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Heavy Metal Distribution in Soil Profiles in Riyadh (Saudi Arabia)

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The distribution of Pb, Zn, Cu, Cr and Ni in Riyadh soil profiles was determined. Their levels were investigated in relation to organic matter content, soil pH and samples location. Samples were collected from urban, suburban, rural, highway and industrial area. Surface soils of highway and urban areas were found to be highly polluted with Pb and with a lesser extent Zn. High correlation was found between Pb, Zn, Cu and Cr indicating automobiles as a common source. No evidence of Ni contamination of soils was obtained. Soil profile results showed that Pb, Zn and Cu were largely concentrated in the upper surface soils, which is attributed to the low rainfall in the study area. It was found that approximately 74.7% of the lead, 56.6% of the zinc and 40.3% of the copper are concentrated in the top 5 cm confirming an airborne origin.

INTRODUCTION

In areas of active aerial contamination, the metal profile in soil tends to show highest concentrations in the upper layer of soil profiles. This is true of a diverse range of contaminated sites such as roadsides, close to smelters and other industrial sources, near mines and in certain agricultural situations[1]. A consideration of soil depth distribution of an individual heavy metal is of prime importance when plants are to be used to monitor that metal. Soil profile data are also important to confirm the airborne origin of metal enrichment in contaminated surface soils. The distribution of metals in soil profiles is dependent on many factors, including soil organic matter and pH.

Motto *et al.*[2] examined the lead variation within a soil pofile and showed a marked decrease in concentration in the 15–30 cm zone compared with the upper 15 cm. Yassoglou *et al.*[3] evaluated the airborne contamination of roadside soils with Zn and Pb in Athens. The distribution of total lead in the soil profiles indicated that most of the lead was concentrated in the upper 5 cm. Roadside soils were also found to be enriched with airborne zinc, but to a lesser degree than Pb.

Page and Ganje[4] investigated the distribution of lead as a function of depth in an urban soil profile and showed that practically all of the lead which has accumulated remained in the surface few centimetres. Davies *et al.*[5] investigated the contamination of surface soil by atmospheric deposition of Zn, Cu and Pb in Manchester and demonstrated a marked surface accumulation consistent with

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pollution by atmospheric deposition. Buchauer[6] studied the contamination of soil with Zn, Cd, Cu and Pb near a zinc smelter and found that about 90% of metal deposited on the soil surface had been retained in the top 15 cm of the soil profile. Surface enrichment of lead occurs in soils not only close to active sources of aerial contamination but also distant from contamination sources. Sharama and Shupe[7] reported lead concentrations in soil profiles in Utah and noted surface enrichment even in relatively uncontaminated sites. Similar accumulation of lead in surface soils is evidenced by the data of Wilkins[8] for 500 sites in west Pembrokeshire (UK).

The aim of this work is to investigate the contamination of Riyadh soil with heavy metals and to determine their vertical distribution within the soil body.

EXPERIMENTAL

Sample collection and treatment: A total of 200 soil profile samples were collected from urban, suburban, rural, roadside and industrial areas. Soil profile samples were collected from five sites at depths of 0–3, 3–5, 5–10, 10–15, 15–20, 20–30, 30–40 and 40–50 cm.

All samples collected from the field were thinly spread on polyethylene sheets and allowed to dry in air at ambient temperatures. They were then desegregated and passed through a two millimetre aperture nylon sieve. A subsample of 25 g was taken from each sample by coning and quartering and packed in clean self-sealing plastic bags with their field numbers. All soil samples were then dried at 105°C to a constant weight and stored in clean plastic containers with distinctive laboratory numbers. The organic content of the soil samples was determined gravimetrically by the loss in weight of the sample after ignition at 430°C.

Measurement of soil organic matter and pH: Bradley and Cox[9] stated that pre-treatment of soil samples at 430°C prior to acid extraction is sufficient for the pyrolysis of organic compounds and provides a good estimate of the organic content of soils. Pre-treatment at 430°C also permits a good estimate of the concentration of metals in the soil. The organic content of the soil samples was therefore determined gravimetrically by the loss in weight of the sample after ignition at 430°C. The pH was measured for the soil samples using a pH meter.

Sample digestion: Due to its reliability, simplicity, flexibility and wide use by many researchers, aqua regia was used in this work to digest soil samples.

Subsamples (1 g) were weighed into Pyrex test tubes, to each of which 10 mL of aqua regia (3 HCl : 1 HNO_3) was added. The tubes were then placed in a controlled heating block and the samples digested for 1 h at 60°C, 2 h at 80°C, 2 h at 105°C and 3 h at 120°C, successively. After cooling, samples were then centrifuged and made up to volume. Metal contents were then determined by flame atomic absorption spectrometry (Perkin-Elmer model 1100).

Analytical precision and accuracy

In order to obtain acceptable results during the analysis of soil samples, the following procedures were employed for precision and accuracy.

The analytical work was divided into batches of 50 samples. To assess the

precision, 20% of the samples in each batch were randomly chosen and duplicated. The precision is expressed as the % coefficient of variation (CV). Generally, the CV for all the metals determined was < 10%.

The accuracy is evaluated by analysing certified reference materials and quoting the percentage recovery. Accuracy in this work was checked by including samples of Buffalo River Sediment (SRM 2704) and BCR Reference Soil (No. 141, calcareous loam) with each soil batch.

RESULTS AND DISCUSSION

Fig. 1 shows the levels of the heavy metals in surface soils (0–3 cm) and subsurface soils (10–15 cm), with the highest heavy metal concentrations measured in the highway and urban area soils. In comparison with rural area it reveals that these two sites are more polluted with Pb, Zn and to a lesser extent Cu and that the metals hardly move from the upper layers. Figs. 2 to 6 show the typical evolution of the heavy metals content as a function of profile depth of urban, suburban, rural, roadside and industrial areas. The elemental distributions in soil profiles are summarized in Tables 1–5. Tables 7 and 8 show the variation of soil organic matter content and pH are shown in Tables 6 and 7 respectively.

