A Comparative Study of Some Heavy Metals Distribution in Roadside and "Palm" "Plant" in Al-Najaf Region-Iraq

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Abstract

Copper, lead, cadmium, and zinc levels were analyzed by atomic absorption spectrophotometry in surface soil and Palm Plants samples taken from both sides of the major street connecting Al Kufa bridge with the 20th revolution square in Al Najaf as shown in Figure (1) . Elevated levels of the studied elements were found in both soil and plant on the right side and on the left side of the road compared with the background values. The higher levels of heavy metals right of the road were due to the westerly prevailing wind at the sampling sites.

The contamination decreased exponentially with distance from the edge of the road and decreased to the background level at about 60 m. In soil samples, the average concentrations, 1.5 m right of the highway, were 40.32, 1.52, 200.5 and 167.8 µg/g for Cu, Cd, Pb, and Zn, respectively. The levels of these elements in plants 3 m right of the constrictions of highway were 31.5, 17.5, and 122.3 µg/g for Cu, Pb, and Zn, respectively. The values of the heavy metals suggest that automobiles are a major source of these metals in the roadside environment and also these values were compared with results found by other investigators in various countries worldwide. Finally, the roadside soil and plants had significantly high contents of heavy metals and their levels increased with increasing traffic densities.

الخلاصة

حلل كل من النحاس و الرصاص و الكادميوم و الزنك بواسطة جهاز طيف الامتصاص الذري. أخذت العينات من تربة و(سعف النخيل) من جانبي الطريق الرئيسي الذي يربط بين جسر الكوفة و ساحة ثورة العشرين في مدينة النجف كما مبين في الشكل رقم (1).

لقد تناول هذا البحث تراكيزا لعناصر الثقيلة في كل من عينات التربة و النبات على جانبي الطريق الايمن والايسر. كانت تراكيز العناصر الثقيلة في جانب الشارع الايمن من الجانب الايسر و ذلك بسبب كون الرياح غربية في المناطق التي أخذت منها العينات في معظم أيام السنة.

تراكيز العناصر الثقيلة تقل مع الابتعاد عن جانب الطريق و تستمر بالنقصان حتى الوصول إلى مسافة 60 متر عن حافة الشارع الذي أخذت منه العينات. في عينات التربة كانت تراكيز العناصر بالنسبة لمسافة 1.5 متر عن حافة الشارع الجانب الايسر هي 40.32, 1.52, 200.5, 167.8(µg/g) لكل من Cu, Cd, Pb و Zn بالتتابع.

و تراكيز هذه العناصر لعينات النباتات بالنسبة لمسافة 3 متر عن حافة الطريق الجانب الايسر كانت 31.5, 17.5, 122.3 (µg/g) لكل من Cu, Pb و Zn بالتتابع.

تعتبر المركبات التي تعمل بالوقود المصدر الرئيسي لهذه العناصر الثقيلة في بيئة جانب الطريق و قد قورنت هذه النتائج مع دراسات أخرى أجريت في عدة بلدان حول العلم. أخيرا إن عينات التربة و نباتات جانب الطريق تحتوي على نسب عالية من العناصر الثقيلة و هذه التراكيز تزداد بزيادة نسبة المركبات المارة على الشارع.

Introduction

Roadside soils often contain high concentrations of metallic contamination. The bioavailability and environmental mobility of the metals are dependent upon the form in which the metal is associated with the soil. Lead street dust and roadside soil has been extensively studied, and found to be present at elevated levels(Page *et al.*, 1971; Goldsmith *et al.*, 1976; Harrison *et al.*, 1980; Ho & Tai, 1988). The lead in roadside soil is mainly found in the form of lead sulfate[3]. Little interest has been focused on the contamination of roadside soil by other heavy metals. Metals, such as Cu, Fe, Zn, and Cd are essential components of many alloys, wires, tires and many industrial processes, and could be released into the roadside soil and plants as a result of mechanical abrasion and normal wear. Analyses of roadside soil (Harrison *et al.*, 1980; Cool *et al*, 1980; Hewitt & Candy, 1990) and plants(Ward *et al.*, 1975; Otte *et al.*, 1991) revealed that they contain elevated levels of these heavy metals. Toxicities of some heavy metals to man and animals are well known and were published some years ago(WHO ,1972; Schuberk, 1974). Of all the toxic metals in the environment, lead is by far the one of most concern; it poisons many thousands of people annually, especially children in urban area s(Spiro & Stigliani, 1996).

