at the western side of the high way, and from 14.84 to 28.91 ppm on the eastern side of the highway. However, these concentrations were higher at the top soil than at the lower soil of the same locations (figure 2a). These results are comparable with other studies done in Jordan such as (El-Hasan et al. 2006) who reported that the range Mn concentration 55.127 ppm with mean 86.68 ppm, and (Jiries, 2003) who reported the range 70 to 237.5 ppm with mean 1444.43 ppm as well as with other sites from the world such as Dubai (Aslam et al. 2013) and Nigeria (Oludare et al. 2013)

Table (2) : Concentration of the heavy metals at surface soil in the study area in ppm

		West			East		
		Distance from Highway			Distance from Highway		
		0 m	30m	60m	0 m	30m	60m
Mn	Min	8.31	7.51	5.59	17.48	15.33	5.17
	Max	42.52	33.74	33.88	50.61	34.45	24
	Mean	26.17	21.66	16.68	28.91	23.17	14.84
	±STD	8.8	7.2	5.2	5.7	5.4	7.7
Ni	Min	0.663	0.605	0.403	0.512	0.497	0.35
	Max	0.992	0.866	0.811	0.973	0.745	0.636
	Mean	0.81	0.73	0.58	0.72	0.65	0.48
	±STD	0.14	0.11	0.15	0.17	0.09	0.11
Cu	Min	0.545	0.343	0.365	3.648	0.513	0.396
	Max	12.56	2.973	1.621	6.413	5.25	0.741
	Mean	4.74	1.66	0.95	5.25	3.11	0.56
	±STD	4.8	1.2	0.5	1.1	1.8	0.14
Zn	Min	2.509	0.534	0.298	2.862	1.2	0.842
	Max	6.416	4.349	3.878	6.275	5.013	4.351
	Mean	5.02	2.5	1.45	4.88	3.14	1.99
	±STD	1.5	1.4	1.5	1.3	1.5	1.4
Pb	Min	0.807	0.295	0.295	2.822	0.413	0.209
	Max	6.463	2.886	1.986	5.556	4.467	1.203
	Mean	2.62	1.2	0.75	4.11	1.62	0.63
	±STD	2.3	1.05	0.7	1.1	1.7	0.38
Cd	Min	0.023	0.017	0.004	0.028	0.022	0.019
	Max	0.589	0.554	0.101	0.545	0.325	0.319
	Mean	0.19	0.17	0.05	0.18	0.11	0.10
	±STD	0.23	0.22	0.04	0.21	0.13	0.13

Table (3) : Concentration of the heavy metals at 20 cm depth in the study area in ppm

		West		East	
		Distance from Highway Depth:20 cm		Distance from Highway Depth:20 cm	
30m		30m	60m	30m	60m
Mn	Min	4.45	1.98	8.80	1.92
	Max	38.99	9.34	32.74	11.53
	Mean	18.06	7.30	19.0	6.84
	±STD	6.1	3.4	6.9	2.4
Ni	Min	0.41	0.237	0.481	0.055
	Max	0.902	0.47	0.819	0.344
	Mean	0.61	0.37	0.63	0.27
	±STD	0.2	0.09	0.13	0.12
Cu	Min	0.399	0.332	0.3	0.223
	Max	0.464	0.893	0.725	0.561
	Mean	0.42	0.55	0.45	0.38
	±STD	0.03	0.21	0.17	0.12
Zn	Min	0.113	0.046	0.206	0.259
	Max	3.131	2.861	1.609	1.45
	Mean	1.19	0.84	1.02	0.58
	±STD	1.2	1.2	0.5	0.5
Pb	Min	0.161	0.017	0.196	0.099
	Max	0.914	0.750	0.493	0.510
	Mean	0.40	0.31	0.33	0.26
	±STD	0.3	0.3	0.12	0.15
Cd	Min	0.001	0.001	0.011	0.008
	Max	0.049	0.047	0.228	0.161
	Mean	0.02	0.02	0.07	0.05
	±STD	0.02	0.02	0.09	0.06

The high Mn concentration in the investigated area can be attributed to anthropogenic origin mainly due to the use of unleaded fuel, which contains Mn as an additive to the unleaded fuel in the form of Methylcyclopentadienyl manganese tricarbonyl. The high Mn concentrations in the investigated soil supports the idea of vehicle emission as a source of these metals to the investigated site.