TABLE-1
LEAD (μg/g) VARIATION WITH SOIL DEPTH IN DIFFERENT AREAS IN RIYADH CITY

Depth (cm)	Urban	Suburban	Rural	Highway	Industrial
1.5	1717.28 ± 81.27	1150.40 ± 365.26	16.22 ± 1.42	2060.14 ± 240.48	60.10 ± 14.64
4.5	1006.39 ± 175.90	537.16 ± 179.92	10.12 ± 0.76	1085.91 ± 192.94	33.13 ± 9.13
7.5	238.92 ± 69.34	79.62 ± 46.62	6.76 ± 0.61	332.87 ± 142.42	14.35 ± 5.24
12.5	77.88 ± 31.46	125.22 ± 57.91	6.31 ± 0.87	33.77 ± 14.05	5.00 ± 0.37
17.5	35.84 ± 14.40	33.67 ± 13.51	5.50 ± 0.85	12.35 ± 2.53	4.76 ± 0.39
25	22.26 ± 7.75	18.03 ± 5.62	6.76 ± 1.14	7.11 ± 0.38	5.15 ± 0.35
35	10.75 ± 1.66	14.04 ± 4.22	5.89 ± 0.98	6.03 ± 0.75	5.23 ± 0.40
45	10.67 ± 1.80	18.68 ± 5.29	5.25 ± 1.13	6.07 ± 0.34	4.92 ± 0.27

TABLE-2
ZINC (μg/g) VARIATION WITH SOIL DEPTH IN DIFFERENT AREAS IN RIYADH CITY

Depth (cm)	Urban	Suburban	Rural	Highway	Industrial
1.5	164.84 ± 7.87	85.16 ± 13.51	69.00 ± 16.27	168.43 ± 14.01	93.51 ± 11.59
4.5	100.50 ± 12.74	56.69 ± 11.11	48.00 ± 4.57	75.52 ± 8.54	52.15 ± 7.91
7.5	37.16 ± 2.63	33.97 ± 5.30	26.00 ± 0.86	36.96 ± 6.73	23.38 ± 2.82
12.5	23.58 ± 2.16	36.21 ± 4.85	18.00 ± 1.60	23.78 ± 2.48	15.98 ± 0.84
17.5	24.98 ± 2.23	28.47 ± 2.72	16.00 ± 2.31	21.58 ± 2.31	19.58 ± 4.30
25	22.78 ± 1.46	26.22 ± 1.89	16.00 ± 2.79	17.38 ± 0.98	16.18 ± 1.39
35	22.18 ± 0.86	23.48 ± 1.55	19.00 ± 2.69	15.98 ± 0.45	15.58 ± 0.93
45	22.58 ± 1.03	24.23 ± 1.31	16.00 ± 2.73	14.99 ± 0.32	14.79 ± 0.66

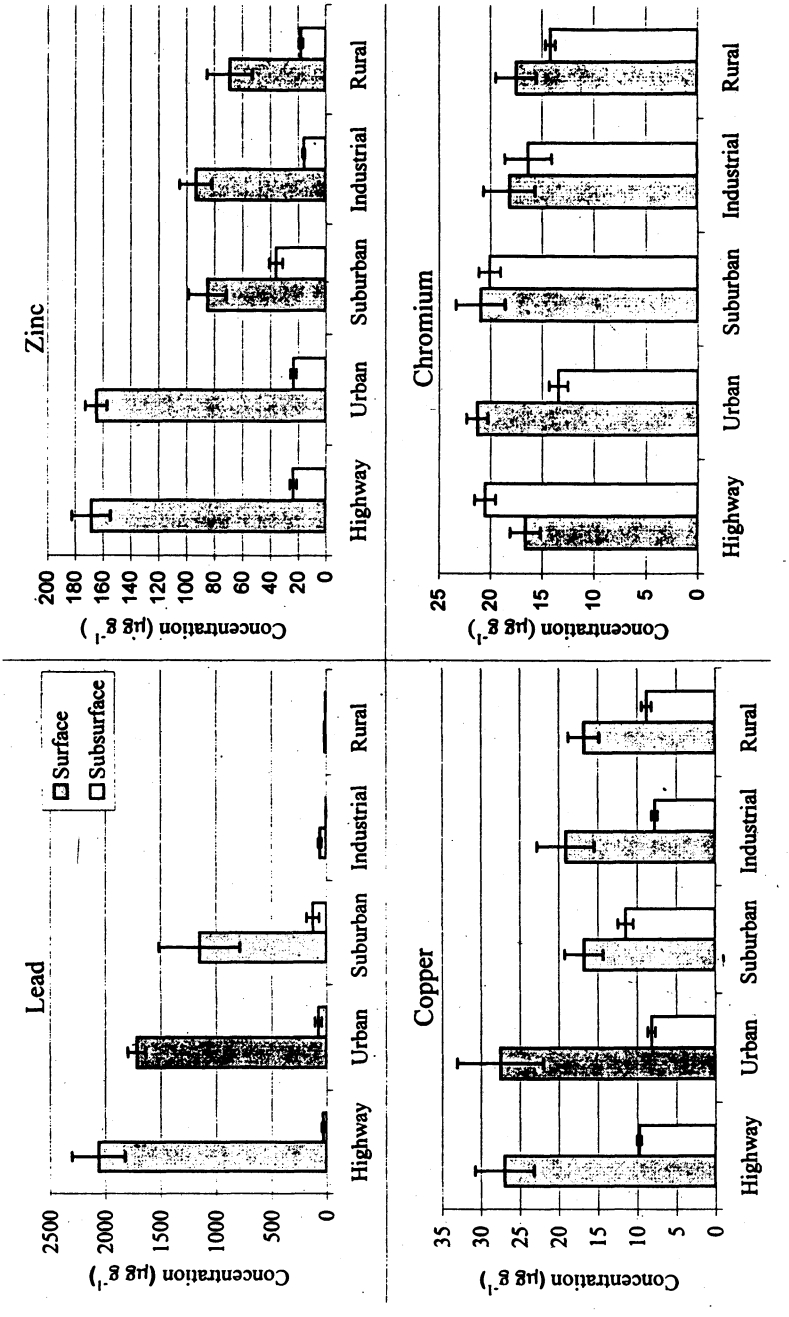

Fig. 1. Metal levels in surface and subsurface soils in Riyadh city (mean and SE error bars).

