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Impact of Traffic Density on Roadside Pollution by Some Heavy Metal Ions in Madinah City, Kingdom of Saudi Arabia

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In this study, the impact of traffic activities on K, Cr, Ir and Pd heavy metals ion concentration of roadside soil of Madinah city, Saudi Arabia. Surface and 20 cm under surface soil samples from 12 different sites were collected and analyzed. The measured concentration of the four heavy metal ions was correlated to the traffic density which was monitored in roads near the sampling sites. In addition, a comparison was made between the concentration and those of Zn and Pb investigated previously. The results revealed significant dependence of Cr and Ir on traffic density with correlation coefficients of 0.948 and 0.898, respectively. The other two metals, K and Pd showed no dependence on traffic density and no dependence between the surface and under surface concentration. The values of pollution indices such as contamination factor, degree of contamination and geo-accumulation index indicated various levels of contamination in the roadside soil. The degree of contamination values in the most five polluted sites were 258.718, 180.854, 142.737, 88.477 and 79.153, corresponding to the airport road (1), Taibah University street (2), Orwah Valley street (3), Qubaa Municipality (4), East Al-Haram area (5), respectively. These results insure that traffic emissions and other anthropogenic activities are major sources of the metal contamination.

Keywords: Roadside soil, Heavy metal ions, Soil pollution, Traffic impact on pollution, Madina.

INTRODUCTION

Nowadays, the heavy metal ions pollution is one of the most serious environmental threats[1]. The main problems in these pollutants include: their ease mobility in the eco-system, their toxicity[2] their bioaccumulation in the food processes[3,4]. For this reason, the continuous monitoring of heavy metals concentrations in the environment especially near roadside is of vital importance[5].

Traffic activity is considered as one of the major anthropogenic activities that usually produce heavy metal pollution in urban areas[6]. Pollution from traffic source consists of tyre wear, brake linings, batteries metals and others. Moreover, the emission of the platinum group (PGE) including Pt, Pd, Rh and Ir that catalyze the conversion of HC, CO and NO_x to H_2O, CO_2 and NO_2 has also gained attention in the last years[7]. Most of the heavy metal ions produced from the above activities are emitted first to the air then subsequently are deposited into soils. Accordingly, a high correlation between metal ions concentration in the air dust and in roadside soil[8]. Consequently, roadside soils in urban areas is considered as a good indicator for the pollution by heavy metal ions[9].

Recently, developed countries have started to regulate and set up upper limits for the heavy metal ions concentration in the environment[10]. Thus, many research studies dealing roadside pollution with metal ions have emerged in developed countries with only few studies developing countries[11-13]. On the other hand, in Saudi Arabia, very limited research has been carried out concerning heavy metal ions contamination in roadside soil. Al-Shayeb and Seaward[14] determined the concentration of the metals Pb, Zn, Cu, Cr and Ni in roadside surface and subsurface. They reported the level of Pb, Zn and Cu correlated well with traffic density. Zinc level was also measured since it represents a product of tire tare on roads[15]. In a more recent study, Assirey and Al-Shahawi[16] studied the effect of traffic density on heavy metal concentration in roadside of city Madinah. They reported a good correlation between Pb and Zn concentration with traffic density while other ions such as V, As, have low correlation values with traffic density.

It is familiar that Madinah is the second holiest place for Muslims and receives more than 13 million visitors every year. In part one of this study, the impact of traffic density on the concentration of As, Co, Pb, V and Zn. For this reason, this study was devoted to investigate the impact of traffic density

TABLE-1
DESCRIPTION OF THE SAMPLING SITES IN MADINAH ROADS AND STREETS

Site No.	Sampling site	Description of the sampling area	Traffic cars/day
1	West airport road	Sandy soil, heavy traffic	36768
2	West to Taibah University	Sandy soil and somewhat harsh, heavy traffic	33480
3	Orwah valley street	Clay soil	21744
4	Qubaa Municipality	Muddy soil	16416
5	East Al-Haram area	Sandy soil, old buildings were removed	15144
5	Legend Hall street	Clay soil and easy drilling	12624
7	Oyon street	Near valleys, muddy soil, easy to drill, high traffic	10032
8	West AlHaram area	Used as parking lots for cars, medium sandy earth	6960
9	Walking street	Easy to soil, presence of rigs, traffic	5112
10	Al-Ansar area	Agricultural land, the soil sample was wet	4992
11	East airport road	Sandy soil	768
12	Land near Rashed Mall	Rocky ground	216

on K, Cr, Ir, Pd heavy metal ion of content in the roadside of Madinah and to compare the results with those of Zn and Pb obtained previously. The results were correlated with traffic density in these roads. Then to calculate the overall contamination for the ions that have strong correlation with traffic density. Results will help the local government to take some measures to control and organize the traffic movements in the city.