Nickel has been shown to be an essential element in certain microorganisms animals, and plants (Howari et al 2004). High nickel contents in soil are usually due to human activities, such as mining, purifying of zinc, steel production, coal burning, and from mechanical abrasion, and oil spills of vehicles,(Pais and Benton Jones, 1997)

The mean concentration of nickel ranged from 0.58 to 0.81ppm in the top soil at the western side of the high way, and from 0.48 to 0.72 ppm on the eastern side of the highway. However these concentrations were higher at the top soil than at the lower soil of the same locations (figure 2b). These results were lower compared with other studies, (Jaradat and Momani, 1998) reported the range (36.5-121.7Mg/g), (Howari et al 2004) reported the range (30-210ppm, (Jiries 2003) reported the range (237.5-625pm), and (El-Hassan et al 2006) reported the range 34-165ppm.

High Ni contents in soil are usually due to human activities. (Pais and Benton Jones 1997), The Ni concentration in the investigated area due to mechanical abrasion and oil spills of vehicles.

Lead is a naturally occurring bluish-gray metal found in small quantities in Earth crust. Lead is number two (after arsenic) on the top 20 list of the most poisoning heavy metals, (HMRC 2003, Homady et al 2002, Massadeh et al 2004). The measured mean concentration of the lead in the top soil ranged from 0.75 to 2.62 ppm in the western side of the highway, and from 0.63 to 4.11 ppm on the eastern side of the highway, while the lead concentrations were low at the lower soil of the same locations, (figure 2c).

Several studies conducted in Jordan to measure the lead concentration in soil road, low level of lead (0.2375-1.5667 ppm) were detected in polluted area (Jiries 2003) and (Jaradat et al 1998) reported the range of 0.21 to1.15mg/l, high level of lead (25.09 – 75.33 ppm) in (El-Hasan et al 2006), and ranged 45 to 122 ppm were detected in (Howart et al, 2004), while(Mcgrath 1986) reported 75mg/kg as the mean value for lead in urban topsoils of England and Wales. The roadside soils usually contain higher lead contents.(Culbared et al ,1988) reported the range of 45 to 9660 mg/kg of total lead in roadside dust of urban areas in UK with the geometric mean value of 786 mg/kg. The result of this study compared to the previous discussed studies reveal the non polluted of the investigated area respect to lead, slight contamination is to be considered in D site because the government used unleaded fuel for cars which used the benzene since 2002. The actual concentration of lead a long highways sides are variable and depend on various factors, such as site traffic factor, prevailing wind and humidity (Adudat, 2000)

The average natural a abundance of cadmium in Earth's crust has most often been reported to be (0.1-0.5)ppm, but much higher and much lower values have also been cited depending on a large number of factors (Howari et al 2004).

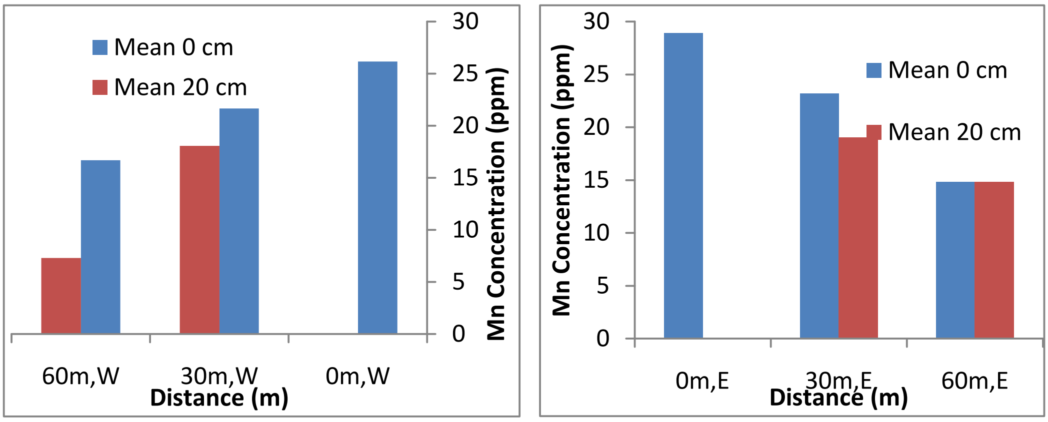
Figure (2d) shows the mean concentration ranged from 0.05 to 0.19 ppm in western side of the highway, and from 0.1 to 0.18 ppm in the eastern side of the highway in the top soil , while the cadmium concentration in the lower soil was much less than the average natural abundance of cadmium in Earth's crust. These results are very low comparable with other studies done in Jordan such as (Jiries 2003) found the concentration of cadmium range 0.15 to 2.5 ppm, and (Jaradat et al, 1998) found the concentration of cadmium range 0.38 to 1.15 μg/g with the mean 0.75 μg/g, as well as with other sites from the world such as(Aksoy 1996) who found mean Cd concentration for urban roadside soils and rural roadside near Bradford as 2.44Mg/g and 1.04Mg/g, respectively, and (Akbar et al 2003) reported the cadmium concentration ranged from 0.3 μg/g to 3.8 μg/g with mean value of 1.4 μg/g in the surface soils in Britain.