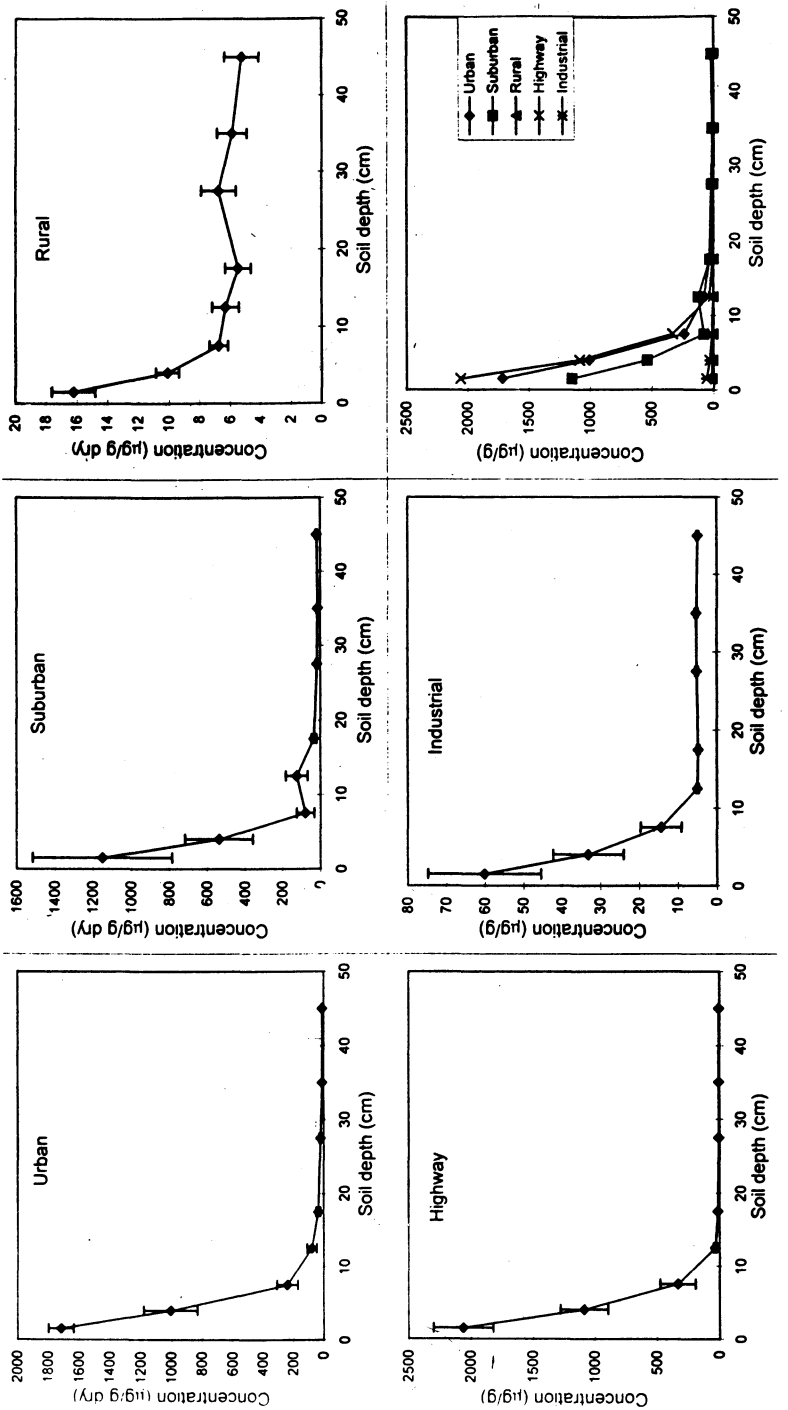

Fig. 2. Lead variation with the soil depth in different areas in Riyadh City.