EXPERIMENTAL

Sampling area: Medinah city is located in the western region of Saudi Arabia, 150 km east of the Red Sea and on the longitudes (39 42 36 – 39 96 00) and latitude (24 36 00 – 24 21 00). Medina's total area is about 589 km^2 of which 293 km^2 is considered as urban area, while the rest is outside the urban area. More information about Madinah city are found in recent publication[16].

Soil samples were collected from different roadsides of Madinah. It is clear that the sampling sites are distributed evenly in all directions of the city and were selected to cover most crowded streets in and around the city including those having heavy and light traffic.

The names and a brief description of the sampling sites are given Table-1. During the sampling process, twelve soil samples (humus) were carefully collected from the surface of roadsides and another twelve samples were collected from points 20 cm under the ground surface.

Sample collection: As in part I of this investigation[16], chemicals of analytical grade were used as received. The tested heavy metal ions in this part were K, Cr, Ir and pd. Stock solutions (1000 µg mL^{-1}, BDH, Poole, England) of these ions were used to prepare diluted solutions. In the digestion process for the collected soil samples and the certified reference material (IAEA-soil-7), concentrated HF, HCl and HNO_3 (Merck, Darmstadt, Germany) were used. Low density polyethylene (LDPE) bottles were used to keep ions solutions. These bottles were carefully cleaned first with hot detergent, then soaked in 50 % w/v HCl, 0.2 M HNO_3 then washed by 0.5 M HCl. and finally rinsed with deionized water. The glassware's used in all experiments were cleaned by immersing them in 1.5 % w/v HNO_3 for 24 h before use[16].

Soil sample analysis: All soil samples were prepared according to the method of Narin *et al.*[17]. These samples were first heated for 2 h until dryness at 110 °C, then grounded and sieved using a 200 mesh and stored. After that 0.50 g of the prepared soil sample was digested using the microwave digestion method. The details of this microwave digestion process system is found in the first part of this investigation[16].

The accuracy and precision of analytical experimental results were checked using a standard reference material[7,16,18]. The results obtained by proposed procedures of the digestion and analysis are shown in Table-2. It is clear from Table-2 that there is a good agreement among experimental and certified values. This confirms the suitability and applicability of the applied digestion procedure of soil samples.

TABLE-2
ANALYTICAL DATA OF SOME SELECTED METAL IONS IN CERTIFIED REFERENCE MATERIAL (IAEA SOIL-7) BY EMPLOYED DIGESTION PROCEDURE AND ICP-MS*

Element	Certified values		Present work, ICP-MS
	Conc. (ppm)	95 % confidence interval	Conc. (ppm)
Cr	60.0	49-74	57.0 ± 0.003
Ir	11.51	10.5-15.5	12.1 ± 0.003
Pd	4.52	4-1-6.0	5.5 ± 0.003
K**	12100	11300-12700	11500 ± 0.16

*Average of five measurements ± relative standard deviation.
**Analyzed by FAAS.

Traffic density: The data of traffic density obtained in the first part of investigation are used in the present study[16]. The traffic data were obtained by a team of workers who assigned to count the traffic in the streets near the sampling sites. They were distributed in the streets in such a way that in each point two workers counted the traffic in both sides of the road for a period of 1 h. The whole team started at the same time in all the 12 places and repeated the process three times to obtain a mean value. These values are tabulated in Table-1 and used in the correlation step.