During the last few years, the number of vehicles in Iraq, mostly operated by leaded fuel, has increased rapidly leading to increasingly high levels of some heavy metals and other pollutants in the dust, soil and plants near main streets of urban areas. Although there have been a considerable number of studies on the concentrations of heavy metals in roadside soil and plants, the vast majority have been carried out in developed countries with long histories of industrialization and extensive use of leaded gasoline since 1935 (Page *et al.*, 1971; Goldsmith *et al.*, 1976; Ward *et al.*, 1975; Otte *et al.*, 1991; Schuberk, 1974; Mateu *et al.*, 1995; Spiro & Stigliani, 1996). Very few studies have been carried out in developing countries such as Iraq and data on pollutant metal concentrations and distribution in such areas are extremely scarce. Therefore, this study was initiated to assess the level of contamination of surface roadside soil and plants by some heavy metals along a major traffic street, since there have been no studies about the extent of contamination of the roadside ecosystem by priority heavy metal pollutants.

Experimental Works

Study area

Six sites were selected for the study along the street connecting Al Kufa bridge, with the 20th revolution square in Al Najaf (city center). At each site, samples were collected at different distances from the edge of the main road (1.5, 10, 25, and 60 meters) on sides, right and left. It is worth mentioning that there is a prevailing westerly wind at the sampling sites and the sites are numbered in order of increasing traffic density.

Sampling Procedure

Samples were collected from may 2007 until June 2007 to avoid rain washing out of the heavy metals. Five soil samples (the upper 2 cm) were collected from each, at the above mentioned distances at each site, with a
stainless steel trowel. The samples were stored in polyethylene bags then treated and analyzed separately.
The plant samples (palm) were collected at each indicated distance, if present, and transported to the laboratory in polyethylene bags. The plants were washed with deionized water and the green shoots were dried at 80^0 C for 24 hrs.

Sample Preparation and Analysis

for the soil samples were gently ground using a porcelain pestle and mortar, and the plant samples (palm) were cut to small pieces then washed it with deionized water and put it in nylon sieves. Then follow these steps in order to analyze soil and plant samples. (Ho and Tai, 1988).

1- Put the samples into a beaker (wash with deionized water and dried well) then put it in the oven with a temperature 110^{o}c for two hours to dry the sample.
2- Take (1 gm) from the dry samples and put it in a beaker (250 ml) using an analytical balance.

3- Add (15 ml) of concentrated hydrochloric acid HCl with (5 ml) of concentrated Nitric acid HNO_3.
4- Heat the sample in a hot sand bath until the brown vapor disappear and the sample will dry and this stage take about (45-60 min.).
5- Cool the beaker to the room temperature and then add (5 ml) of concentrated Hydrochloric acid HCl and heat again until the sample dry and this stage take (5-10 min.).
6- Cool the beaker to the room temperature and then add (5 ml) of concentrated Hydrochloric acid HCl and (50 ml) of the hot deionized water to wash the side wall of the beaker.
7- Heat the mixture to the boiling point for (2-3 min.).
8- Filtrate with a filter paper (no. 0.42) and put the filtrate in a volumetric flask (100 ml).
9- Wash the precipitate with deionized water and add the latter to the filtrate and complete the volume to 100 ml volumetric flask with deionized water.
10-Metal analysis was carried out with a flame atomic absorption spectroscopy (PEKIN-ELMER, model 5000 USA), quantitation of Pb, Cu, Zn, and Cd was carried out using standard solutions in the same acid matrix.

Figure (1):- Location of the sampling sites

Result and discussion

Heavy metals in soil

Table 1 gives the mean and the concentration range of four heavy metals in surface soil, taken from the six sites, at different distances from the main road. Copper concentrations at the right side of the road were higher than in the left side, and decreased exponentially with distance from the edge of the road. Cu is derived from engine wear, from thrust bearings, bushing and bearing metals. Some studies show much higher contamination levels (Ndiokwere, 1984; Ho & Tai, 1988), but our result is higher than those found in North Wales (Davies *et al.*, 1985) and Auckland (Ward *et al.*, 1977) (Table 2).