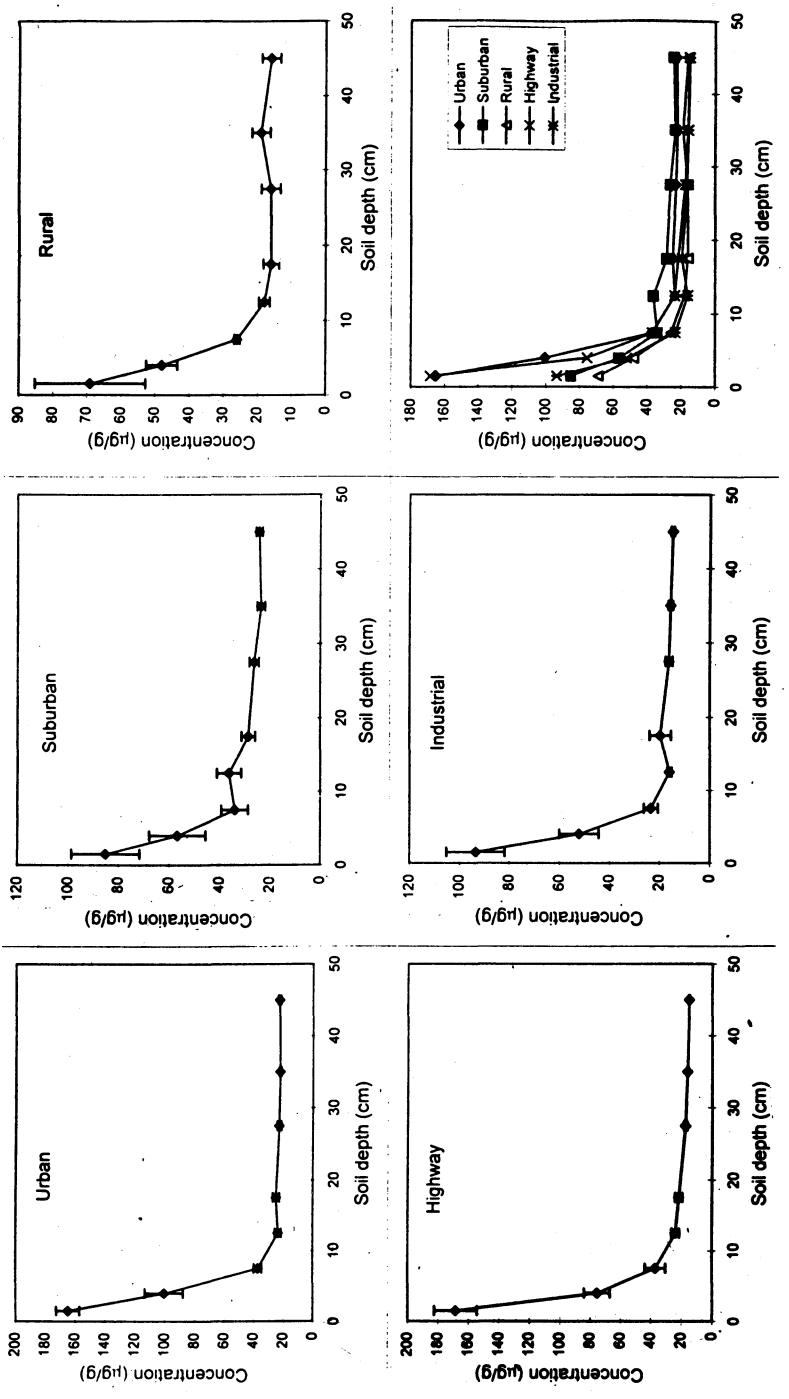

Fig. 3. Zinc variation with soil depth in different areas in Riyadh city.

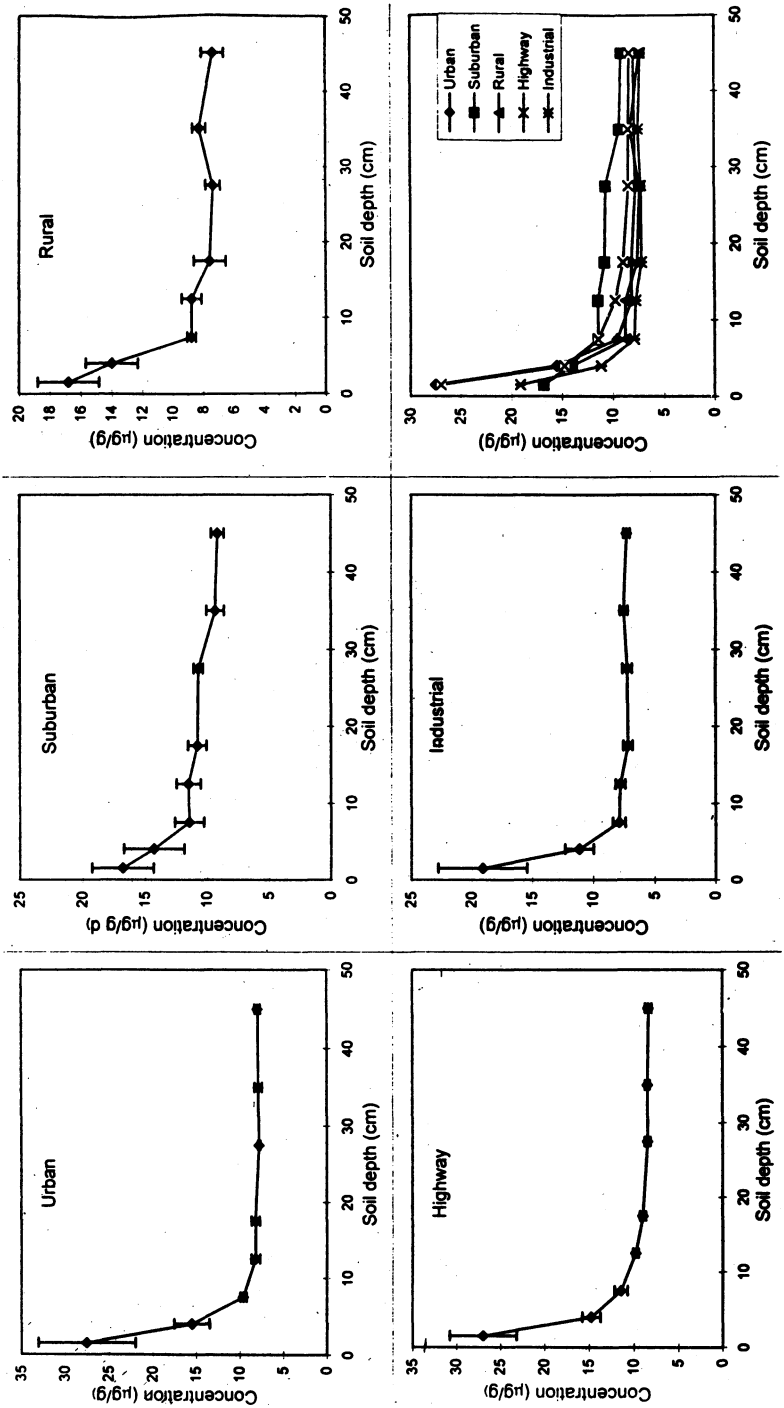

Fig. 4. Copper variation with soil depth in different areas in Riyadh city.