Instrumental analysis: In this part of investigation as in the previous part, an ICP-mass spectrometry (ICP-MS) Perkin-Elmer Sciex (model Elan DRC II, USA) and a Perkin Elmer inductively coupled plasma-optical emission spectrometer (ICP-OES) model Optima 4100 DV, USA and spectrometers were used to measure the heavy metals concentration in the test samples. The ICP-MS analyzer was optimized every day before use and operated as recommended by the manufacturers catalogues. In addition, a Perkin-Elmer atomic absorption spectrometer (FAAS) (Model Analyst 800) was used in the measurement of potassium ion concentration. A Milli-Q Plus system (Millipore, Bedford, MA, USA) was operated obtain deionized water used in the preparation of the standard solutions for all ions.

Soil contamination level with heavy metal ions: Roadside soil contamination with heavy metal ions is a very important parameter in the assessment process of the pollution of urban areas by traffic and human activities. In this investigation, the contamination level was calculated using indices proposed by Hakanson[19]. These indices are the contamination factor (CF) and integrated degree of contamination (CD). These indices are defined as follows:

$$\text{Contamination factor (CF)} = C_m/C_b \quad (1)$$

$$\text{Degree of contamination (CD)} = \Sigma CF \quad (2)$$

where, C_m is the measured heavy metal concentration (µg/g) and C_b is the reference concentration of the heavy metals in the uncontaminated soil (µg/g). According to Mmolawa *et al.*[20] the contamination factor levels were classified into four categories. On the other hand, integrated degree of contamination levels CD are divided into four categories to describe metal contamination levels in the sampling sites. In addition, the geo-accumulation (I_{geo}) index was defined by Müller[21] will be used in this study as before. Eqn. 3 will be used to calculate this index:

$$I_{geo} = \log 2[C_s/(1.5C_b)] \quad (3)$$

The factor 1.5 is introduced to eliminate the possible variations effects of reference values of a given metal in addition to minor anthropogenic influences. Lu *et al.*[22] classified geo accumulation index (I_{geo}) for each metal into 7 grade-categories.

The classifications of the three indices are shown in Table-3. It should be noted that if the degree of contamination exceed 20 and the I_{geo} exceeds 5 then it will be necessary to take immediate counter measures to reduce heavy metal contamination in the road environment.

TABLE-3
LEVELS OF CONTAMINATION FACTOR, INTEGRATED DEGREE OF CONTAMINATION AND GEO-ACCUMULATION INDICES

Index equation	Range	Classification
$CF = C_m/C_b$	CF < 1	Low
	1 ≤ CF < 3	Moderate
	3 ≤ CF < 6	Considerable
	6 ≤ CF	Very high
CD = ΣCF	CD < 5	Low
	5 ≤ CD < 10	Moderate
	10 ≤ CD < 20	Considerable
	20 ≤ CD	Very high
$I_{geo} = \log 2[C_s/(1.5C_b)]$	$I_{geo} < 0 =$	Practically unpolluted
	$0 < I_{geo} \leq 1$	Unpolluted to moderately polluted
	$1 < I_{geo} \leq 2$	Moderately polluted
	$2 < I_{geo} \leq 3$	Moderately to strongly polluted
	$3 < I_{geo} \leq 4$	Strongly polluted
	$4 < I_{geo} \leq 5$	Strongly to extremely polluted
	$I_{geo} \geq 5$	Extremely polluted

Statistical analysis: In the present study, statistical analyses were performed using Statistical Package for Social Sciences (SPSS) Program. The values of descriptive statistics parameters like mean, range and standard deviation were obtained. The correlation coefficients (r) between the heavy metal concentration and the traffic density were calculated by $p < 0.05$. In addition, the contamination ratio for each sampling site was calculated. The contamination ratio is defined as the ratio of the average metal concentration of a site to that of the metal of the reference site (control).

RESULTS AND DISCUSSION

Heavy metal concentration in roadside of Madinah soil: Twelve sites were chosen for soil sampling in order to measure heavy metal ion concentration. The first eleven sites are considered as urban zones since they are characterized by high population density of more than 50 persons per hectare in addition to high traffic density[20].

As mentioned above, K, Cr, Ir and Pd, ions concentration were measured in 12 different sites. Table-4 shows some basic statistical parameters for the distribution of two arbitrary metals concentration in these sites. These metals are chromium and iridium.

It is evident from Table-3 that the values of standard deviation as a measure of random error, are relatively low. The average values of triplicate measurements of these metals concentrations over soil surface and under soil surface were estimated in µg/g. All metal concentration measurements in addition to traffic density are presented in Figs. 1-4.

