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THE COMPARISON STUDY OF SOME SELECTED HEAVY METALS IN THE IRRIGATED AND NON-IRRIGATED AGRICULTURAL SOILS

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Abstract

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A research was carried out to investigate the status of four micronutirents, iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn), and five other heavy metals cadmium (Cd), cobalt (Co), chromium (Cr), nickel (Ni) and lead (Pb) in agricultural soils of Bursa plain, Turkey. Soil samples were digested by nitric acid (HNO_3)-hydrochloric acid (HCl) for determination of total contents of the nine elements, while DTPA method was used for determination of extractable form of these elements. Total and DTPA extractable element contents were found at the highest concentration in the surface horizons of the irrigated sites. Nevertheless, total and DTPA extractable elements were found moderate to low concentrations in the surface horizons of the non-irrigated sites. Among the soil properties examined, clay content had a good relation with total and DTPA extractable element contents in the topsoil. The obtained results were indicated that irrigated alluvial soils were polluted with heavy metals due to long-term irrigation with the polluted Nilufer River.

Key words: heavy metals, alluvial, irrigated soil, non-irrigated soil, Nilufer River

Introduction

The extent of chemical degradation of agricultural lands has been commonly assessed by plant nutrient changes and the level of acidification. An aspect of chemical degradation of soils, which is often neglected, is the accumulation of heavy metals in agricultural lands under intensive cultivation and fertilization (Logan, 1990; Csillag et al., 1998). There is some indirect evidence of possible heavy metal build-up in some arable lands because of long-term application of inorganic phosphate fertilizers (Ewa et al., 1999) and possibly organic manure (Agbenin and Felix-Henningsen, 2001). Under long-term applications of inorganic fertilizers and organic wastes to soils, periodic risk assessment of heavy metal accumulation in agricultural lands becomes imperative (Williams et al., 1987). Heavy metals can be added to soils through industrial wastes, atmospheric deposition, parent materials (Oliver, 1997) and the long-term application of organic wastes, such as sewage sludge to soils (Williams et al., 1987). Sims and Kline (1991) showed, for instance, that application of composted sewage sludge to soils increased the concentrations of Cr, Ni

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and Cd in soils. Soil management practices such as the application of inorganic fertilizers, organic wastes and lime are critical factors affecting heavy metal pollution of agricultural lands (Williams et al., 1987; Dowdy et al., 1991). Under acidic soil conditions most heavy metals are soluble and mobile, thus increasing the risk of ground water and food chain contamination (Naidu et al., 1994; Oliver, 1997; Harter and Naidu, 2001). The vertical distribution of heavy metals in soils has been extensively studied to clarify the mechanisms of contamination of soils and groundwater (Fujikawa et al., 2000) and agricultural lands fertilized with organic wastes containing heavy metals (Williams et al., 1987; Dowdy et al., 1991).

Soil serves many vital functions in our society, particularly for food production. It is thus of extreme importance to protect this resource and ensure its sustainability. Deteriorating environmental conditions and increasing reliance on agrochemicals have led to a growing public concern over the potential accumulation of heavy metals and other contaminants in agricultural soils (Nriagu, 1988; Alloway, 1990; Kabata-Pendias, 1995; Fuleky et al., 2002). Owing to rapid economic development, heavy metal contamination of agricultural soils has also become increasingly serious in the research area (Aydinalp and Marinova, 2003; Aydinalp and Cresser, 2005; Aydinalp et al., 2005).

Bursa is a highly populated industrial and agricultural based province of Turkey. The orchards and vegetables are main crops, which are mostly grown in the alluvial soils occupying 118.255 ha of the province (Anonymous, 1995). The alluvial soils are the main important agricultural soils, which are occupied 10.7% of the province. These soils were formed from different kinds of parent materials derived from limestone and sediments of the Nilufer River. The yield was high in the plain with respect to other region of the country due to number constraints of which soil was dominant. Recently, the yield has been decreasing due to several factors. The objective of this research was to determine the heavy metal status of the irrigated and non-irrigated agricultural soils and to relate with the pollution levels.

Materials and Methods

Description of study area

The research area formed from calcareous alluvial sediments of the Nilufer River system. The soil type is Fluvisols (FAO/Unesco, 1990) in the research area. Genesis and properties of these soils relating to fertility vary with physiography. The research area is located on between 40° 13^{I} - 40° 15^{I} N latitudes and 29° 10^{I} - 29° 20^{I} E longitudes in the eastern Bursa plain of Turkey. The area has a Mediterranean type of climate with annual precipitation 714.1 mm with rainy season extending from November to May. The soil moisture and temperature regimes are xeric and thermic in the research area.

Soil samples

Ten irrigated and ten non-irrigated alluvial soil sites were selected for this research. The irrigated soil sites were located along side the Nilufer River under various summer crops and orchards. The soil profiles in each site were dug down to parent material. Soil samples were taken from each soil horizon and analyzed for their physical and chemical properties.

Water samples

The Nilufer River is the main irrigation water source for soils in the region. Ten water collection points were chosen for irrigated soil sites at a spacing of 500 m along the river. The water samples were collected one a week for 4 weeks in July 2006. This month is the most intensive irrigation period for various crops in the region.

Methods for soil analysis

Bulk soil samples were air dried, crushed with a mortar and pestle, and sieved to remove coarse (>2 mm) fragments. Soil samples were analyzed for particle-size distribution by the hydrometer method (Gee and Bauder, 1982), pH in a 1:2 soil: water ratio (McLean, 1982). Other were determinate organic carbon (Nelson and Sommers, 1982), total nitrogen (Bremner and Mulvaney, 1982), EC (SCS, 1972), calcium carbonate (Nelson, 1982), available phosphorus (Olsen, 1982), CEC (Rhoades, 1982), exchangeable cations (Thomas, 1982), and DTPA-extractable Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn (Lindsey and Norvell, 1978). 1 g soil samples were digested in a mixture of concentrated HNO_3 and HCl (3:1 ratio) and analyzed for total concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn were determined by ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometer). Statistical analyses were carried according to Svab (1973) using a special 3 factorial variance analysis where no real replication exists.

Methods for water analysis

Ten water samples were collected from the ten irrigation points in the Nilufer River on four separate occasions. The results were presented as mean monthly values.

Water samples were collected from a depth of 0.5 m in 1-litre polyethylene bottles. At the sampling site, the bottles were rinsed twice with the water to be sampled prior to filling. After sampling, water samples were filtered using membrane filters with pore diameters of 0.45 mm. The filtrated samples were acidified to pH 2 with ultrapure grade nitric acid (Merck) in order to minimize precipitation and adsorption on the walls of the container. All analytical methods used were based on standard methods for examination of water (Anonymous, 1988).

pH of water samples was measured in the field by using a portable pH meter. Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in filtered water determined by ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometer).