Table (1):- The arithmetic mean, standard deviation and concentration range of Cu, Cd, Pb and Zn in roadside soil(μg/g)

Distance m	Cu Mean ±sd Range	Cd Mean ±sd Range	Pb Mean ±sd Range	Zn Mean ±sd Range
1.5 m R*	40.32 ± 10.8 55.32 – 25.32	1.52 ± 0.32 1.96 – 1.08	200.5 ± 10.53 213.4 – 187.6	167.8 ± 9.5 181.4 – 154.2
10 m R	21.08 ± 6.27 29.88 – 12.27	1.20 ± 0.31 1.56 – 0.84	115.7 ± 13.28 132.9 – 98.5	83.4 ± 9.65 97.0 – 69.8
25 m R	19.96 ± 6.63 29.24 – 10.68	1.04 ± 0.31 1.48 – 0.60	89.4 ± 9.09 100.4 – 78.4	59.9 ± 9.89 75.3 – 44.5
60 m R	16.64 ± 6.04 25.08 – 8.20	0.88 ± 0.23 1.16 – 0.60	66.3 ± 7.23 75.4 – 57.2	38.1 ± 4.93 44.8 – 31.4
1.5 m L*	33.78 ± 6.88 42.56 – 24.88	1.32 ± 0.36 1.80 – 0.84	123.5 ± 3.74 127.9 – 119.1	137.6 ± 17.02 162.0 – 113.2
10 m L	18.16 ± 6.29 26.56 – 9.76	1.12 ± 0.19 1.37 – 0.88	93.3 ± 5.54 101.4 – 85.2	79.4 ± 8.98 93.2 – 65.6
25 m L	17.24 ± 6.01 25.64 – 8.84	0.93 ± 0.08 1.04 – 0.81	74.7 ± 7.73 85.2 – 64.2	43.8 ± 6.21 52.5 – 35.1
60 m L	14.84 ± 3.68 20.04 – 9.64	0.74 ± 0.08 0.85 – 0.063	57.8 ± 5.57 66.2 – 49.4	26.3 ± 4.72 33.4 – 19.2

R: Right of the roadside; L: Left of the roadside

Cadmium, on the other hand, exhibited lower levels of contamination than those of other studies (Harrison *et al.*, 1980; Davies *et al.*, 1985; Culbard *et al.*, 1988). However, the level of Cd in this study is comparable with those found in Nigeria (Ndiokwere, 1984) and about twice that in Birmingham (Carey *et al.*, 1980). The sources of cadmium in the urban areas are much less well defined than those of Pb, but metal plating and tire rubber were considered the likely sources of Cd (Hewitt & Rashed, 1988) . Cadmium and Zinc are found in lubricating oils as part of many additives. It was reported that the cadmium level in car tires is in the range of 20 to 90 μg/g as associated. Cd contamination in the process of vulcanization. In the absence of any major industry in the sampling sites, the levels of Cd could be due to lubricating oils and/or old tires, that are frequently used, and the rough surfaces of the roads which increase the wearing of tires(Ward *et al.*, 1977).

Table (2):- The levels of Cu, Cd, Pb and Zn (µg/g) in roadside soil compared with other studies worldwide.

Place	Cu	Cd	Pb	Zn	Ref
Al Najaf	40.32	1.52	200.5	167.8	This study
Lancaster	19-199	5.2	-	300-350	(Harrison *et al.*, 1980)
Hong Kong	120	1.1	991	633	(Ho and Tai, 1988)
Ecuador	-	0.36	293	509	(Hewitt and Candy, 1990)
Nigeria	61	1.3	247	163	(Ndiokwere, 1984)
North Wales	24	6.8	1779	1143	Davies *et al.*, 1985)
Auckland	27	0.4	1650	180	(Ward *et al.*, 1977)
London	-	4.2	1354	513	Culbard *et al.*, 1988)
Birmingham	-	0.70	180	205	(Davies, 1984)
USA (different cities)	-	0.89	444	-	(Carey *et al.*, 1980)