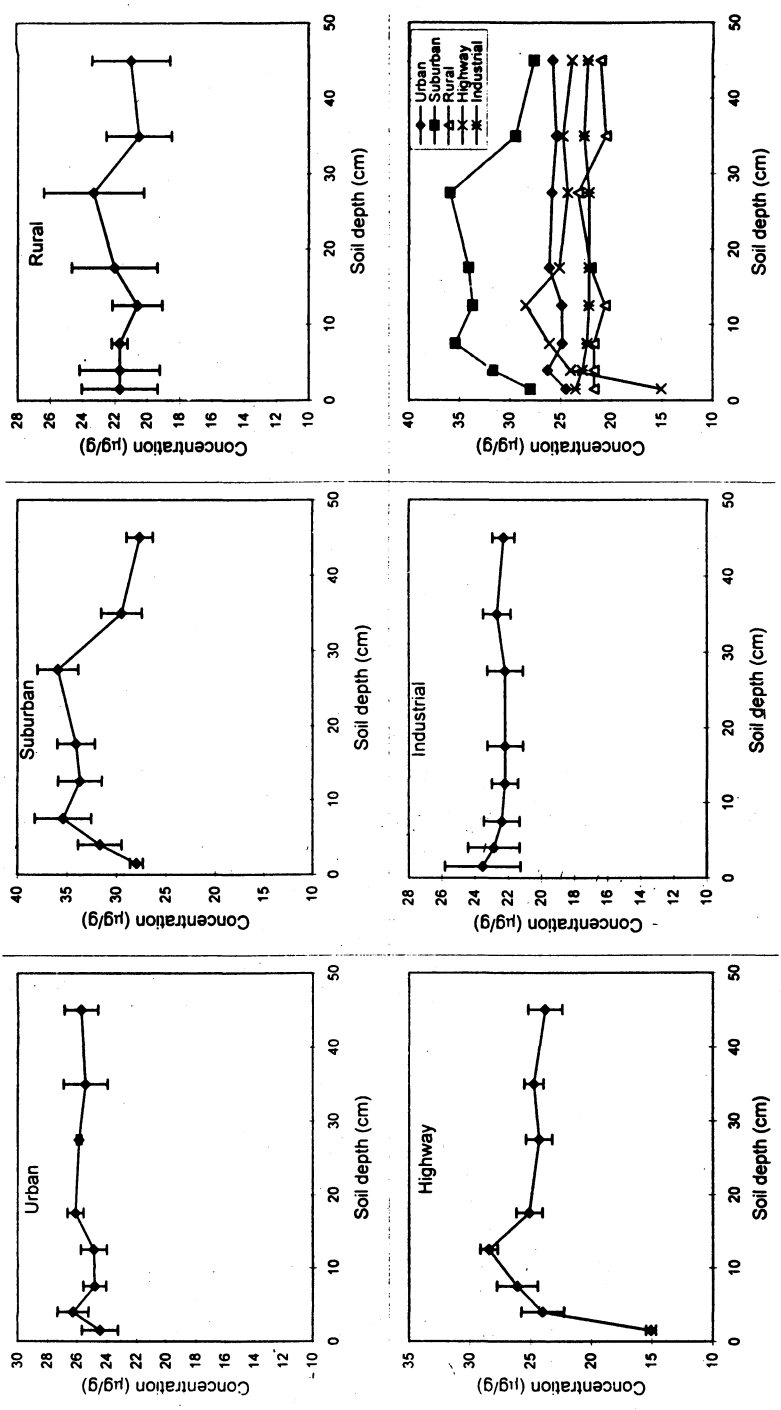

Fig. 5. Nickel variation with soil depth in different areas in Riyadh city.