Fig. 1 shows the variation of potassium ion concentration in samples taken from the surface and 20 cm under the surface in the 12 sites. The figure also depicts the variation of traffic density in roads and streets near those sites. It should be noted that the sites are numbered according to the traffic density. This means that site number 1 has the highest traffic density and site number 12 has the lowest traffic density.

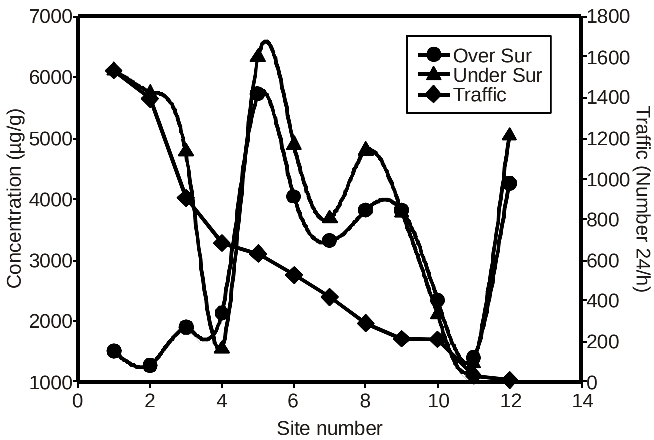

Fig. 1. Variation of potassium, surface and under surface concentration and traffic density across the sampling site

It is evident from Fig. 1 that potassium, concentration in the twelve sites varies from 1261.5 to 5725 and from 1301 to 6335 µg/g in surface and under surface samples, respectively. It is familiar that K is widely distributed in the Earth's crust is considered as an important component of soil. These values

TABLE-4
SOME STATISTICAL ANALYSIS DATA FOR Cr AND Ir SAMPLES COLLECTED FROM SURFACE AND UNDER SURFACE IN 12 DIFFERENT SITES OF MADINAH CITY

Site	Place	Cr			Ir		
		Mean (µg/g)	Std. Dev.	RSD (%)	Mean (µg/g)	Std. Dev.	RSD (%)
1	OS	150.85	0.0445	1.48	39.6	0.0092	1.16
	US	88.2	0.01	0.57	4.75	0.0069	7.26
2	OS	145.95	0.011	0.38	19.5	0.0036	0.91
	US	51.55	0.01	0.97	3.6	0.007	9.69
3	OS	135.8	0.0339	1.25	14.6	0.006	2.05
	US	51.25	0.009	0.88	3.5	0.0079	11.21
4	OS	56.7	0.0026	0.23	3.85	0.0135	17.60
	US	45.75	0.0041	0.44	3	0.0033	5.53
5	OS	45.1	0.0037	0.41	3.6	0.0085	11.82
	US	32.8	0.0054	0.82	2.4	0.0018	3.81
6	OS	44.00	0.0053	0.6	3.6	0.0028	3.90
	US	27.1	0.0051	0.94	1.95	0.0093	23.50
7	OS	37.6	0.0026	0.35	3	0.0064	10.52
	US	25.5	0.0025	0.65	1.95	0.0048	12.42
8	OS	34.05	0.0055	0.8	2.65	0.0066	12.40
	US	24.45	0.0043	0.88	1.8	0.0013	3.70
9	OS	26.6	0.0025	0.47	1.8	0.0082	22.90
	US	22.00	0.0017	0.39	1.35	0.0028	10.27
10	OS	24.65	0.0033	0.66	0.8	0.053	34.05
	US	19.45	0.0025	0.65	1.1	0.001	4.57
11	OS	18.1	0.0042	1.17	0.7	0.0048	33.13
	US	10.65	0.0017	0.80	0.5	0.0037	36.32
12	OS	16.2	0.0025	0.77	0.3	0.0017	28.87
	US	5.35	0.0012	1.09	0.05	0.0032	320.96

are within the normal range of potassium concentration in the earth's crust[23] which is about 15,000 (µg/g). In addition, 98 % of potassium ions are bound in the mineral form, while 2 % only are dissolved in soil solution and exchangeable phases[24]. As noted from Fig. 1, the values of potassium concentration in some sites of Madinah soil are higher. Moreover, it is clear that traffic has no any influence on potassium concentration since Fig. 1 shows that heavy traffic density sites have relatively the same concentration of potassium ions as low traffic density sites.

