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Study of Soil Pollutants in Omdurman Industrial Area, Sudan, Using X-ray Fluorescence Technique

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ABSTRACT: In this work *X-ray fluorescence* (XRF) technique was used to evaluate the soil pollution with heavy metals for twenty four surface soil samples (0–10 cm in depth) from various locations to cover the industrial area in Omdurman city, Sudan. Concentrations of 10 elements Cr, Ni, Cu, Zn, Zr, Pb, Rb, Co, Cd and As were determined. It was found that Cr, Cu and Cd concentrations for almost all studied sites are greater than the normal values, while most the Ni, Zn, Co, As and Pb concentrations are lower than the normal values. Some of the concentrations of As are greater than the normal values. The elemental concentrations were compared with the normal values and other studies in different locations from the world. The correlation between elements appears that pollution inside the investigated area results from different sources of contamination present inside it. The results establish a database reference of radioactivity background levels around this region.

Key words: XRF, Heavy metals, Surface soil, Industrial area, Omdurman

INTRODUCTION

Soil contamination by heavy metals resulting from emission of fumes and smokes from transportation and industrial plants is recognized as a major problem in different countries. Studying the levels of radionuclide distribution in the environment provides essential radiological information (Censi *et al.*, 2006, Aktaruzzaman *et al.*, 2013, Aktaruzzaman *et al.*, 2012, Dolan *et al.*, 2006). As a result of rapid urbanization and industrial development, the environmental contaminants are widely distributed in air, water, soil and sediment. Among environmental pollutants, heavy metals are of particular concern, due to their potential toxic effect and ability to bio-accumulate in ecosystems (Rahman, 2014). A soil pollution assessment becomes very complex when different sources of contamination are present and their products are variably distributed. In these cases, the spatial variability of heavy metal concentrations in soils is basic information for identifying the possible sources of contamination and to delineate the strategies of site remediation. The pH value affects on the level of soil pollution.

The attractiveness of non-destructive methods and the ability to perform simultaneous multi-elemental determinations has led to an extensive application in industrial and research laboratories of accurate, precise and sensitive atomic and nuclear analytical techniques such as neutron activation analysis (NAA), X-ray fluorescence (XRF), and inductively coupled plasma (ICP). For the analysis of environmental samples XRF has the advantage of being a rapid and inexpensive method with a simple sample preparation. Quantitative and qualitative analyses are performed without acid digestion processes and a great number of elements can be determined simultaneously in a short time (Ene *et al.*, 2010).

The most frequently reported heavy metals with regards to potential hazards and occurrence in soils are: Al, Co, Cu, Fe, Pb, Mn, Ni and Zn (Tumuklu *et al.*, 2007, Al-Kashman and Shawabkeh 2009). Heavy metal concentrations such as Cd, Cu, , As, Zn and Pb in surface soils have been a focus of investigation over the past decades (Adriano, 1986). Kung and Ying determined some heavy metal concentrations. Their results revealed that soil pollution occurred predominantly around industrial complexes (Kung and Ying, 1990). The content of Pb, Cr, Cd, Hg and As from different industrial areas was investigated. Results show that the concentration of heavy metals was so high that these soils need immediate decontamination or at least remediation measures (Elbagermi *et al.*,

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2013). Metals content in Irish soils from an area with modern industrial development was generally indicative low pollution input (Mcgrath, 1995). Assessment of heavy metals in soil and roadside dust around Misurata City Centre and industrial areas revealed that the heavy metals concentration in industrial area was higher as compared to the nonindustrial area (Elbagermi et al. 2013). (Ezekiel *et al.*, 2013); reported that the concentration of the metals decreased with distance from the site of industrial area. Heavy metals in effluents of pharmaceutical Industries were determined (Ramola and Singh, 2013), results show that the concentrations of some heavy metals are above the permissible limit recommended by WHO standards. X-ray fluorescence (XRF) technology was used to evaluate the soil pollution with heavy metals in soil in Ado Ekiti, Nigeria. The experimental results indicate that the concentrations of heavy elements are greater than the level detected in a control soil. Anthropogenic releases give rise to highest concentrations of the metals relative to the normal background values and in some locations their levels exceed the alert level admitted by the Nigeria guideline (Ogunmodede and Ajayi, 2014).