Lead, the element of most concern in environmental heavy metal pollution, exhibited high levels of contamination as we got closer to the main road. Decreases elemental concentrations with distance from the road would indicate surface soil contamination by extraneous sources. Whereas unchanging levels would show that the heavy metal concentrations were a function of the soil itself. Since the fuel used by automobiles in Iraq (Al Najaf) is mostly leaded, the most probable source of such contamination is the lead particulate matter emitted from gasoline vehicles (Harrison & Laxen, 1981). As the distance from the road increased, the Pb level fell sharply reaching the normal soil lead level, which was estimated to be less than 60 µg/g.. However, some investigators found that lead contamination of soil may reach 100 m from the main road(Ward *et al.*, 1977). The average value of lead 1.5 m right the road was much lower than those found in Hong Kong (Ho & Tai, 1988), North Wales (Davies *et al.*, 1985), Auckland (Ward *et al.*, 1977), and London(Culbard *et al.*, 1988), and it is comparable with that found in Nigeria (Ndiokwere, 198 x4) and more than found in Birmingham (Davies, 1984) as shown in Table 2.

Zinc, in the soil next to the road, exhibited elevated levels, 167.8 µg/g 1.5 m right of the road. This value is small compared with many other studies((Harrison *et al.*, 1980; Davies *et al.*, 1985; Ho & Tai, 1988 ; Culbard *et al.*, 1988; Culbard *et al.*, 1988), and it is comparable with that found in Nigeria (Ndiokwere, 1984). In this study, the Pb/Zn ratio in soil was greater than unity, which may indicate soil-lead pollution caused by automobiles. Similar results were found by other investigators (Ho & Tai, 1988; Ndiokwere, 1984; Davies *et al.*, 1985; Hewitt & Candy, 1990). However, other reports (Hewitt & Candy, 1990; Davies, 1984) found a ratio of less than unity, which was related to the local conditions. Since no major industry exists in the study areas such as smelting operations, we may assume that the primary sources of Zn are probably the attrition of motor vehicle tire rubber exacerbated by poor road surfaces, and the lubricating oils in which Zn is found as part of many additives such as zinc dithio phosphates.

The metal contamination decreased with distance from the road, and this is consistent with what was found in Nigeria(Ndiokwere, 1984). The clearly higher levels of the elements right compared with those left of the road. This latter trend can be attributed to the westerly prevailing winds in the study areas. For the four metal the higher concentration was found at the distance 1.5 m right and the lower concentration were found at the distance 60 m west.

The following tables (3-6) deals with the four metal concentration for each site with the standard deviation.

Table (3):- Cadmium concentration in soil samples µg/g ± SD

Site no	1.5 meter		10 meter		25 meter		60 meter	
	R ±10.80	L ±6.88	R ±6.27	L ±6.29	R ±6.63	L ±6.01	R ±6.04	L ±3.68
Site 1	41.21	37.33	21.78	18.71	20.65	17.35	16.76	15.06
Site 2	55.32	42.56	29.88	26.56	29.24	25.64	25.08	20.04
Site3	32.20	28.48	16.56	12.84	15.12	12.80	12.16	12.24
Site 4	39.52	30.11	20.38	17.61	19.36	17.13	16.52	14.62
Site 5	48.44	38.96	25.6	23.48	24.80	21.68	21.12	17.44
Site 6	25.32	24.88	12.27	9.76	10.68	8.84	8.20	9.64
average	40.32	33.78	21.08	18.16	19.96	17.24	16.64	14.84

Table (4):- Copper concentration in soil samples µg/g ± SD

Site no.	1.5 meter		10 meter		25 meter		60 meter	
	R ±0.32	L ±0.36	R ±0.31	L ±0.19	R ±0.31	L ±0.08	R ±0.23	L ± 0.08
Site 1	1.56	1.40	1.40	1.23	1.16	0.95	1.00	0. 77
Site 2	1.96	1.80	1.56	1.37	1.48	1.04	1.16	0. 85
Site3	1.28	1.00	0.92	0.98	0.84	0.88	0.68	0. 68
Site 4	1.48	1.24	1.00	1.01	0.92	0.91	0.76	0. 71
Site 5	1.76	1.64	1.48	1.26	1.24	0.98	1.08	0. 80
Site 6	1.08	0.84	0.84	0.88	0.60	0.81	0.60	0. 63
average	1.52	1.32	1.20	1.12	1.04	0.93	0.88	0. 74