The cadmium concentration in the investigated area can be attributed to anthropogenic origin mainly due to the use of tire rubber, metal plating and lubricating oils as part of additives (Hewitt et al 1988).

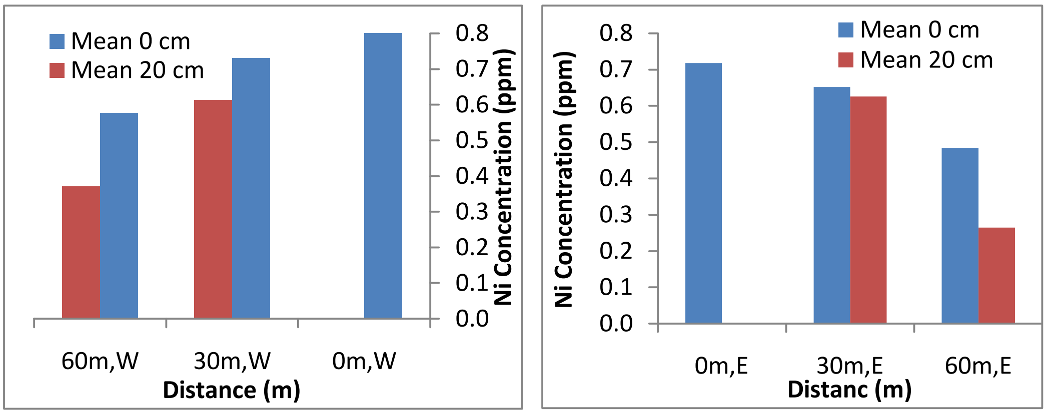
Figure (2e) shows the low concentration of Cupper were the mean concentration ranged from 0.95 to 4.74 ppm at the western side of the highway, and from 0.56 to 5.25 ppm at the eastern side of the highway. However these concentrations were higher at the top soil than the lower soil of the same location. These results are comparable with other local studies such as (Almomani et al 2008) reported the concentration of copper from 0.7 to 17 μg/l and(Jiries 2003) reported the range of copper from 50 to 600 ppm, where its mean concentration less than these studies. While the international studies such as (Alloway 1995) found mean cupper concentration for urban roadside soils within the range of 0 to 250 μg/g, and (Akbar et al 2003) reported the copper content in the roadside soils ranged from 15 to 240 μg/g with the mean value of 87.3 μg/g in England. Cupper concentration in the investigated area is derived from engine wear, thrust bearing, bushing and bearing metals.

Zinc is a common metal in the human environment, little is known about its toxic effects toward human beings (Homady et al 2002). Zinc enters the air, water and soils as a result of natural processes, but mostly as a result of human activities, such as mining, purifying of zinc, lead and cadmium ores, steel production, coal burning and burning of waste (Howars et al 2004). The primary sources of Zn are probably the attrition of motor vehicle tire rubber exacerbated by poor road surface, and the lubricating oils in which Zn is found as part of many additives such as zinc dithiophospates, (Jaradat et al 1998).