Fig. 2 shows the variation of chromium metal ion concentration in samples taken from the surface and 20 cm under the surface in the 12 sites.

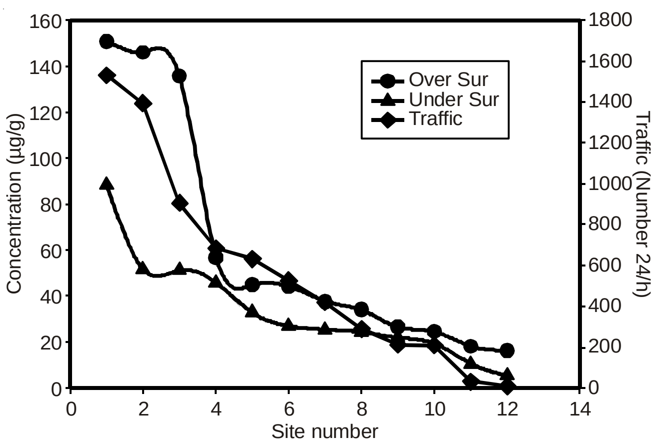

Fig. 2. Variation of chromium surface and under surface concentration and traffic density across the sampling site

It could be seen in Fig. 2 that in these sites, chromium concentration ranges from 16.2 to 150.85 and from 5.35 to 88.2 µg/g in surface and under surface samples, respectively. The values of chromium ion concentrations shown in Fig. 3 shows positive relation with trafc density. This behaviour is attributed to the non-exhaust emissions produced by traffic such as brake wears, tire wears, galvanized body parts and of abrasion road surface[25]. Chromium ion usually exists as in soil as Cr(III) or Cr(VI) and both forms have different properties. Chromium(VI) forms the oxyanion CrO_4^{2-}, which is considered as a strong oxidizing agent and carcinogenic. In contrast, chromium(III) hydrolyzes into cationic species $[Cr(OH)^{2+}]$ and it is essential to human beings. In soil, cationic form of Cr(VI) is soluble and mobile, whereas the cationic form of Cr(III) are easily adsorbed or precipitated[26]. Chromium(III) is not mobile in the soil because it usually present as insoluble carbonate and oxide of chromium(III)[27].

Fig. 3 shows the variation of iridium ion concentration in samples taken from the surface and 20 cm under the surface in the 12 sites.

It is evident from Fig. 3 that in these sites, iridium concentration ranges from 0.3 to 39.6 and from 0.05 to 4.75 µg/g in surface and under surface samples, respectively. Fig. 4 shows that the highest Ir concentrations corresponds to samples collected from sites near the highest traffic density. It is known that iridium is one of the rarest elements in the earth's crust hard metal. It has good resistance to corrosion and it is an extremely hard metal. For this reason it widely used in automotive industries[28].

So far, there are only few studies that have been carried out to measure iridium content in roadside soils in urban

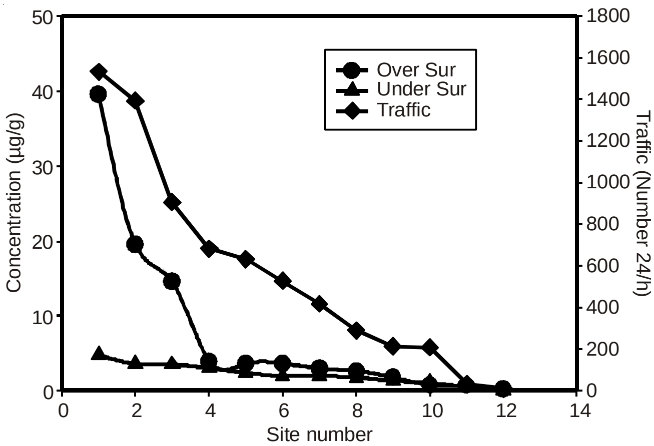

Fig. 3. Variation of iridium surface and under surface concentration and traffic density across the sampling site