Table (5):- Lead concentration in soil samples µg/g ± SD

Site no.	1.5 meter		10 meter		25 meter		60 meter	
	R ±10.53	L ±3.74	R ±13.28	L ±5.54	R ±9.09	L ±7.73	R ±7.23	L ±5.57
Site 1	205.8	125.7	119.9	94.3	93.7	77.9	69.4	58.8
Site 2	213.4	127.9	132.9	101.4	100.4	85.2	75.4	66.2
Site3	191.4	120.2	104.4	90.1	81.2	69.3	60.1	55.3
Site 4	195.2	121.3	111.5	92.3	85.1	71.5	63.2	56.8
Site 5	209.6	126.8	127.0	96.5	97.6	80.1	72.5	60.3
Site 6	187.6	119.1	98.5	85.2	78.4	64.2	57.2	49.4
average	200.5	123.5	115.7	93.3	89.4	74.7	66.3	57.8

Table (6):- Zinc concentration in soil samples µg/g ± SD

Site no.	1.5 meter		10 meter		25 meter		60 meter	
	R ±9.50	W ±17.02	R ±9.65	R ±9.89	L ±6.21	R ±4.93	L ±4.72	L ±8.98
Site 1	169.8	139.6	86.5	60.9	44.9	38.9	27.3	80.4
Site 2	181.4	162.0	97.0	75.3	52.5	44.8	33.4	93.2
Site3	161.7	126.4	77.2	57.3	39.4	34.2	24.2	76.2
Site 4	165.8	135.6	80.3	58.9	44.9	37.3	25.3	78.4
Site 5	173.9	148.8	89.6	62.5	48.2	42.0	28.4	82.6
Site 6	154.2	113.2	69.8	44.5	35.1	31.40	19.2	65.6
average	167.8	137.6	83.4	59.9	43.8	38.1	26.3	79.4

Heavy metals in "Palm" Plant

Cadmium levels in plants were below the detection limits of the flame AA used in this study. Other studies have had similar results(Lagerwer and Specht, 1970; Ho & Tai, 1988). Therefore, the study of plants contamination was restricted to Cu, Pb, and Zn. Table 4 shows the concentration of the three elements in the studied plant (palm). However, Table 7 summarizes a comparison between our results and some other studies worldwide. The selectivity of different plants for heavy metals is different, but rough comparison of heavy metals in plants with other studies shows that the copper level was higher than those found elsewhere (Ward *et al.,* 1977; Ho & Tai, 1988; Otte & Bestebroer,1991). However, the lead level in this study, was much lower than that of others(Ho & Tai, 1988; Ward *et al.,* 1977). This could be due to different plant types and different number of vehicles per day in those places.

Zinc have the highest concentration of the three metals which measured and lead show the low concentration compared with the other metals. This result similar with the other studies as shown in table 8.

Table (7):- The arithmetic mean, standard deviation and concentration range of Cu, Cd, Pb and Zn in roadside plants (μg/g)

Distance m	Cu mean±sd Range	Pb mean±sd Range	Zn mean±sd Range
3 m R*	31.5 ± 1.56 33.7 – 29.3	17.5 ± 0.49 18.1 – 16.9	122.3 ± 2.48 125.4 – 119.2
10 m R	26.1 ± 1.19 27.8 – 24.4	14.3 ± 0.43 14.9 – 13.7	75.8 ± 3.92 81.9 – 69.7
25 m R	22.8 ± 1.79 25.3 – 20.3	13.1 ± 0.37 13.6 – 12.6	66.2 ± 4.16 72.7 – 59.7
50 m R	19.4 ± 0.77 20.5 – 18.3	11.7 ± 0.61 12.6 – 10.8	43.7 ± 2.78 47.6 – 39.8
3 m L*	28.7 ± 1.11 30.1 – 27.3	9.8 ± 0.68 10.8 – 8.8	112.9 ± 3.78 118.5 – 107.3
10 m L	20.5 ± 0.98 21.8 – 19.2	8.4 ± 0.51 9.1 – 7.7	84.4 ± 3.91 89.1 – 79.7
25 m L	18.7 ± 1.10 20.1 – 17.7	7.5 ± 0.53 8.2 – 6.8	55.9 ± 2.69 60.0 – 51.8
50 m L	18.3 ± 0.73 19.4 – 17.2	5.6 ± 0.91 6.2 – 4.4	37.8 ± 0.71 38.8 – 36.8

E*: Right of the roadside; W*: West of the roadside

Table (8):- Levels of Cu, Pb, Zn (μgm/gm) in plant compared with other studies worldwide

place	Cu	Pb	Zn	Ref
Al Najaf	31.5	17.5	122.3	This study
Hong Kong	17	134	124	4
Dutch Coast	3-24	-	30-180	8
Auckland	17	180	-	16
USA	-	-	32-85	20
Belgium	-	-	37-114	22

The following tables (9-11) show the three metals concentration measured in the selected plant for each site with the standard deviation.