Results and Discussion

Water quality of the Nilufer River

Some selected chemical results of the water samples were presented in Table 1. The pH of water samples ranged from 6.90 to 6.72 during the four weeks period and values decreased slightly with stream flow direction from sampling point 1 to 10. The obtained water results indicated that the river water was contained 45 mg l^{-l} silt in this irrigation period and polluted with all the heavy metals determined. The pH values of waters from sampling point 1 to 10,

Table 1
The selected properties of the Nilufer River for July 2006

Sampling points	pH	Concenctration, mg l^{-l-l}								
		Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	6.90	1.20	3.00	5.10	2.90	4.00	1.20	4.10	1.90	3.40
2	6.88	1.30	3.20	5.40	3.00	4.20	1.40	4.50	2.00	3.60
3	6.85	1.30	3.30	5.40	3.00	4.20	1.40	4.70	2.20	3.80
4	6.85	1.60	3.30	5.50	3.30	4.40	1.70	4.70	2.20	3.90
5	6.80	1.60	3.50	5.60	3.40	4.50	1.90	4.90	2.50	3.90
6	6.78	1.90	3.60	5.90	3.40	4.80	2.00	5.00	2.50	4.10
7	6.76	2.20	3.60	5.90	3.60	4.90	1.80	5.30	2.30	4.00
8	6.75	2.50	3.70	6.00	3.60	5.10	1.60	4.80	2.00	3.80
9	6.72	2.80	3.50	6.00	3.70	5.00	1.60	4.70	1.70	3.40
10	6.72	2.80	3.50	6.20	3.70	4.80	1.40	4.70	1.70	3.10
Min.	6.72	1.20	3.00	5.10	2.90	4.00	1.20	4.10	1.70	3.10
Max.	6.90	2.80	3.70	6.20	3.70	5.10	2.00	5.30	2.50	4.10
Mean	6.80	1.92	3.42	5.70	3.36	4.59	1.60	4.74	2.10	3.70
St. Dev.	0.07	0.62	0.21	0.35	0.30	0.38	0.25	0.31	0.29	0.32

suggesting that the river is becoming more acid due to inputs of acid pollutants on progressing down stream.

The distributions of metal concentrations in the water samples were determined at 10 sampling points for July, which was most intensive irrigation period in the region. The Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn concentrations in the water samples were presented in Table 1. The values of Cd varied from 1.2 to 2.8 mg l^{-1}, Co from 3.0 to 3.7 mg l^{-1}, Cr from 5.1 to 6.2 mg l^{-1} and Cu from 2.9 to 3.7 mg l^{-1}. Fe and Mn values ranged from 4.0 to 5.1 mg l^{-1} and 1.2 to 2.0 mg l^{-1} respectively. The values of Ni varied from 4.1 to 5.3 mg l^{-1}, Pb from 1.7 to 2.5 mg l^{-1}, and Zn from 3.1 to

luted with a wide range of heavy metals due to inputs of wastewater from industrial and urban activities in the region.

Soil properties

Some physical and chemical properties of the irrigated soils are presented in Tables 2, 3 and 4. The soil texture is loam throughout all profiles expects the lowest horizons. The clay values ranged from 13.1 to 30.5% and increased with depth. Soil pH varied 7.4 to 8.2 and the values gradually increased with depth. EC values ranged from 0.62 to 1.24 dS m^{-1} and consistently increased with depth. The results were indi-

Table 2

The some physical and chemical properties of the irrigated alluvial soil profiles

Horizon (FAO/UNESCO)	Depth. cm	Sand. %	Silt. %	Clay. %	Texture	pH 1:2 soil:water	EC. dS m-l	Org. C. %	Total N. %	C/N	CaCO3. %	Available P. mg kg-l	CEC	Exchangeable cations				BS. %
														Ca	Mg	K	Na	
													---cmol (+) kg^{-1}---					
Profile 1																		
Ap	0-20	41.2	34.2	22.4	L	7.5	0.7	1.55	0.17	9.1	2.1	10.5	25	19	2.8	1.9	1.4	100
C1	20-45	35.1	38.1	25.1	L	7.6	0.82	0.94	0.13	7.2	3.4	7.18	27	23	2.5	1.1	1.8	100
C2	45-75	33.1	35.4	30.5	CL	7.7	0.88	0	---	---	5.3	5.03	31	27	2.4	0.8	2.2	100
Profile 2																		
Ap	0-30	40.4	39.2	18.5	L	7.5	0.77	1.32	0.16	8.2	1.7	8.77	21	16	2.5	2	1.6	100
C1	30-60	31.5	43.5	23.7	L	7.6	0.85	0.81	0.14	5.8	2.5	6.03	27	22	2.2	1.7	1.9	100
C2	60-95	33.4	37.8	28.2	CL	7.6	0.9	0	---	---	4.7	3.12	33	29	2	1	2.1	100
Profile 3																		
Ap	0-25	40.3	41.5	15.8	L	7.4	0.62	1.25	0.14	8.9	1.2	7.58	19	14	2.9	1.8	1.3	100
C1	25-55	32.9	46.2	19.4	L	7.5	0.78	0.7	0.11	6.4	2	6.14	24	19	2.6	1.4	1.8	100
C2	55-80	33.1	39.7	26.3	L	7.6	0.85	0	---	---	3.8	4.05	29	25	2.4	0.9	2.2	100

(continued)

Table 2 (continued)