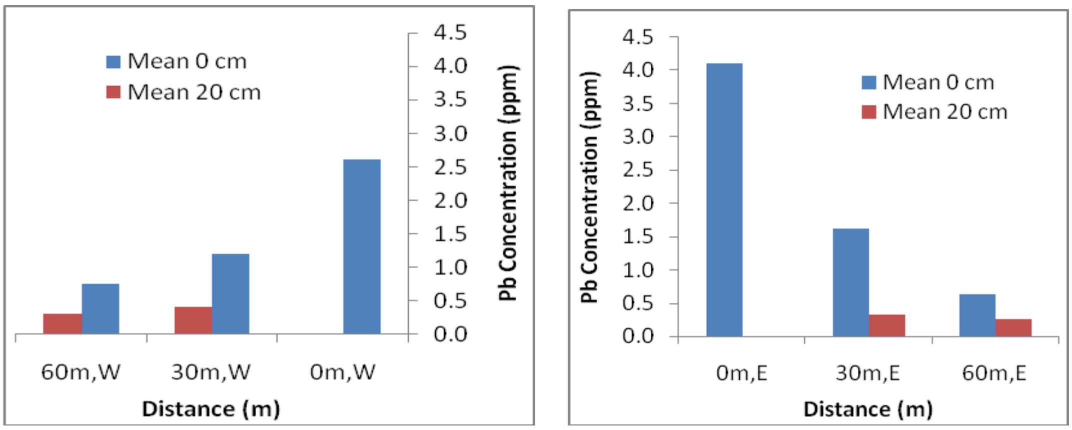
The mean concentration of Zinc in the top soil at the western side of the highway ranged from 1.45 t0 5.02 ppm, and from 1.99 to 4.88 in the eastern of the highway, but the zinc concentration is less than the upper soil in the same location, (figure 2f). Most of the locations exhibit lower values than the average world soil (Alloway 1995) value of 90ppm and the amount of zinc in the roadside soils ranged from 56.7 to 480 μg/g with mean value of 174.6 μg/g (Akbar et al, 2003) . According to Jiries et al (2001) and Ellis and Revitt (1982), Zinc may be derived from mechanical abrasion and oil leaks from vehicles. (Al-Momani et al 2008) reported the range of Zn concentration (1.4-370 mg/L), (Nazzal et al 2013) investigated highways ranges from 39 to 394ppm, and (Howari et al 2004) reported the range of zinc ranges from 30 to 210 ppm.



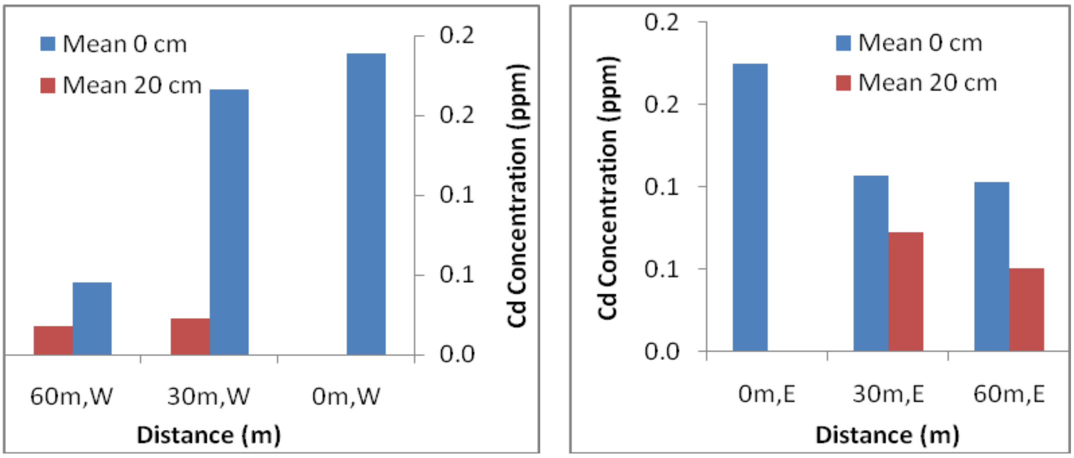
a: Mn concentration (ppm)