Table (9):- Copper concentration in Plant samples µg/g ± SD

Site no.	3 meter		10 meter		25 meter		50 meter	
	R ±1.56	L ±1.11	R ±1.19	L ±0.98	R ±1.79	L ±1.10	R ±0.77	L ±0.73
Site 1	32.6	29.7	26.9	21.3	24.0	19.7	19.9	18.6
Site 2	33.7	30.1	27.8	21.8	25.3	20.1	20.5	19.4
Site3	30.4	27.7	25.3	19.7	21.6	17.7	18.9	18.0
Site 4	31.2	28.3	25.9	20.2	22.2	18.4	19.2	18.1
Site 5	31.8	29.1	26.3	20.8	23.4	19.0	19.6	18.5
Site 6	29.3	27.3	24.4	19.2	20.3	17.3	18.3	17.2
average	31.5	28.7	26.1	20.5	22.8	18.7	19.4	18.3

Table (10):- Lead concentration in Plant samples µg/l ± SD

Site no.	3 meter		10 meter		25 meter		50 meter	
	R ±0.49	L ±0.68	R ±0.43	L ±0.51	R ±0.37	L ±0.53	R ±0.61	L ±0.91
Site 1	17.9	10.2	14.6	8.8	13.4	7.9	12.0	6.2
Site 2	18.1	10.8	14.9	9.1	13.6	8.2	12.6	6.8
Site3	17.1	9.4	14.0	8.0	12.8	7.1	11.4	5.0
Site 4	17.2	9.7	14.2	8.3	13.0	7.3	11.5	5.1
Site 5	17.8	9.9	14.4	8.5	13.2	7.7	11.9	6.1
Site 6	16.9	8.8	13.7	7.7	12.6	6.8	10.8	4.4
average	17.5	9.8	14.3	8.4	13.1	7.5	11.7	5.6

Table (11):- Zinc concentration in Plant samples µg/g ± SD

Site no.	3 meter		10 meter		25 meter		50 meter	
	R ±2.48	L ±3.78	R ±3.92	L ±3.91	R ±4.16	L ±2.69	R ±2.78	L ±0.71
Site 1	125.4	118.5	81.9	89.1	72.7	60.0	47.6	38.8
Site 2	124.5	115.0	76.8	88.4	67.2	56.9	45.7	38.3
Site3	120.1	110.8	74.8	80.4	65.2	54.9	41.7	37.3
Site 4	121.3	112.7	75.3	84.1	66.1	55.3	43.4	37.7
Site 5	123.3	113.1	76.3	84.7	66.3	56.6	44.0	37.9
Site 6	119.2	107.3	69.7	79.7	59.7	51.8	39.8	36.8
average	122.3	112.9	75.8	84.4	66.2	55.9	43.7	37.8

Conclusions

The following conclusions may be drawn:

1- The roadside surface soil, Plant plants in Najaf are relatively contaminated with heavy metals when compared with the background values. The contamination is relatively lower than that of other places worldwide.

2-More heavy metal contaminations in soil and plants was observed on the right side of the road than the left side. This could be due to the westerly prevailing winds.

3- The levels of heavy metal contamination in both surface soils and vegetation, exponentially decreased to background levels with distance on either side of the main road. The decrease of elemental concentrations with distance from the main road would indicate aerial deposition of metal particulates in the roadside environment from extraneous sources and not a function of soil type. In Iraq (Najaf) motor vehicles that burn leaded gasoline are mostly responsible for the build up of heavy metals in soild and in grasses along the road through the emissions of particulates.

4- The concentration of Pb, especially in soil, exhibited a larger variation with distance from the road than those of Cd, Cu and Zn. This may be explained by the relatively higher background values of Cd, Cu and Zn in the samples.

5- The roadside environment had a significantly high content of heavy metals, especially Pb, and generally their levels increased with increasing traffic volumes and become elevated in urban areas.

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