Profile 4																		
Ap	0-20	33.5	44.2	20.7	L	7.4	0.65	1.4	0.17	8.2	1.9	12.4	23	19	2.7	1.6	1.5	100
C1	20-48	26.3	48.5	24.2	L	7.5	0.74	0.85	0.12	7.1	2.8	9.52	28	24	2.5	1.1	1.9	100
C2	48-82	33.3	37.3	28.8	CL	7.7	0.83	0	---	---	4.2	6.34	32	28	2.2	0.7	2.3	100
Profile 5																		
Ap	0-28	33.2	40.4	23.5	L	7.5	0.72	1.44	0.18	8	2.3	11.3	27	21	2.5	1.9	1.8	100
C1	28-53	26.9	45.1	25.8	L	7.6	0.8	0.62	0.1	6.2	4	9.84	29	24	2.3	1.5	2.1	100
C2	53-75	32.9	36.7	29.1	CL	7.7	0.89	0	---	---	5.1	7.19	34	29	2	1	2.5	100
Profile 6																		
Ap	0-18	47.6	32.4	17.2	L	7.7	0.84	1.15	0.14	8.2	3.2	8.94	20	14	2.9	2.1	1.9	100
C1	18-38	42.8	35.2	19.8	L	7.8	0.92	0.52	0.08	6.5	4.1	7.78	22	17	2.7	1.8	2	100
C2	38-60	35.7	38.7	24.1	L	7.8	0.94	0	---	---	4.8	6.45	27	21	2.6	1.7	2.1	100
C3	60-105	54.2	23.4	21.3	SCL	7.9	0.98	0	---	---	6.5	5.82	24	19	2.3	1.2	2.2	100
Profile 7																		
Ap	0-20	49.6	28.4	19.5	L	7.8	0.88	1.04	0.14	7.4	3.5	9.74	22	16	2.7	2.2	2	100
C1	20-55	43	31.6	23.4	L	7.9	0.94	0.41	0.08	5.1	4.6	8.5	26	20	2.5	2	2.2	100
C2	55-75	35.5	35.9	26.9	L	7.9	0.97	0	---	---	5.2	8.04	30	25	2.4	1.6	2.3	100
C3	75-100	56.8	26.3	16.2	SL	8.1	1.2	0	---	---	6	7.36	18	14	2.1	1	2.5	100
Profile 8																		
Ap	0-30	50.1	32.5	15.4	L	7.7	0.8	1.1	0.13	8.5	3	8.81	19	13	2.9	1.9	1.8	100
C1	30-60	43.8	35.8	18.7	L	7.8	0.92	0.63	0.1	6.3	3.7	6.74	22	16	2.8	1.7	2.1	100
C2	60-78	37.2	39.2	22.3	L	7.8	0.95	0	---	---	4.4	5.9	25	20	2.6	1.2	2.3	100
C3	78-112	58.5	27.4	13.1	SL	8	1.04	0	---	---	5.8	3.82	16	12	2.2	0.8	2.4	100
Profile 9																		
Ap	0-22	44.6	34.3	18.9	L	7.8	0.9	0.95	0.12	7.9	2.8	10.1	23	17	2.8	1.8	2.1	100
C1	22-45	39.1	37.5	21.7	L	7.9	0.95	0.32	0.05	6.4	3.4	8.62	26	20	2.6	1.5	2.3	100
C2	45-65	32.5	41.7	24.5	L	8	0.98	0	---	---	3.9	7.87	27	22	2.4	1.1	2.4	100
C3	65-95	55.2	24.8	19.3	SL	8.2	1.24	0	---	---	5.7	4.05	22	17	2.1	0.9	2.7	100
Profile 10																		
Ap	0-20	48.4	29.2	20.2	L	7.7	0.87	0.9	0.11	8.2	3.1	11.4	24	18	2.7	2	1.9	100
C1	20-48	41.8	33.1	23.5	L	7.9	0.93	0.27	0.04	6.7	4.2	10.7	27	22	2.4	1.7	2	100
C2	48-64	36.1	36.7	26.1	L	8	0.97	0	---	---	5.4	9.15	30	25	2.2	1.4	2.3	100
C3	64-105	58.5	19.6	21.4	SCL	8.2	1.18	0	---	---	6.3	5.78	24	19	2	0.8	2.5	100
Statistical Values LSD 95%		---	---	---	---	0.1	0.07	0.47	0.06	3.2	1.1	2.1	5.2	5.2	0.4	0.4	0.3	---

bon values varied from 0.27 to 1.55% and total N from 0.04 to 0.18% and both decreased consistently with depth. C/N ratios were ranged from 5.1 to 9.1. The low organic carbon and total nitrogen values due to rapid decomposition of organic matter under Mediterranean type of climate in the northwestern Turkey.

Table 3
Total metal concentrations of the irrigated alluvial profiles

Horizon (FAO/Unesco)	Depth, cm	Metal concentration, mg kg^{-1}								
		Fe	Mn	Zn	Cu	Cd	Co	Cr	Ni	Pb
Profile 1										
Ap	0-20	26.657.000	1143	248	130.5	4.28	37.54	170.1	186.9	23.1
C1	20-45	20.054.000	1014	237.5	90.04	3.97	33.68	144.3	173.8	21.39
C2	45-75	16.812.000	890	224.9	61.59	1.31	31.3	93.51	168.7	19.76
Profile 2										
Ap	0-30	23.541.000	989	204	97.89	5.59	32.09	196	188.6	25.24
C1	30-60	17.103.000	887	146.8	88.91	5.17	30.42	172.6	179.5	24.12
C2	60-95	14.572.000	833	92.6	67.24	2.26	22.35	126.8	172.8	22.62
Profile 3										
Ap	0-25	31.058.000	1239	221.9	86.41	6.25	38.73	160.5	183.6	24.68
C1	25-55	21.264.000	1126	172.6	72.12	5.82	30.85	109.5	175.3	23.74
C2	55-80	12.937.000	1024	131.9	42.03	2.93	22.82	84.18	168.1	21.42
Profile 4										
Ap	0-20	23.785.000	1115	237.5	120.3	5.56	33.52	142	194.8	23.29
C1	20-48	17.626.000	1011	210.1	93.48	3.87	30.71	99.73	182	21.13
C2	48-82	13.941.000	862	145.9	62.16	1.94	26.5	82.14	179.6	18.91
Profile 5										
Ap	0-28	31.563.000	1043	168.9	102.6	5.83	34.31	215.3	185	13.89
C1	28-53	26.792.000	994	144	89.34	4.22	29.87	181	176.1	11.9
C2	53-75	18.914.000	885	123.7	54.82	1.24	18.93	153.7	172.8	10.04
Profile 6										
Ap	0-18	41.112.000	1498	356.7	84.47	3.01	45.18	124	176	17.96
C1	18-38	35.696.000	1352	291.8	83.5	2.83	42.65	116.2	171.8	17.04
C2	38-60	30.835.000	1275	230.4	63.41	2.71	40.12	98.55	165.4	15.46
C3	60-105	17.491.000	764	175.8	60.25	1.95	37.48	83.14	161.6	14.75
Profile 7										
Ap	0-20	44.685.000	1360	421.8	71.63	3.78	43.57	140.3	174.1	18.52
C1	20-55	34.439.000	1104	372.6	66.72	3.64	40.92	123.8	170.1	17.78
C2	55-75	27.411.000	876	353.5	65.98	3.59	38.08	107.3	163.3	17.31
C3	75-100	16.176.000	788	155.3	43.44	2.07	35.99	92.66	156.3	16.58
Profile 8										
Ap	0-30	36.907.000	1563	412.3	67.62	4.23	45.68	149.6	167.5	16.7
C1	30-60	31.610.000	1459	346.3	61.79	3.91	42.61	141.5	164.2	15.69
C2	60-78	24.459.000	1073	305.2	43.08	3.32	40.15	116.5	161.8	15.08
C3	78-112	20.893.000	668	221.2	33.41	2.84	37.42	83.21	149	14.67

(continued)

Table 3 (continued)