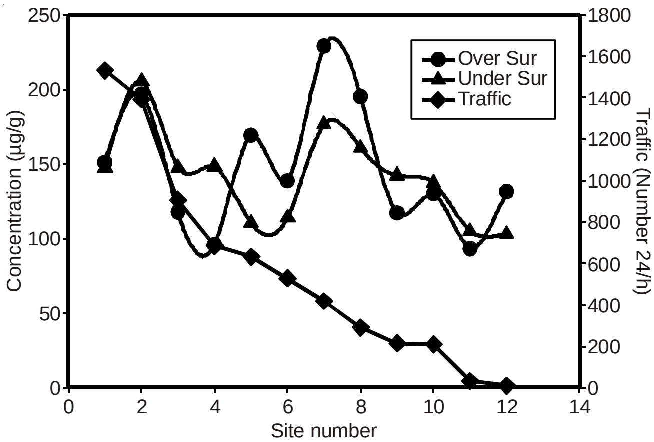

Fig. 4. Variation of palladium, surface and under surface concentration and traffic density across the sampling site

highways. These studies investigated the anthropogenic contribution to roadside and Ir enrichment as a result of environmental release caused by the attrition of catalysts[29]. Ely *et al.*[29] collected soil samples from interstate highways, urban roads and side streets in around South Bend, Indiana. The background South Bend Ir content (± SD) of 0.06 ± 0.04 ng/g was similar to the normal values for the upper crust, which ranged from 0.025 to 0.05 ng/g according to Wedepohl[30], but all soils showed levels significantly higher than those of the background and iridium concentrations in some soil samples was as much as five to seven times the background.

Muller and Heumann[31] reported that Ir content increased with decreasing distance from the highway. Ir concentrations was more than 20 times the normal background at 0.20 m from the road and decreased to the background level at a distance of 3 m showing levels of 0.37 ± 0.09, 0.16 ± 0.07 and 0.13 ± 0.07 ng/g at 0.6, 1.8 and 3 m from the road, respectively.

Fritsche and Meisel[7] investigated the distribution of Ru, Rh, Pd, Os, Ir, Pt and rare earth elements in soils along major motorways. They concentrated on the anthropogenic input of iridium as this metal is now also used in automobile catalytic converters. They reported that in all sites Rh, Pd and Pt but also Ir and Re concentration significantly exceed natural background values and concentrations reached 13, 25, 134, 1.1 and 9.8 ng/g, respectively. These results showed that traffic could contribute in the iridium enrichment in the roadside soil as result of environmental and catalytic attrition.

Fig. 4 shows the variation of palladium metal concentration in samples taken from the surface and 20 cm under the surface in the 12 sites.

It is evident from Fig. 4 that in these sites, palladium concentration ranges from 92.95 to 229.25 and from 102.9 to 205.6 µg/g in surface and under surface samples, respectively. These values are not within the normal range of palladium concentration in the earth's crust which is about 0.001-0.005 µg/g, but there is no effect of the traffic density[32].

In the previous part of this investigation[16], it was concluded that the concentration of lead and zinc were affected by the traffic density. The concentration ranges of Pb was from 0.3 to 33.35 and from 0.1 to 3.3 µg/g in surface and under surface samples, respectively. While zinc concentration ranges from 16.5 to 90.5 and from 10.5 to 49.75 µg/g in surface and under surface samples, respectively. Accordingly, four heavy metal ions concentration show relatively high dependence on traffic density.

Correlation between metals concentration and traffic density in Madinah city: Inter-correlation calculations using Pearson correlation coefficient (r), between the surface heavy metals concentration of the 12 sites and traffic density are shown in Table-5. It is familiar that this coefficient measures the strength of a linear relationship between any two variables. Its scale ranges from -1 for a perfect inverse relationship, through 0 when there is no relationship to +1 for a perfect sympathetic relationship. In this study, the raw geochemical data were used in calculating the correlation coefficient using the SPSS (Statistical Program for the Social Sciences) computer software package (SPSS Inc., version 16.0).