At present, very little is known about the heavy metals concentrations, distribution and extent of environmental pollution in the soils of Omdurman. Therefore, the main goal of the present research was to assess the heavy metals concentrations in the industrial area, Omdurman city, Sudan.

MATERIALS & METHODS

Samples were collected during December 2012 and July 2013. Twenty four Soil samples (three replicates) were collected at surface level (0–10 cm in depth) from various locations to cover the industrial area in Omdurman city, Sudan. The distance between each successive sample is about 150 meters. The soil samples were dried, homogenized and sieved at 200 mesh grain size.

Trace elemental analysis of samples by X-Ray fluorescence were performed using a Philips PW X-Unique II X-ray spectrometer with automatic sample changer PW 1510, (30 positions). This instrument is connected to a computer system using X-40 program for spectrometry. The trace elements concentrations are calculated from the program's calibration curves which were set up according to international reference materials, (standards). The detection limit is the lowest concentration, and it is function of the level of background noise relative to an element signal (Norrish and Chappell, 1966). The detection limit for the elements measured by XRF technique is estimated at 2 mg kg^{-1} for Rb, Zn, As, Co and Cr and at 8 mg kg^{-1} for Pb and Cu and 5 mg kg^{-1} for other measured trace elements.

RESULTS & DISCUSSION

XRF results for collected surface soil samples from industrial area, in Omdurman city, evident the existence of the following elements: Cr, Ni, Cu, Zn, Zr, Rb, Pb, Co, Cd and As, shown in Table 1. It can be seen that Cd, Cr and Cu concentrations for almost all studied sites are greater than the normal values 1.0 30.0 and 20.0 mg/kg, respectively, while most the Ni, Zn and Pb concentrations are lower than the normal values 20, 100 and 20, respectively (Antoaneta, 2009) except site 5 near a paint factory which recorded high concentrations. A soil pollution assessment becomes very complex when different sources of contamination are present and their products are variably distributed (Akyuz, 2002). Table 2 gives the comparison of trace element concentrations in present work with other reference data (Elbagermi *et al.*, 2013, Ezekiel *et al.*, El-Bahi *et al.*, 2013, Al-shayeb, 2002, Dingjian, 2012, Vandana 2011, Adriano, 2006). It can be seen that the present concentrations of Cr and Zr are lower than that of Wadi El Rayan in Eygpt (El-Bahi *et al.*, 2013), and Hyderabad city in India (Vandana *et al.*, 2011) and lower than threshold values as well (Adriano 2001). Table 2 shows also that the present concentrations of Ni, Cu and Zn exceed all reference data (Elbagermi *et al.*, 2013, El-Bahi *et al.*, 2013, Al-shayeb, 2002, Dingjian, 2012, Vandana *et al.*, 2011, Adriano, 2001). Existences of all these elements with different values caused many diseases if reached to human bodies. For example, Cr causes carcinoma, Cu causes cirrhosis, nausea, vomiting and diarrhea.

Using the elemental analysis data obtained (Table 1), we have calculated the matrices shown in Tables 3, by calculating the Pearson's correlation coefficient R^2 (Lohninger 1999) between each two elements in soils collected from the industrial area.From the correlation matrix (Table 3), it can be seen that the Pearson coefficient R^2 has greater values than 0.60 for the following pairs of elements: Cr-Ni, Cr-Cu, Cr-Zn, pb-Cr, Cr-Rb, Cr-Co, Ni-Pb, Pb-Cu, Cu-Co, Co-Zn, Rb-Pb, Rb-Co and Pb-Cd. This means that all elements that make an R- squared value greater than 0.60 with another element will co-precipitate, to some extent, with that element. This relationship proofs that the pollution inside it is caused by different sources of contamination.