Profile 9										
Ap	0-22	40.032.000	1513	324	89.13	3.19	46.7	147.3	168.1	17.34
C1	22-45	27.895.000	1132	288.6	82.75	2.81	44.68	122.7	164.8	16.52
C2	45-65	23.822.000	763	272.2	75.93	2.23	41.82	114.5	157.1	15.7
C3	65-95	22.176.000	655	231.7	54.58	2.2	40.93	91.08	147.6	12.87
Profile 10										
Ap	0-20	39.576.000	1450	330.2	94.31	2.8	47.21	138.6	176.6	16.03
C1	20-48	34.841.000	1314	287.6	68.04	2.42	45.43	122.1	172.6	15.1
C2	48-64	28.952.000	871	196.7	49.41	2.07	43.85	96.82	165.5	13.8
C3	64-105	16.764.000	623	148.7	36.75	1.94	42.04	81.45	156.8	12.97
Statistical Values LSD 95%	---	5791	318	63.8	23.4	1.6	4.6	22.6	7.44	0.94

The $CaCO_3$ concentrations ranged from 1.2 to 6.5% and increased with depth due to calcareous parent material. Available P values ranged from 3.12 to 11.43 mg kg^{-1} and gradually decreased with depth. The surface horizons had higher values that were adequate levels. The CEC values ranged from 16.2 to 33.7 cmol (+) kg^{-1}, and along with clay content, increased with depth. Exchangeable Ca and Mg varied from 11.9 to 29.3 cmol (+) kg^{-1} and from 2.0 to 2.9 cmol (+) kg^{-1}. Exchangeable K ranged from 0.7 to 2.2 cmol (+) kg^{-1} and decreased with depth. Exchangeable Na varied from 1.3 to 2.7 cmol (+) kg^{-1} and increased with depth. Base saturation was 100% throughout the all profiles, due to the alkaline parent material and climate.

The total Fe, Mn, Zn, Cu, Cd, Co, Cr, Ni, and Pb concentrations are present in Table 3. The concentration of Fe varied from 12,937.000 to 44,685.000 mg kg^{-1}, Mn from 623 to 1563 mg kg^{-1}, Zn from 92.60 to 421.80 mg kg^{-1}, and Cu from 33.41 to 130.52 mg kg^{-1}. Cd ranged from 1.24 to 6.25 mg kg^{-1}, Co from 18.93 to 47.21 mg kg^{-1}, and Cr from 81.45 to 215.25 mg kg^{-1}. Ni varied from 147.58 to 194.76 mg kg^{-1} and Pb from 10.04 to 25.24 mg kg^{-1}.

The DTPA extractable Fe, Mn, Zn, Cu, Cd, Co, Cr, Ni, and Pb concentrations are present in Table 4. The values of Fe ranged from 3.75 to 13.50 mg kg^{-1}, Mn from 4.05 to 10.28 mg kg^{-1}, Zn from 1.14 to 5.92 mg kg^{-1}, and Cu from 4.03 to 15.12 mg kg^{-1}. Cd varied from 0.18 to 0.94 mg kg^{-1}, Co from 0.52 to 1.45 mg kg^{-1}, Cr from 0.10 to 0.25 mg kg^{-1}. The values of Ni and Pb varied from 0.61 to 1.13 mg kg^{-1} and from 0.83 to 2.10 mg kg^{-1} respectively.

The total and DTPA-extractable element concentrations for irrigated sites decreased gradually with depth from surface horizon to lowest horizon. The surface horizons had higher concentrations of heavy metals due to longer period of surface irrigation from polluted Nilufer River. These sites were irrigated and fertilized with diammonium phosphate, triple super phosphate, diammonium sulfate and ammonium nitrate to obtain enough yields by farmers. The all studied soils were plugged intensively in the research area. These soils were irrigated approximately once a week for 2 or 3 hours from June to September due to climatic conditions and water requirement of the crops in the region. The farmer uses flow irrigation pumping set, which pump 90 m^3/h water. The Nilufer River contains 45 mg l^{-1} silt and continuous irrigation silting up the irrigated sites. The continuous surface irrigation was affected physico-chemical properties of these soils under Mediterranean type of climate. The accumulation of heavy metals in the irrigated soils due to a long period of irrigation with polluted water from the Nilufer River is readily apparent in Table 1. The water results showed that the irrigation water was polluted with industrial wastewater and city sewage effluents. Even although the heavy metals may be con-

Table 4
DTPA-extractable some metal concentrations of the irrigated alluvial soil profiles

Horizon (FAO/ Unesco)	Depth, cm	Metal concentration, mg kg^{-1}								
		Fe	Mn	Zn	Cu	Cd	Co	Cr	Ni	Pb
Profile 1										
Ap	0-20	8.74	7.85	3.18	15.12	0.63	1.03	0.2	1.07	1.88
C1	20-45	6.27	6.92	3.02	10.47	0.6	0.95	0.17	0.91	1.75
C2	45-75	5.03	6.07	2.73	7.51	0.2	0.87	0.11	0.85	1.62
Profile 2										
Ap	0-30	7.62	6.78	2.47	12.55	0.81	0.92	0.23	1.1	2.1
C1	30-60	5.18	6.12	1.78	11.67	0.75	0.85	0.2	0.98	2
C2	60-95	4.35	5.75	1.14	9.05	0.33	0.63	0.15	0.9	1.87
Profile 3										
Ap	0-25	9.54	8.43	2.79	10.28	0.94	1.08	0.19	1.02	2.03
C1	25-55	6.28	7.65	2.21	9.13	0.87	0.87	0.13	0.93	1.95
C2	55-80	3.75	6.92	1.7	5.42	0.45	0.65	0.1	0.85	1.77
Profile 4										
Ap	0-20	7.84	7.64	3.2	13.52	0.75	0.97	0.17	1.13	1.9
C1	20-48	5.57	6.88	2.83	11.05	0.53	0.9	0.12	1	1.72
C2	48-82	4.25	5.9	2.02	7.38	0.27	0.78	0.1	0.97	1.55
Profile 5										
Ap	0-28	10.15	7.05	2.15	11.53	0.87	0.93	0.25	1.05	1.14
C1	28-53	8.07	6.73	1.81	10.27	0.65	0.81	0.21	0.95	0.98
C2	53-75	5.48	6.02	1.53	6.09	0.18	0.52	0.18	0.91	0.83
Profile 6										
Ap	0-18	12.42	10.05	4.82	10.83	0.52	1.32	0.15	0.98	1.51
C1	18-38	10.53	9.12	3.9	10.05	0.48	1.25	0.14	0.92	1.43
C2	38-60	9.15	8.55	3.13	8.77	0.46	1.18	0.12	0.85	1.31
C3	60-105	5.07	5.1	2.45	8.12	0.34	1.1	0.1	0.8	1.25
Profile 7										
Ap	0-20	13.5	9.01	5.92	8.95	0.6	1.28	0.17	0.95	1.58
C1	20-55	10.07	7.28	5.03	7.8	0.57	1.2	0.15	0.9	1.52
C2	55-75	8.11	5.8	4.71	7.25	0.54	1.12	0.13	0.82	1.48
C3	75-100	4.73	5.12	2.07	5.43	0.33	1.05	0.11	0.73	1.4
Profile 8										
Ap	0-30	11.05	10.28	5.8	8.67	0.65	1.35	0.18	0.85	1.44
C1	30-60	9.27	9.54	4.73	8.35	0.6	1.27	0.17	0.81	1.38
C2	60-78	7.13	7.07	4.15	6.07	0.51	1.2	0.14	0.78	1.3
C3	78-112	6.05	4.43	2.98	4.43	0.43	1.13	0.1	0.62	1.25