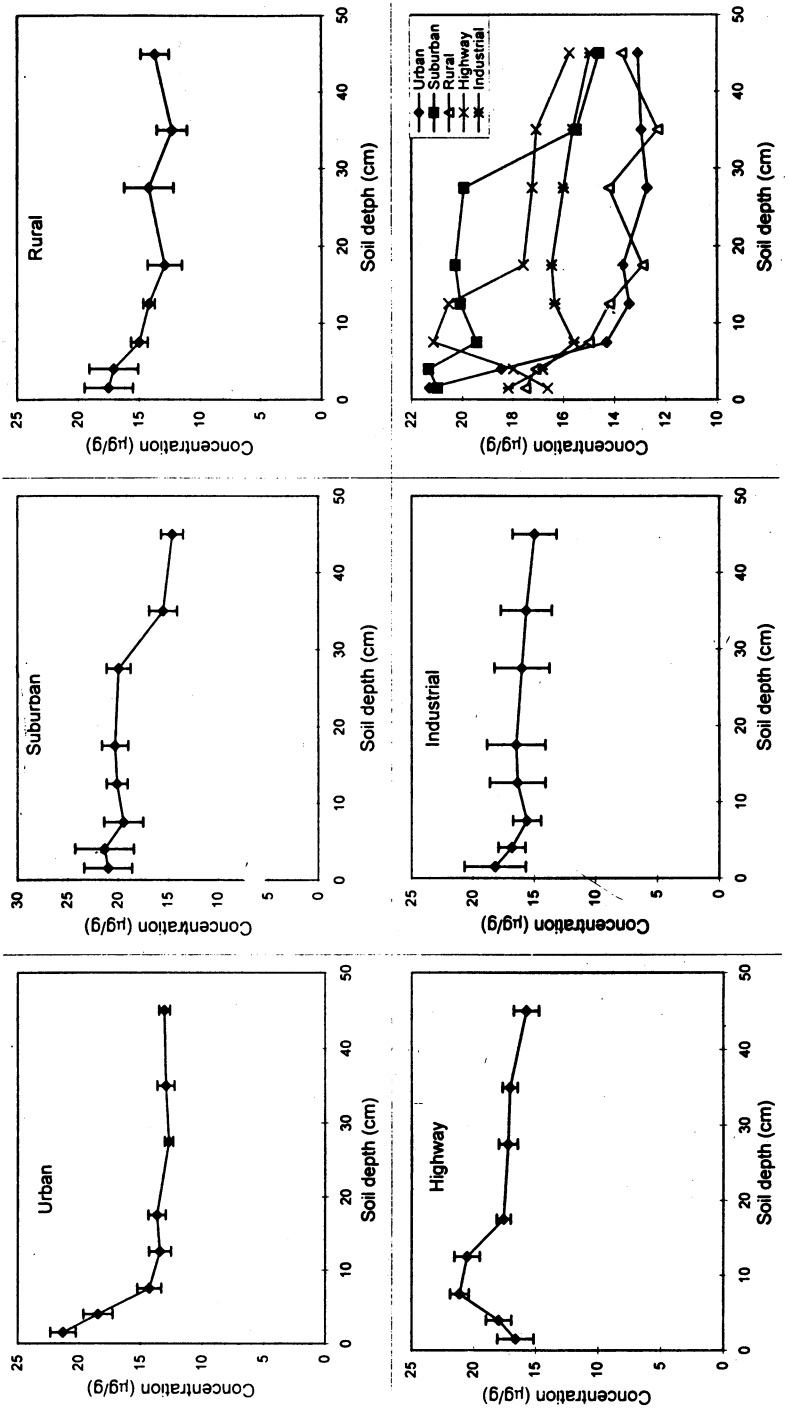

Fig. 6. Chromium variation with soil depth in different areas in Riyadh city.

TABLE-3
COPPER (μg/g) VARIATION WITH SOIL DEPTH IN DIFFERENT AREAS IN RIYADH CITY

Depth (cm)	Urban	Suburban	Rural	Highway	Industrial
1.5	27.53 ± 5.55	16.78 ± 2.45	16.80 ± 1.98	26.97 ± 3.80	19.10 ± 3.68
4.5	15.50 ± 2.02	14.29 ± 2.43	14.00 ± 1.69	14.75 ± 1.01	11.15 ± 1.16
7.5	9.59 ± 0.37	11.44 ± 1.17	8.80 ± 0.29	11.43 ± 0.72	7.91 ± 0.51
12.5	8.19 ± 0.49	11.49 ± 0.97	8.80 ± 0.65	9.79 ± 0.30	7.79 ± 0.39
17.5	8.19 ± 0.47	10.79 ± 0.74	7.60 ± 1.05	8.99 ± 0.33	7.19 ± 0.38
25	7.79 ± 0.14	10.69 ± 0.37	7.40 ± 0.48	8.47 ± 0.31	7.23 ± 0.39
35	7.87 ± 0.43	9.34 ± 0.72	8.30 ± 0.43	8.47 ± 0.27	7.51 ± 0.31
45	7.95 ± 0.32	9.14 ± 0.51	7.40 ± 0.72	8.35 ± 0.36	7.27 ± 0.26

TABLE-4
NICKEL (μg/g) VARIATION WITH SOIL DEPTH IN DIFFERENT AREAS IN RIYADH CITY

Depth (cm)	Urban	Suburban	Rural	Highway	Industrial
1.5	24.46 ± 1.21	27.97 ± 0.65	21.70 ± 2.34	15.06 ± 0.41	23.54 ± 2.28
4.5	26.28 ± 1.04	31.67 ± 2.20	21.70 ± 2.48	24.02 ± 1.74	22.86 ± 1.55
7.5	24.82 ± 0.77	35.39 ± 2.85	21.70 ± 0.49	26.09 ± 1.68	22.38 ± 1.08
12.5	24.86 ± 0.87	33.67 ± 2.22	20.60 ± 1.55	28.41 ± 0.72	22.18 ± 0.79
17.5	26.09 ± 0.54	34.07 ± 1.92	22.00 ± 2.64	25.09 ± 1.08	22.18 ± 1.07
25	25.85 ± 0.16	35.91 ± 2.08	23.30 ± 3.10	24.30 ± 1.08	22.18 ± 1.07
35	25.41 ± 1.48	29.42 ± 2.06	20.50 ± 2.02	24.74 ± 0.80	22.66 ± 0.83
45	25.73 ± 1.13	27.57 ± 1.33	21.00 ± 2.41	23.82 ± 1.40	22.26 ± 0.66

TABLE-5
CHROMIUM (μg/g) VARIATION WITH SOIL DEPTH IN DIFFERENT AREAS IN RIYADH CITY

Depth (cm)	Urban	Suburban	Rural	Highway	Industrial
1.5	21.30 ± 1.04	20.98 ± 2.38	17.50 ± 1.98	16.62 ± 1.46	18.18 ± 2.51
4.5	18.46 ± 1.19	21.33 ± 2.92	17.10 ± 2.00	17.98 ± 1.02	16.82 ± 1.11
7.5	14.31 ± 0.98	19.43 ± 1.95	15.00 ± 0.68	21.14 ± 0.76	15.58 ± 1.15
12.5	13.43 ± 0.90	20.08 ± 1.05	14.20 ± 0.68	20.54 ± 1.02	16.34 ± 2.27
17.5	13.67 ± 0.71	20.28 ± 1.32	12.90 ± 1.41	17.58 ± 0.57	16.46 ± 2.39
25	12.71 ± 0.34	19.93 ± 1.19	14.20 ± 2.03	17.22 ± 0.76	15.98 ± 2.25
35	12.95 ± 0.70	15.48 ± 1.40	12.30 ± 1.25	17.06 ± 0.61	15.62 ± 2.09
45	13.07 ± 0.44	14.59 ± 1.10	13.70 ± 1.16	15.74 ± 1.02	14.95 ± 1.80

TABLE-6
ORGANIC MATTER VARIATION WITH SOIL DEPTH IN DIFFERENT AREAS IN RIYADH CITY

Depth (cm)	Urban	Suburban	Rural	Highway	Industrial
1.5	4.66 ± 0.53	2.92 ± 0.17	3.80 ± 0.65	2.28 ± 0.22	5.54 ± 0.78
4.5	3.76 ± 0.37	2.80 ± 0.30	4.48 ± 0.89	3.52 ± 0.40	5.04 ± 0.60
7.5	3.62 ± 0.44	3.35 ± 0.52	4.88 ± 0.27	4.00 ± 0.38	5.28 ± 0.45
12.5	3.82 ± 0.57	3.30 ± 0.31	4.72 ± 0.45	4.52 ± 0.22	5.68 ± 0.38
17.5	3.76 ± 1.13	3.28 ± 0.11	5.06 ± 0.45	4.74 ± 0.25	5.44 ± 0.35
25	5.84 ± 2.59	3.75 ± 0.53	3.98 ± 0.54	4.12 ± 0.16	5.28 ± 0.33
35	8.90 ± 5.73	2.52 ± 0.28	4.78 ± 0.49	4.04 ± 0.12	5.90 ± 1.51
45	2.90 ± 0.33	3.03 ± 0.71	5.66 ± 0.64	3.46 ± 0.80	4.58 ± 0.38