CONCLUSION

The elemental analysis of soil samples, collected from different sites in Omdurman industrial area, Sudan, was carried out using XRF technique, provided concentration levels of different elements and gave an insight into the possible sources, namely, natural sources like soil dust and anthropogenic sources such as fuel burning, automotive exhaust and industrial activities. Results show that, Ni, Cu and Pb are the major emitted elements in Omdurman industrial area.

Table 1. Trace elements concentrations (in mg/kg) using XRF spectroscopy for surface soil samples from different sites in Omdurman industrial area

Sample	Cr	Ni	Cu	Zn	Zr	Rb	Pb	Co	Cd	As
1	12	67	24	36	144	18	13	15	7	4
2	11	45	21	28	111	21	22	13	10	8
3	16	71	33	29	133	18	18	22	14	2
4	23	88	62	46	177	22	24	26	13	3
5	46	134	77	86	188	35	33	34	20	9
6	17	51	55	27	122	23	22	17	9	2
7	9	59	34	19	112	17	16	12	7	8
8	14	77	39	25	129	19	21	14	9	7
9	13	55	37	32	115	21	17	14	6	10
10	12	71	35	28	149	16	16	16	7	6
11	23	99	43	49	145	25	19	22	6	10
12	15	69	40	37	182	23	19	20	6	9
13	18	66	41	28	138	26	20	19	11	6
14	15	76	37	33	188	18	22	23	7	5
15	14	56	33	28	151	18	19	16	6	7
16	16	95	22	14	223	16	16	12	4	9
17	34	96	50	36	320	28	26	28	13	4
18	14	87	31	26	203	17	14	10	5	7
19	17	75	25	22	230	16	17	9	4	8
20	15	80	33	31	168	23	16	22	8	7
21	15	78	29	31	118	24	21	18	10	9
22	14	88	22	32	260	21	20	15	9	10
23	15	77	30	30	201	21	19	17	6	6
24	16	72	45	30	276	27	22	21	9	8

Table 2. Comparison of the trace element concentrations (in mg/kg) for studied samples with other studies in different locations from the world

Element	Omdurman Industrial area	Wadi El Rayan(El-Bahi et al., 2013)	Ikere-Ekiti (Ogunmodede and Ajayi, 2014)	Riyad(Al-shayeb, 2002)	Jiangxi province of China (Dingjian, 2012)	Misurata (Elbagermi et al., 2013)	Hyderabad, (Vandana et al., 2011)	Threshold value(Adriano, 2001)
Cr	11 – 46	23 - 203	2.42	1.20	27.68	19.7	12.3 - 480.6	10 – 50
Ni	45 – 134	14 - 18	0.22	1.14	-	22.5	12.6 - 132.0	10 - 50
Cu	21 – 77	43 - 52	2.71	2.22	23.20	32.1	11.1 - 186.6	10 - 40
Zn	14 – 86	27 - 33	8.33	4.25	47.18	67.5	40.8 - 882.2	20 - 200
Zr	111 – 320	98 - 737	-	-	-	-	-	-
Rb	16 – 35	18 - 25	-	-	-	-	-	150
Pb	13 – 33	u.d - 2	4.58	3.19	23.15	2.25	42.9 - 1832.5	10 - 30
Co	9 – 34	-	1.39	-	-	-	-	8
Cd	4 – 20	27 - 32	0.28	-	0.13	29.1	-	1.0
As	2 – 10	-	-	-	-	-	-	6

Table 3. Correlation coefficient between trace elements in Omdurman industrial area, Sudan

Element	Cr	Ni	Cu	Zn	Zr	Rb	Pb	Co	Cd	As
Cr	1									
Ni	0.62	1								
Cu	0.61	0.22	1							
Zn	0.67	0.45	0.55	1						
Zr	0.15	0.20	0.006	0.004	1					
Rb	0.61	0.25	0.52	0.56	0.05	1				
Pb	0.64	0.64	0.60	0.50	0.06	0.62	1			
Co	0.63	0.34	0.61	0.62	0.05	0.60	0.58	1		
Cd	0.52	0.19	0.48	0.47	0.001	0.50	0.63	0.59	1	
As	0.001	0.02	0.02	0.0002	0.05	0.03	0.001	0	0.003	1

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