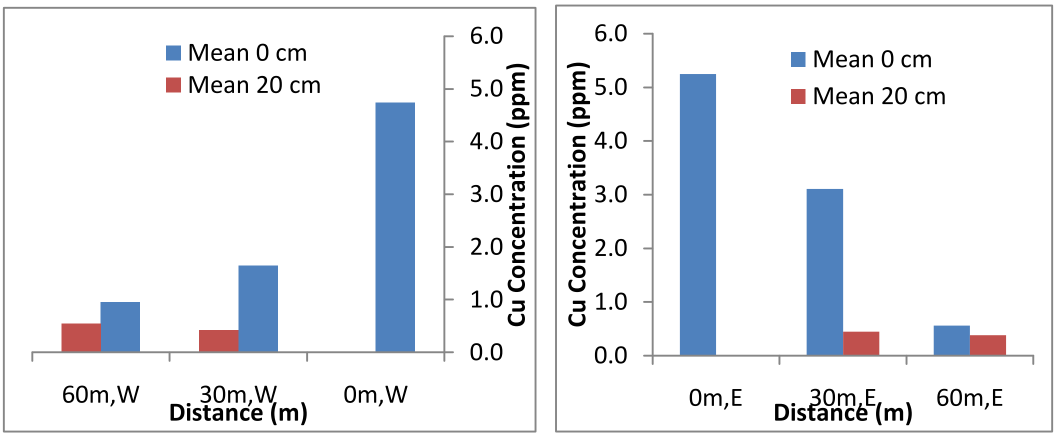
b: Ni concentration (ppm)



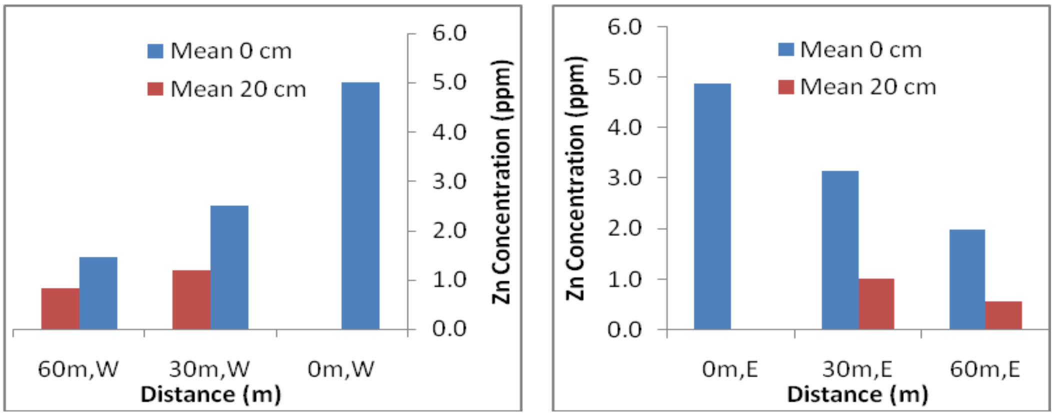
c:Pb concentration (ppm)



d: Cd concentration (ppm)



e: Cu concentration (ppm)



f: Zn concentration (ppm)

Figure 2. Heavy metal contents of soil as a function of distance from the highway, (a) Mn; (b) Ni; (c) Pb ; (d) Cd; (e) Cu; (f) Zn

4. Conclusion

The results of this study showed that all heavy metals except Mn are lower than other studies, the average mean metal concentration were determined in roadside soils (ppm) in the top soil to be Mn, Ni, Cu, Zn, Pb and Cd are 21.9, 0.661, 2.71, 3.1, 1.82, and in the lower soil 0.133 and 12.8, 0.47. 0.45, 0.91, 0.325 and 0.04 ppm respectively. Heavy metals contamination in the soils from the roadside verges in the study area was lower as compared to the background levels. The highest concentrations were detected in the samples collected from the verges of the roadside, and there was a trend of gradual decrease in metal contents with the increasing distance from the verges of the roadside, More heavy metal contaminations in soil was observed on the east side of the road than the west side. This could be explained by the westerly prevailing wind, while the heavy metals content in the top soil was higher than lower soils due to weak leaching of these metals under alkaline pH condition which enhance precipitation rather than dissolution. The result suggests that heavy metal contamination associated with highway is significant and may involve health risks in the future.

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