TABLE-7
pH VARIATION WITH SOIL DEPTH IN DIFFERENT AREAS IN RIYADH CITY

Depth (cm)	Urban	Suburban	Rural	Highway	Industrial
1.5	7.22 ± 0.17	7.75 ± 0.09	8.28 ± 0.65	8.26 ± 0.10	8.18 ± 0.14
4.5	7.66 ± 0.07	7.70 ± 0.20	8.34 ± 0.89	8.04 ± 0.07	8.18 ± 0.14
7.5	7.58 ± 0.15	7.83 ± 0.08	8.42 ± 0.27	8.08 ± 0.06	8.14 ± 0.08
12.5	7.44 ± 0.12	7.68 ± 0.05	8.28 ± 0.45	8.16 ± 0.04	8.04 ± 0.08
17.5	7.48 ± 0.18	7.85 ± 0.05	8.18 ± 0.45	8.16 ± 0.05	7.94 ± 0.07
25	7.68 ± 0.12	7.90 ± 0.07	7.90 ± 0.54	8.18 ± 0.02	7.94 ± 0.10
35	7.90 ± 0.08	7.95 ± 0.05	7.90 ± 0.49	8.18 ± 0.02	7.98 ± 0.04
45	7.80 ± 0.20	7.80 ± 0.18	8.56 ± 0.64	9.06 ± 0.25	7.96 ± 0.04

Lead

The distribution of lead in soil profiles located in urban area (Fig. 2) clearly shows that elevated concentrations of lead are present in surface layers (0–5 cm), where values range from 1452 to 1920 μg g^{-1}, with an average value of 1717 μg g^{-1}. In urban areas about 170 times more lead was found in top soils than in soils at a depth of 35 cm. Similar trends have been found in soil profiles located in other areas studied. The lead content in the surface layer in roadside soil profiles varied from 1247 to 2560 μg g^{-1}, with an average value of 2060 μg g^{-1}, which is about 300 times higher than the content in soils at a depth of 35 cm. This surface enrichment of lead can be attributed to the atmospheric deposition of lead from automobile exhausts (cf. Beavington[10], Ndiokwere[11], Tam *et al.*[12], Yassoglou[3], Ho and Tai[13]) and to the low rainfall in the study area (80 mm per annum).

In the surface layer of soil profiles in the rural area, the lead content varied from 11.55 to 20.33 μg g^{-1} with an average value of 16.22 μg g^{-1}. At a depth of 7.5 cm, soil lead content was 6.76 μg g^{-1}, which can be regarded as a background value for soils of the studied area. The relatively high value in the surface layer can be attributed to atmospheric deposition emanating from the combustion of leaded gasoline. The lead content in the top layer of the soil profiles in the second industrial city ranged from 24.58 to 99.30 μg g^{-1} with an average value of 60.10 μg g^{-1}. At a depth of 12.5 cm, lead level decreased to 5.0 μg g^{-1}.

TABLE-8
INTRA-METAL CORRELATION IN SOIL PROFILE FROM VARIOUS ENVIRONMENTS IN RIYADH CITY

Area		Pb	Zn	Cu	Ni	Cr	Li	OM%	pH
Urban	Pb	1.00							
	Zn	1.00	1.00						
	Cu	0.98	0.99	1.00					
	Ni	–0.34	–0.33	0.43	1.00				
	Cr	1.00	0.99	0.97	–0.29	1.00			
	Li	0.48	0.45	0.34	0.13	0.53	1.00		
	OM%	–0.14	–0.13	–0.10	–0.04	–0.19	0.02	1.00	
	pH	–0.62	–0.62	–0.67	0.54	–0.62	–0.14	0.42	1.00
Suburban	Pb	1.00							
	Zn	0.99	1.00						
	Cu	0.95	0.98	1.00					
	Ni	–0.45	–0.36	–0.18	1.00				
	Cr	0.50	0.58	0.73	0.50	1.00			
	Li	–0.44	–0.35	–0.17	0.96	0.55	1.00		
	OM%	–0.32	–0.27	–0.15	0.76	0.36	0.77	1.00	
	pH	–0.49	–0.56	–0.58	0.10	–0.49	–0.06	0.03	1.00
Rural	Pb	1.00							
	Zn	0.98	1.00						
	Cu	0.96	0.99	1.00					
	Ni	0.15	0.06	0.01	1.00				
	Cr	0.86	0.90	0.90	0.23	1.00			
	Li	0.33	0.32	0.32	0.09	0.41	1.00		
	OM%	–0.71	–0.61	–0.61	–0.50	–0.58	–0.42	1.00	
	pH	0.11	0.22	0.20	–0.29	0.38	0.11	0.49	1.00
Highway	Pb	1.00							
	Zn	0.99	1.00						
	Cu	0.98	1.00	1.00					
	Ni	–0.85	–0.87	–0.87	1.00				
	Cr	–0.17	–0.18	–0.15	0.57	1.00			
	Li	–0.95	–0.95	–0.94	0.94	0.43	1.00		
	OM%	–0.86	–0.85	–0.85	0.89	0.44	0.92	1.00	
	pH	–0.18	–0.17	–0.16	–0.13	–0.56	0.00	–0.26	1.00
Industrial	Pb	1.00							
	Zn	1.00	1.00						
	Cu	0.98	0.99	1.00					
	Ni	0.94	0.94	0.94	1.00				
	Cr	0.84	0.88	0.87	0.76	1.00			
	Li	0.28	0.27	0.21	0.08	0.52	1.00		
	OM%	0.03	0.06	0.12	0.19	0.35	0.29	1.00	
	pH	0.81	0.76	0.71	0.72	0.59	0.55	0.01	1.00