(continued)

Table 4 (continued)

Profile 9										
Ap	0-22	12.28	9.87	4.62	9.9	0.57	1.38	0.18	0.87	1.47
C1	22-45	8.44	7.15	4.05	8.65	0.5	1.32	0.15	0.82	1.4
C2	45-65	7.09	5.09	3.84	8.03	0.41	1.25	0.14	0.73	1.32
C3	65-95	6.72	4.38	3.08	5.57	0.39	1.21	0.11	0.61	1.08
Profile 10										
Ap	0-20	12.05	9.49	4.55	9.73	0.52	1.45	0.17	0.97	1.37
C1	20-48	10.82	8.52	3.83	7.32	0.44	1.4	0.15	0.93	1.28
C2	48-64	8.8	5.68	2.71	5.15	0.38	1.37	0.12	0.84	1.17
C3	64-105	5.08	4.05	2.08	4.03	0.35	1.29	0.1	0.72	1.1
Statistical Values LSD 95%	---	1.77	2.04	0.94	2.35	0.23	0.12	0.03	0.07	0.07

Table 5

The some physical and chemical properties of the non-irrigated alluvial soil profiles

Horizon (FAO/UNESCO)	Depth, cm	Sand, %	Silt, %	Clay, %	Texture	pH 1:2 soil:water	EC, dS m^{-1}	Org. C, %	Total N, %	C/N	$CaCO_3$, %	Available P, mg kg-l	CEC	Exchangeable cations			
														Ca	Mg	K	Na
													-----------------cmol (+) kg^{-1}---------------				
Profile 1																	
Ap	0-15	26.1	40.4	32.2	CL	7.3	0.65	1.83	0.15	12.2	1.5	13.51	30.1	24.2	2.6	2.4	1.8
C1	15-40	19.8	43.7	35.5	CL	7.4	0.6	1.04	0.1	10.4	2.4	11.04	33.3	28.1	2.5	2	1.5
C2	40-80	32.8	38.3	28.1	CL	7.5	0.54	---	---	---	3.1	6.27	25	21	2	1.8	1.1
Profile 2																	
Ap	0-20	25.6	42.5	30.4	CL	7.4	0.62	1.67	0.13	12.8	1.8	15.04	27.3	22.1	2.5	2.1	1.6
C1	20-50	15.3	45.8	37.8	CL	7.5	0.57	0.82	0.07	11.7	2.9	12.72	34.2	30.3	2.2	1.7	1.4
C2	50-90	27.1	40.1	31.9	CL	7.6	0.51	---	---	---	3.6	7.44	28.5	25.1	2	1.1	1
Profile 3																	
Ap	0-18	31.6	38.2	29	CL	7.3	0.55	1.51	0.12	12.6	1	11.37	26.4	20.5	2.7	2.5	1.9
C1	18-55	26.8	40.7	32.6	CL	7.5	0.5	0.77	0.07	11	2.2	9.52	28.7	24	2.1	2	1.7
C2	55-100	32.2	36.8	30.3	CL	7.6	0.42	---	---	---	3.4	5.48	25.1	21.3	2	1.5	1.5

(continued)

Table 5 (continued)

Profile 4																	
Ap	0-25	27.9	41.5	29.2	CL	7.5	0.68	1.95	0.15	13	2	14.07	27.1	20.9	2.9	2.2	1.8
C1	25-60	20	46.2	32.7	CL	7.6	0.61	0.91	0.09	10.1	2.8	11.25	29.3	24.4	2.6	1.8	1.4
C2	60-95	30.3	38.4	30.5	CL	7.7	0.54	---	---	---	3.5	8.11	26	22.3	2.5	1.4	1.2
Profile 5																	
Ap	0-20	29.3	37.1	32	CL	7.4	0.59	1.73	0.14	12.3	1.7	15.62	28.3	22.7	2.7	2.1	1.7
C1	20-60	21	40.9	36.8	CL	7.5	0.52	0.87	0.08	10.9	2.5	12.47	31.4	26.8	2.4	1.7	1.6
C2	60-85	31.6	36.7	30.7	CL	7.6	0.43	---	---	---	3.2	9.39	25.8	22.2	2.3	1.2	1
Profile 6																	
Ap	0-15	24.7	39.8	34.2	CL	7.3	0.71	1.61	0.12	13.4	1	10.35	22.1	15.8	2.9	2.4	1.9
C1	15-55	17	44.5	37.5	CL	7.5	0.64	0.87	0.07	12.4	2.1	8.5	25.5	20.2	2.7	1.9	1.6
C2	55-90	27.4	41.7	30.1	CL	7.6	0.5	---	---	---	3.6	4.73	21.3	16.8	2.5	1.5	1.4
Profile 7																	
Ap	0-25	30.3	39.7	28.8	CL	7.5	0.58	1.87	0.16	11.7	2.7	13.28	25.4	20	2.6	2	1.6
C1	25-65	22.8	43.2	33.1	CL	7.6	0.53	0.94	0.09	10.4	3.5	10.45	29	24.4	2.3	1.6	1.5
C2	65-105	27.1	41.5	30.7	CL	7.7	0.45	---	---	---	4	6.19	26.5	22.7	2.1	1.2	1.2
Profile 8																	
Ap	0-20	29.1	38.1	31.5	CL	7.3	0.55	1.58	0.12	13.2	1.6	15.12	28.2	22.1	2.8	2.3	1.9
C1	20-40	20.4	42.7	35.8	CL	7.4	0.48	0.7	0.06	11.7	2.9	11.4	32.7	27.7	2.4	1.9	1.5
C2	40-85	25.6	40.2	33.2	CL	7.5	0.4	---	---	---	3.7	7.28	29.9	25.9	2	1.5	1.3
Profile 9																	
Ap	0-18	24.9	40.9	32.7	CL	7.4	0.67	1.77	0.14	12.6	2.1	12.34	29	23.4	2.7	2	1.7
C1	18-50	15.6	46.7	36.5	CL	7.5	0.59	0.88	0.08	11	3.2	10.71	33.4	28.6	2.5	1.7	1.5
C2	50-80	26.2	41.5	31.3	CL	7.6	0.55	---	---	---	4.4	6.58	27.2	23.2	2.4	1.2	1.2
Profile 10																	
Ap	0-20	25.8	42.8	30.1	CL	7.3	0.74	1.91	0.15	12.7	1.2	11.55	26.7	20.4	2.9	2.4	1.9
C1	20-60	17.1	47.4	34.4	CL	7.4	0.65	0.72	0.06	12	1.9	9.03	30.1	24.7	2.6	1.9	1.7
C2	60-80	30.6	40	28.5	CL	7.5	0.57	---	---	---	2.8	5.17	24.6	20.8	2.1	1.6	1
Statistical Values LSD 95%	---	---	---	---	---	0.1	0.07	0.47	0.06	3.2	1.1	2.1	5.2	0.4	0.4	0.4	0.2