Table-5 indicated significant positive correlations ($p < 0.05$) between traffic density (TD), with both Cr and Ir. The correlation values are TD/Cr ($r = 0.948$) and TD/Ir ($r = 0.898$). This significant positive correlations between Cr and Ir metals with TD indicate possible contamination of the roadside soil by traffic non-exhaust and exhaust emissions. On the other hand, the correlation between K and Pd is positive but lower

TABLE-5
CORRELATION ANALYSIS AMONG METALS CONCENTRATION AND TRAFFIC DENSITY (TD)

Parameter	Traffic volume	K	Cr	Ir	Pd	Pb	Zn
TD	1						
K	0.442	1					
Cr	0.948	-0.556	1				
Ir	0.898	-0.511	0.893	1	1		
Pd	0.255	0.239	0.158	0.148	0.148		
Pb	0.983	-0.409	0.926	0.844	0.844	1	
Zn	0.987	-0.409	0.939	0.873	0.873	0.996	1

than those of Cr and Ir. Table-5 indicates some elemental pairs for example, Pb/Zn (r = 0.996), Cr/Zn (r = 0.939), Cr/Pb (r = 0.926), Cr/Ir (r = 0. 893), Zn/Ir (r = 0.873), Pb/Ir (r = 0.844) have strong correlation with each other. On the other hand, pairs such as Zn/Pd (r = 0.266), Pb/Pd (r = 0.242) Pd/K (r = 0.239), Pd/Cr (r = 0.158), Pd/Ir (r = 0.148) have moderate interdependence. Moreover, pairs of Cr/K, Ir/K, Pb/K, Zn/K and TD/K show no significant correlation with each other. It could be concluded that road side soil contamination by the heavy metals originated from a common anthropogenic sources in addition to local industries since Madinah city area has no heavy or major industrial development.

Inter-correlation calculations was estimated between metal concentration on the surface and under surface. The correlation values were: Cr(OS)/Cr(US), (r = 0.894); K(OS)/Kr(US), (r = 0.460); Ir(OS)/Ir(US), (r = 0.927); Pd(OS)/Pd(US), (r = 0.110). These results indicate that each metal has strong correlation between its over and under surface concentration except potassium.

Madinah soil contamination level with heavy metal ions: It is clear from the above results that chromium, potassium, iridium and palladium concentration values in Madinah roadside soil are above the normal levels. Accordingly, the contamination level of these metals will be considered by calculating the contamination factor (CF) and integrated degree of contamination (CD) in addition to the geo-accumulation (I_{geo}).

Table-5 shows the values of these three indices of six heavy metals. The contamination factor indicated very high contamination level (6 ≤ CF) of Pb in sites from 1 through 11 and moderate contamination (1 ≤ CF < 3) in site number 12 whereas the CF values of Cr indicate very high contamination level (6 ≤ CF) in sites from 1 through 3, considerable (3 ≤ CF < 6) contamination in site number 4 and finally moderate contamination (1 ≤ CF < 3) in sites from 5 through 12. The CF values of Ir indicated very high contamination level (6 ≤ CF) in sites 1 to 9 and moderate contamination (1 ≤ CF < 3) in sites 10 to 12. The contamination factor indicated considerable (3 ≤ CF < 6) contamination of Zn in sites from 1 to 5 and moderate contamination (1 ≤ CF < 3) in sites 6, 7, 8, 9, 10, 11 and 12. The contamination factor, CF of palladium indicated moderate contamination (1 ≤ CF < 3) in sites 1, 2, 5, 6, 7, 8 and 12 and low contamination (CF < 1) in sites 3, 4, 9, 10 and 11. On the other hand, the contamination factor of potassium indicated low contamination (CF < 1) in sites 1,2,3,4,6,7,8,9,10 and11, moderate contamination (1 ≤ CF < 3) in site number 12.

The values of degree of contamination estimated for each site is shown in Table-6. It is clear from Table-6 that sites 1 to 10 showed high degree of contamination (20 ≤ CD), site 11 showed considerable degree of contamination (10 ≤ CD < 20) and finally site 12 showed moderate contamination (5 ≤ CD < 10). This indicates that long term exposure within the neighborhood of sites 1 to 10 can lead to adverse health effects to human particularly on children, pregnant women and the aged who are all known to be vulnerable[33,34].