Zinc

The variation of zinc levels in soil profiles shows the same trend as in the case of lead (Fig. 3). Although it has greater mobility than lead[14], zinc similarly showed enrichment in the upper surface soils, which can be attributed to the low precipitation in the study area. In urban area, the level in the top layer of the soils ranged from 142.86 to 183.82 $\mu g\ g^{-1}$ with an average level of 164.84 $\mu g\ g^{-1}$, whereas in the soil from a depth of 25 cm it was only 22.78 $\mu g\ g^{-1}$. The top layer in the soil profiles in roadsides contained 168.43 $\mu g\ g^{-1}$, which is about 10 times more than that at a depth of 25 cm. This indicates that zinc may have been introduced into the soil from the polluted air. Although, the top soil layer in the second industrial city is enriched with zinc (93.51 $\mu g\ g^{-1}$), it decreased to 16.18 $\mu g\ g^{-1}$ at a depth of 25 cm emphasising its atmospheric origin. Zinc content in soil profiles in rural areas also showed relatively high levels with an average value of 69.0 $\mu g\ g^{-1}$ in surface soils which decrease to 16.0 $\mu g\ g^{-1}$ at a depth of 17.5 cm which can be considered as a background level for zinc.

Copper

Copper distribution in soil profiles exhibited a pattern similar to that of zinc (Fig. 4). All sites showed a surface enrichment of copper. The effect of urban pollution on copper accumulation in the top layer is clear, where the content ranged from 17.18 to 48.55 $\mu g\ g^{-1}$, with an average of 27.53 $\mu g\ g^{-1}$. At a depth of 25 cm, the copper level has decreased to 7.79 $\mu g\ g^{-1}$ indicating atmospheric deposition on the surface. The concentration of copper in the top layer of roadside soils was 26.97 $\mu g\ g^{-1}$, which is about 3 times higher than at a depth of 25 cm. In soil profiles in the rural area, copper levels show a similar pattern to that shown by zinc. Relatively high copper levels were found in the top layers with an average value of 16.80 $\mu g\ g^{-1}$ compared with 7.6 $\mu g\ g^{-1}$ at a depth of 17.5 cm, which can be referred to as a background value. These relatively high levels of zinc and copper in the rural area are attributable to their inherent levels in Riyadh soils and to the use of fertilisers and manures since these micronutrients are often added to them[15].

Nickel and chromium

The vertical distribution of nickel in the soil profiles (Fig. 5) did not appear to be related to airborne contamination. The nickel content in the studied areas appeared to be mainly related to the texture and the origin of the soil parent materials, and not attributed to pollution by automobiles. In the urban area, for example, the nickel content in the top layer varied from 21.38 to 28.57 $\mu g\ g^{-1}$, with an average value of 24.46 $\mu g\ g^{-1}$, whereas its content at a depth of 45 cm ranged from 22.78 to 29.77 $\mu g\ g^{-1}$ with a mean value of 25.73 $\mu g\ g^{-1}$.

The chromium content in profiles (Fig. 6) showed slight enrichment in the top layers of urban, rural and industrial area soils. In urban area, the chromium level in the top layers varied from 18.18 to 23.98 $\mu g\ g^{-1}$, with a mean value of 21.30 $\mu g\ g^{-1}$, and at a depth of 12.5 cm chromium was 13.43 $\mu g\ g^{-1}$.

In order to establish intra-metal relationships in the samples, the correlation coefficients were calculated for areas studied as shown in Table-8. Lead, zinc, copper and chromium were found to be highly correlated in all studied areas indicating a common source (*i.e.*, automobiles). In highway area, the weak correlation of chromium indicates the presence of another source beside automobiles (*i.e.*, the extensive use of chromium for roadside lines).

Profile samples show that lead, zinc and copper were largely concentrated in the top 5 cm soil, confirming an airborne origin. It was found that approximately 74.7 % of the lead, 56.6 % of the zinc and 40.3 % of the copper are concentrated in the top 5 cm (Table-9). Similar findings were reported by Beavington[10], Czarnowska[16], Rutherford and Bray[17], Scokart *et al.*[18] and Glooschenko *et al.*[19]

TABLE-9
METAL PER CENT (%) FOUND AT EACH SOIL DEPTH

Soil depth (cm)	Pb	Cu	Zn	Cr	Ni
1.50	48.50	24.40	35.78	14.41	11.29
4.00	26.23	15.93	20.80	13.90	12.62
7.50	8.53	11.19	10.05	12.84	12.93
12.50	4.72	10.53	7.55	12.68	12.89
17.50	3.11	9.75	7.12	12.13	12.86
27.50	3.30	9.50	6.38	12.02	13.05
35.00	2.91	9.53	6.31	11.08	12.27
45.00	2.70	9.19	6.00	10.93	12.08

The soils in the study areas were found to be neutral soils, with a nearly uniform distribution across the whole profile with an average value of 7.99 ± 0.05 of all site samples. The organic matter contents in soils of all areas were found to be low with an average value of 4.32 ± 0.19, with a similar variation in soil profiles to that of pH. Table-6 shows a negative correlation between Pb, Zn and Cu with the pH of the soils in urban, suburban and highway areas. This explains the low mobility of these metals in soil profiles and their enrichment in the surface soils. Our results are in agreement with the findings of other researchers. For example, Khan *et al.*[20] investigated the mobility of Cr, Ni and Pb through Indian soil and found that decomposition of soil organic matter greatly increased the mobility of heavy metals whereas a rise in pH of the soil caused a decrease. Also, Ram and Verloo[21] determined the mobility of Zn, Cu and Pb under varying acidities and showed that metal mobility in soil increases as soil acidity increases. In general, the capacity of soil for most trace elements is increased with a rise in pH, with the maximum under natural and slightly alkaline conditions[22].

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