verted to colloidal suspension form in the Nilufer River, in this form they will still be transported to the soil profiles via irrigation water, and accumulate in the soil. The heavy metal pollution problem has been reported for irrigated Fluvisols with the Nilufer River in the eastern side of the plain by Aydinalp and Marinova (2003), Aydinalp and Cresser (2005) and Aydinalp et al. (2005). These soils are also under intensive agricultural practices by farmers in the region. The current irrigation practices were caused soil pollution and possibly would be heavy metal accumulation in the crops, which would cause human health risk as well.

The some physical and chemical properties of the non-irrigated soils are presented in Tables 5, 6 and 7. For non-irrigated soils, the soils texture clay loam in all the soil profiles. Clay contents of the non-irrigated

Table 6
Total metal concentrations of the non-irrigated alluvial profiles

Horizon (FAO/Unesco)	Depth. cm	Metal concentration. mg kg-1								
		Fe	Mn	Zn	Cu	Cd	Co	Cr	Ni	Pb
Profile 1										
Ap	0-15	19.646.000	1100	120.3	77.12	0.43	2.95	65.81	86.82	8.56
C1	15-40	17.291.000	816	77.53	63.04	0.35	2.66	43.93	80.15	8.21
C2	40-80	15.512.000	729	61.76	54.25	0.26	2.41	36.72	71.93	8.03
Profile 2										
Ap	0-20	20.711.000	1017	204.9	64.51	0.4	2.64	58.79	106.7	8.29
C1	20-50	18.945.000	898	160.1	55.91	0.36	2.45	36.28	98.35	7.93
C2	50-90	13.687.000	759	95.84	46.15	0.35	2.4	29.3	92.27	7.84
Profile 3										
Ap	0-18	14.850.000	1048	149.7	71.63	0.52	2.67	66.51	114.6	8.44
C1	18-55	10.535.000	845	65.3	57.3	0.33	2.42	51.62	95.48	8.27
C2	55-100	6.961.000	729	49.42	53.94	0.24	2.37	45.19	89.12	8.05
Profile 4										
Ap	0-25	16.302.000	1066	131.9	54.46	0.55	3.04	80.32	101.5	8.29
C1	25-60	12.954.000	953	66.73	35.5	0.45	2.49	65.9	93.38	7.96
C2	60-95	10.407.000	857	55.09	19.32	0.37	2.42	51.34	88.57	7.88
Profile 5										
Ap	0-20	20.038.000	895	171.3	67.41	0.72	3.52	65.98	99.03	9.55
C1	20-60	16.553.000	730	136.3	41.63	0.46	3.14	44.11	91.52	9.19
C2	60-85	11.596.000	564	117.7	36.57	0.45	2.72	29.32	84.69	9.1
Profile 6										
Ap	0-15	20.991.000	787	200.4	89.12	0.45	2.39	59.22	98.45	7.65
C1	15-55	15.795.000	661	152.1	62.65	0.4	1.95	37.12	86.68	7.23
C2	55-90	10.714.000	590	149.3	45.86	0.32	1.76	29.74	77.21	7.2
Profile 7										
Ap	0-25	20.139.000	1027	96.92	89.8	0.41	2.24	59.85	91.37	7.32
C1	25-65	17.842.000	935	67.69	68.97	0.31	1.95	44.71	85.68	7.09
C2	65-105	13.457.000	773	58.71	56.99	0.28	1.58	38.19	67.49	6.99
Profile 8										
Ap	0-20	15.118.000	1102	132.5	57.84	0.33	2.39	67.46	85.12	7.33
C1	20-40	13.681.000	1025	86.98	33.55	0.29	2.09	44.78	76.53	7.08
C2	40-85	7.919.000	938	68.54	26.74	0.28	1.72	37.25	70.82	6.95
Profile 9										
Ap	0-18	18.727.000	1070	111.7	63.38	0.51	2.66	59.22	106.3	8.48
C1	18-50	15.208.000	942	74.25	45.39	0.35	2.27	52.84	97.85	8.12
C2	50-80	6.135.000	826	62.9	37.2	0.31	2.11	38.13	91.18	7.93

(continued)

Table 6 (continued)

Profile 10										
Ap	0-20	17.512.000	881	179.2	57.12	0.43	2.63	52.95	101.4	7.89
C1	20-60	11.745.000	615	142.5	38.08	0.35	2.2	38.9	90.04	7.75
C2	60-80	9.218.000	492	111.3	26.53	0.3	1.89	22.46	83.8	7.58
Statistical Values LSD 95%	---	5791	318	63.8	23.4	1.6	4.6	22.6	7.44	0.94

Table 7
DTPA-extractable some metal concentrations of non-irrigated alluvial soil profiles

Horizon (FAO/ Unesco)	Depth, cm	Metal concentration, mg,kg^{-1}								
		Fe	Mn	Zn	Cu	Cd	Co	Cr	Ni	Pb
Profile 1										
Ap	0-15	6.87	7.28	1.65	7.83	0.09	0.1	0.09	0.52	0.84
C1	15-40	6.02	5.41	1.03	6.91	0.07	0.09	0.06	0.48	0.8
C2	40-80	5.35	4.8	0.81	6.02	0.06	0.08	0.05	0.43	0.78
Profile 2										
Ap	0-20	7.18	6.72	2.7	6.97	0.08	0.09	0.08	0.65	0.81
C1	20-50	6.53	5.96	2.13	5.65	0.07	0.08	0.05	0.6	0.77
C2	50-90	4.7	5.02	1.28	4.11	0.07	0.07	0.04	0.56	0.76
Profile 3										
Ap	0-18	5.08	6.91	1.92	6.52	0.09	0.09	0.09	0.71	0.93
C1	18-55	3.63	5.57	0.85	5.88	0.06	0.07	0.07	0.59	0.9
C2	55-100	2.07	4.8	0.63	5.01	0.05	0.06	0.06	0.55	0.88
Profile 4										
Ap	0-25	5.72	7.01	1.81	5.97	0.1	0.1	0.11	0.62	0.9
C1	25-60	4.51	6.27	0.93	4.08	0.08	0.08	0.09	0.57	0.87
C2	60-95	3.65	5.63	0.75	2.15	0.07	0.07	0.07	0.54	0.86
Profile 5										
Ap	0-20	6.92	5.9	2.27	6.2	0.12	0.11	0.09	0.6	0.95
C1	20-60	5.77	4.81	1.84	4.51	0.09	0.1	0.06	0.55	0.91
C2	60-85	3.95	3.7	1.6	3.08	0.08	0.09	0.04	0.51	0.9
Profile 6										
Ap	0-15	7.42	5.17	2.51	7.45	0.09	0.08	0.08	0.58	0.82
C1	15-55	5.58	4.34	1.95	5.03	0.08	0.07	0.05	0.51	0.79
C2	55-90	3.71	3.88	1.83	4.29	0.07	0.06	0.04	0.46	0.78
Profile 7										
Ap	0-25	7.03	6.72	1.17	7.21	0.08	0.07	0.08	0.55	0.79
C1	25-65	6.22	5.91	0.83	6.74	0.06	0.06	0.06	0.51	0.76
C2	65-105	4.68	5.05	0.7	4.93	0.05	0.05	0.05	0.4	0.74