Furthermore, Table-6 shows the geo-accumulation index, I_{geo} which was calculated for metals, K, Cr, Ir and Pd obtained in this part of study and those Pb and Zn from the first part of this study[16]. For potassium, the pollution level indicates that sites 1, 2, 3, 4, 10 and 11 are practically unpolluted and the other six sites are unpolluted to moderately polluted ($0 < I_{geo} \leq 1$). In the case of lead, site number 12 is unpolluted to moderately polluted ($0 < I_{geo} \leq 1$), sites 4 to 11 are moderately polluted ($1 < I_{geo} \leq 2$) and in sites 1 to 3 are moderately to strongly ($2 < I_{geo} \leq 3$). For chromium, sites from 1 to 3 are moderately polluted ($1 < I_{geo} \leq 2$) and the other sites are unpolluted to moderately polluted ($0 < I_{geo} \leq 1$). For zinc, all sites are unpolluted to moderately polluted ($0 < I_{geo} \leq 1$). For iridium, site number 1 is moderately to strongly ($2 < I_{geo} \leq 3$), sites 2 to 8 are moderately polluted ($1 < I_{geo} \leq 2$) and the other sites are unpolluted to moderately polluted ($0 < I_{geo} \leq 1$). For palladium, all sites are practically unpolluted. According to these results, the environment in the chosen sites is relatively more affected by Pb, Ir and Cr compared to Zn, K and Pd.

Conclusions

The present study was focused on the concentrations of Cr, Pd, K and Ir and their pollution levels in connection with traffic density. The following conclusion can be stated:

- The concentration of Cr and Ir metals showed a clear relationship with traffic conditions with correlation coefficients were 0.948 and 0.898, respectively.
- The most polluted roadside sites with chromium, lead, iridium and zinc were the airport road (1) and Taibah University road (2).

TABLE-6
CONTAMINATION FACTOR (CF), DEGREE OF CONTAMINATION (CD) AND GEO-ACCUMULATION INDEX (I_{geo}) OF POTENTIAL TOXIC METALS IN ROADSIDE DUSTS ALONG ROAD SECTION

Site No.	K		Cr		Ir		Pd		Zn		Pb		CD
	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	CF	I_{geo}	
1	0.351	-0.329	9.311	1.093	132.0	2.245	1.150	-1.931	4.738	0.800	111.166	2.171	258.718
2	0.296	-0.403	9.009	1.079	65.0	1.937	1.496	-1.818	4.052	0.732	101.0	2.129	180.854
3	0.444	-0.226	8.382	1.048	48.666	1.812	0.895	-2.040	3.680	0.690	80.666	2.031	142.737
4	0.499	-0.176	3.5	0.669	12.833	1.233	0.729	-2.129	3.247	0.636	67.666	1.955	88.477
5	1.345	0.253	2.783	0.569	12.0	1.204	1.291	-1.882	3.066	0.611	58.666	1.893	79.153
6	0.950	0.102	2.716	0.558	12.0	1.204	1.057	-1.968	2.866	0.582	50.333	1.826	69.924
7	0.778	0.016	2.320	0.490	10.0	1.124	1.747	-1.750	2.676	0.552	44.333	1.771	61.856
8	0.895	0.077	2.101	0.447	8.833	1.071	1.487	-1.820	2.228	0.472	37.0	1.693	52.547
9	0.895	0.077	1.641	0.340	6.0	0.903	0.892	-2.042	1.923	0.409	31.333	1.620	42.687
10	0.549	-0.135	1.521	0.307	2.666	0.550	0.989	-1.997	1.723	0.361	21.833	1.464	29.284
11	0.325	-0.362	1.117	0.173	2.333	0.492	0.708	-2.142	1.266	0.227	13.0	1.238	18.751
12	1.0	0.124	1.0	0.124	1.0	0.124	1.0	-1.992	1.0	0.124	1.0	0.124	6.0

• The maximum contamination factor (CF) values for Cr, Pb, Ir and Zn were 9.311, 111.166, 132 and 4.738, respectively. This indicates very high contamination level with Cr, Pb, Ir and considerable contamination level with Zn in site 1.

• The maximum value of the degree of contamination (CD) was 258.718 in site 1 and showed high degree of contamination (20 ≤ CD).

• On the other hand the values index of geo accumulation (I_{geo}) for Cr, Pb, Ir and Zn in site 1 were 1.093, 2.1709, 2.245 and 0.800 respectively. These values indicate moderately polluted with Cr, unpolluted to moderately polluted with Zn and moderately to strongly polluted with Ir and Pb.

• The estimated results using the three indices are in good agreement in explaining the levels Cr, Pb, Ir and Zn metals present in the roadside soil samples and the good correlation with the traffic density. More studies are required to investigate the real sources of pollutants in Madinah city.

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