(continued)

Table 7 (continued)

Profile 8										
Ap	0-20	5.15	7.2	1.56	5.8	0.08	0.08	0.09	0.51	0.7
C1	20-40	4.64	6.71	1.03	3.75	0.07	0.07	0.06	0.46	0.67
C2	40-85	2.73	6.13	0.82	2.51	0.07	0.06	0.05	0.42	0.65
Profile 9										
Ap	0-18	6.48	7.05	1.38	6.63	0.09	0.09	0.08	0.63	0.73
C1	18-50	5.24	6.18	0.91	5.19	0.07	0.08	0.07	0.58	0.7
C2	50-80	2.05	5.43	0.75	3.45	0.06	0.07	0.05	0.54	0.69
Profile 10										
Ap	0-20	6.21	5.77	2.3	5.08	0.08	0.08	0.07	0.6	0.75
C1	20-60	4.05	4.03	1.79	3.62	0.07	0.07	0.05	0.53	0.73
C2	60-80	3.18	3.21	1.41	2.7	0.06	0.06	0.03	0.49	0.71
Statistical Values LSD 95%	---	1.77	2.04	0.94	2.35	0.23	0.12	0.03	0.07	0.07

soils were significantly higher than the irrigated soils and ranged from 28.1 to 37.8%, increasing with depth in the C1 horizon. The pH values of soils varied from 7.3 to 7.7 and increased with depth. The organic carbon and total nitrogen values ranged from 0.70 to 1.95% and from 0.06 to 0.15% respectively, and decreased with depth. Soil C/N ratios varied from 10.1 to 13.4. EC values ranged from 0.40 to 0.74 dS m^{-1} and decreased with depth. EC values were higher in the irrigated soils. The $CaCO_3$ content of soils varied from 1.0 to 4.4% and increased with depth. The available phosphorus values ranged from 4.73 to 15.62 mg kg^{-1} and values increased with depth. The CEC values of soils varied from 21.3 to 34.2 cmol (+) kg^{-1} and values increased with depth. Exchangeable Ca and Mg values ranged from 15.8 to 30.3 cmol (+) kg^{-1} and from 2.0 to 2.9 cmol (+) kg^{-1} respectively. K and Na varied from 1.1 to 2.5 cmol (+) kg^{-1} and from 1.0 to 1.9 cmol (+) kg^{-1}. Base saturation was 100% throughout the all profiles, due to the alkaline parent material and climate.

The distributions of total Fe, Mn, Zn, Cu, Cd, Co, Cr, Ni, and Pb concentrations for non-irrigated soils are present in Table 6. The concentration of Fe varied from 6,135.000 to 20,991.000 mg kg^{-1}, Mn from 492 to 1100 mg kg^{-1}, Zn from 49.42 to 204.91 mg kg^{-1}, and Cu from 19.32 to 89.80 mg kg^{-1}. Cd ranged from 0.24 to 0.72 mg kg^{-1}, Co from 1.58 to 3.52 mg kg^{-1}, and Cr from 22.46 to 80.32 mg kg^{-1}. Ni varied from 67.49 to 114.63 mg kg^{-1} and Pb from 6.95 to 9.55 mg kg^{-1}.

The DTPA extractable Fe, Mn, Zn, Cu, Cd, Co, Cr, Ni, and Pb concentrations are presented in Table 7. The values of Fe ranged from 2.07 to 7.42 mg kg^{-1}, Mn from 3.21 to 7.28 mg kg^{-1}, Zn from 0.63 to 2.70 mg kg^{-1}, and Cu from 2.15 to 7.83 mg kg^{-1}. Cd varied from 0.06 to 0.12 mg kg^{-1}, Co from 0.05 to 0.11 mg kg^{-1}, Cr from 0.03 to 0.11 mg kg^{-1}. The values of Ni and Pb varied from 0.40 to 0.71 mg kg^{-1} and from 0.65 to 0.95 mg kg^{-1} respectively.

The irrigated soils had significantly higher silt content than non-irrigated soils. The CEC values were lower in the irrigated sites, which related with lower clay and organic matter content of the soils. The irrigation was affected EC values of the irrigated sites and had higher values than non-irrigated sites. The obtained results indicated that irrigation was affected total and DTPA-extractable element contents of the irrigated sites and caused heavy metal pollution in the studied area.

The concentration total and DTPA-extractable elements for non-irrigated sites decreased gradually with depth. The surface horizons had higher concentrations than the lower horizons. The profile distribution of total and DTPA-extractable elements reflects their association with soil process and maturity of soil profiles. Variation in distribution of elements with depth indicates that pedogenic processes and parent materials control total content, and biological processes affect DTPA-extractable content.

Conclusions

The results of research indicated that industrial wastewater and city sewage effluents pollute the Nilufer River. This unique irrigation water source has been using continuous irrigation in the agricultural land of the study area for couple of decades. This continuous surface irrigation affected irrigated soils and caused heavy metal pollution. The results of total and DTPA-extractable Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn showed that irrigated soils were polluted with these metals. Using this polluted irrigation water would cause increasing heavy metals in these agricultural soils under the semi-arid climate of this region. The total and DTPA-extractable Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn values for non-irrigated soils were lower than the irrigated sites. The concentrations of heavy metals were in low to moderate levels due to using fertilizer, pesticides intensively and possible atmospheric deposition, which was caused by air pollution. The using coals for some heating system, heavy traffic and industrial gas effluents have been causing air pollution in the region. This problem could affect environment of the region.

References

Agbenin, J. O., 2001. The status and fluxes of alkali and alkaline-earth metals in a savanna alfisol under long-term cultivation. *Catena*, **45:** 313 331.

Agbenin, J. O. and P. Felix-Hermingsen, 2001. The status and dynamics of some trace elements in a savanna soil under long-term cultivation. *Science of the Total Environment*, **277:** 57 68.

Anonymous, 1988. Water Analysis. Fresenius W, Schneider W, editors. Berlin, *Springer Verlag.*

Anonymous, 1995. *Bursa Ili Arazi Varligi*. T.C. Basbakanlik Koy Hizmetleri Genel Mudurlugu Yayinlari. Il Rapor No: 16, Ankara.

Alloway, B. J., 1990. Heavy Metals In Soils. *Blackie & Son*, New Jersey.

Aydinalp, C., and S. Marinova, 2003. Distribution and forms of heavy metals in the some agricultural soils. *Polish Journal of Environmental Studies*, **12** (5): 629-633.

Aydinalp C. and M. S. Cresser, 2005. Iron and zinc status in soils, water, and plant samples from a densely populated and industrialized region of Turkey. *Journal of Plant Nutrition*, **28** (4): 567-572.

Aydinalp, C., E. A. FitzPatrick and M. S. Cresser, 2005. Heavy metal pollution in some soil and water resources of Bursa province, Turkey. *Communications in Soil Science and Plant Analysis*, 36, **13&14:** 1691-1716.

Bremner, J. M. and C. S. Mulvaney, 1982. Nitrogen-Total. In: *Methods of Soil Analysis, Part 2*; *Chemical and Microbiological Properties, eds.* A.L. Page, R.H. Miller, and D.R. Keeney, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 595-624.

Csillag, J., A. Lukacs, K. Bujtas and T. Nemeth, 1998. Release of Cd, Cr, Ni, Pb And Zn as a consequence of soil contamination and acidification. *Adv Geoecol.*, **31:** 673 680.

Dowdy, R. H., J. J. Latterell, T. D. Dinesly, R. B. Grossman and D. L. Sullivan, 1991. Trace metal movement aeric ochraqualf following 14 years of annual sludge applications. *Journal of Environmental Quality*, **20:** 119123.

Ewa, I. O. B., Oladipo, M. O. A., and L. A. Dim, 1999. Horizontal and vertical distribution of selected metals in the kubani river, Nigeria as determined by neutron activation analysis. *Communications in Soil Science and Plant Analysis*, **30:** 10811090.

Fuleky, G. and M. Takács, 2002. *Nand Ram :Effect of heavy metal pollutuon and acidification on copper and zinc adsorption of the soil*. Bulletin of the Szent István University 2001-2002. Gödöllõ, 91-102.

Gee, G. W., and J. W. Bauder, 1982. Particle-Size Analysis. In: *Methods of Soil Analysis, Part 1*;

Physical and Mineralogical Methods, eds. A. Klute, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 383-412.

Harter, R. D. and R. Naidu, 2001. An assessment of environmental and solution parameter impact of trace metal sorption by soils. *Soil Science Society of America Journal*, **65:** 597612.

FAO/Unesco, 1990. *Soil map of the world, revised legend*. World Soil Resources Report 60, Rome.

Fujikawa, Y., F. Masami and A. Kudo, 2000. Vertical distribution of trace metals in natural soil horizons from japan. part 1.effect of soil types. *Water Air Soil Pollution,* **124:** 112.

Kabata-Pendias, A., 1995. Agricultural problems related to excessive trace metal contents in soils. In: Salomons, W., Forstner, U., and P. Mader, 3-18. Eds., Heavy Metals: Problems and Solutions. *Springer-Verlag,* Berlin Heidelberg.

Lindsay, W. L., and W. A. Norvell, 1978. Development of a DTPA Soil Test for Zinc, Iron, Manganese and Copper. *Soil Science Society of America Journal,* **42:** 421-428.

Logan, T. J., 1990. *Chemical degradation of soil, eds*. R. Lal, and B.A. Stewart, pp. 187-221. Soil Degradation. Advances in Soil Science, Vol.II. Springer-Verlag, New York.

McLean, E. O., 1982. Soil pH and Lime Requirement. *In: Methods of Soil Analysis, Part 2; Chemical and Microbiological Properties, eds.* A.L. Page, R.H. Miller, and D.R. Keeney, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 199-224.

Naidu, R., N. S. Bolan, R. S. Kookana and K. G. Tiller, 1994. Ionic strength and ph effects on surface charge and cd sorption characteristics of soils. *Journal of Soil Science,* **45:** 419 429.

Nelson, D. W., and L. E. Sommers, 1982. Total Carbon, Organic Carbon, and Organic Matter. In: *Methods of Soil Analysis, Part 2*; *Chemical and Microbiological Properties*, *eds.*A.L. Page, R.H. Miller, and D.R. Keeney, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 583-580.

Nelson, R. E., 1982. Carbonate and gypsum. In: *Methods of Soil Analysis, Part 2; Chemical and Microbiological Properties, eds.* A.L. Page, R.H. Miller, and D.R. Keeney, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 181-198.

Nriagu, J. O., 1988. A silent epidemic of environmental metal poisoning? *Environmental Pollution,* **50:** 139161.

Oliver, M. A., 1997. Soil and human health: A Review. *Eurisian Journal of Soil Science,* **48:** 573592.

Olsen, S. R. and L. E. Sommers, 1982. Phosphorus. In: *Methods of Soil Analysis, Part 2; Chemical and Microbiological Properties, eds.* A.L. Page, R.H. Miller, and D.R. Keeney, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 403-430.

Rhoades, J. D., 1982. Cation exchange capacity. In: *Methods of Soil Analysis, Part 2; Chemical and Microbiological Properties, eds.* A.L. Page, R.H. Miller, and D.R. Keeney, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 149-158.

Sims, J. T. and J. S. Kline, 1991. Chemical fractionation and plant uptake of heavy metals in soils amended with co-composted sewage sludge. *Journal of Envimental Quaitilty,* **20:** 387395.

Soil Conservation Service, 1972. *Soil Survey Laboratory Methods And Procedures For Collecting Soil Samples*. U.S. Government Printing Office, Washington, DC, U.S. Dep. of Agriculture Soil Survey Investigations Rep. No. 1.

Soil Survey Division Staff, 1993. *Soil Survey Manual*. USDA, Washington, DC.

Svab, J., 1973. *Biometry Methods in Research* (Hungarian). Mezõgazdasági Kiadó, Budapest.

Thomas, G. W., 1982. Exchangeable Cations. In: *Methods of Soil Analysis, Part 2; Chemical and Microbiological Properties, eds.* A.L. Page, R.H. Miller, and D.R. Keeney, Madison, Wisconsin: 2nd ed. American Society of Agronomy, pp. 159-166.

Williams, D. E., J. Vlamis, A. H. Pukite and J. E. Corey, 1987. Metal movement in sludge amended soils: A nine year study. *Soil Science,* **143:** 124 131.

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