



RESEARCH ARTICLE

Pollution Loads and Ecological Risk Assessment of Heavy Metals in the Urban Soil Affected by Various anthropogenic Activities

Riyad Al-Anbari¹, Abdul Hameed M.J. Al Obaidy², Fatima H. Abd Ali¹

1. Department of Building and Construction Engineering, University of Technology, Baghdad, Iraq

2. Environmental Research Center, University of Technology, Baghdad, Iraq

Manuscript Info**Manuscript History:**

Received: 19 December 2014
Final Accepted: 24 January 2015
Published Online: February 2015

Key words:

Heavy metals, Soil pollution,
Ecological Risk Assessment

***Corresponding Author**

Fatima H. Abd Ali

Abstract

The present paper deals with the assessment of the concentrations and potential ecological risk of heavy metals in urban soil affected by various anthropogenic activities (Al-Karrada) within Baghdad city. The samples were subjected to HCl and HNO₃ digestion, and an atomic absorption spectrophotometer was used to determine the concentrations of Cd, Cr, Cu, Ni, Pb and Zn. With the exception of Zn, all the soil samples displayed higher concentration than the calculated worldwide mean of unpolluted soil. Nemerow pollution index (16.33) fell in the seriously polluted domain with the soil environment quality classification of ($P_s > 3.0$). The single potential ecological risk showed that soil contamination from Cd (672) had very high potential ecological risk, which translated into the high value of the comprehensive potential ecological risk value (720.63) in the study area.

Copy Right, IJAR, 2015.. All rights reserved

INTRODUCTION

Pollution of the natural environment by heavy metals is a worldwide problem because these metals are permanent and most of them have toxic effects on living organisms when they exceed a certain concentration [1]. The metal toxicity is usually defined in terms of the concentration required to cause an acute response (usually death) or a sub-lethal response [2].

The urban environmental quality is of vital importance as the majority of people now live in cities. Due to the continuous urbanization and industrialization in many parts of the world, metals are continuously emitted into the terrestrial environment and pose a great threat on human health [3]. Urbanization leads to substitution of natural ecosystems by artificial ones, which exert huge chemical, physical, psychical effects on human beings [4,5].

Investigations of the content of heavy metals in soil are mainly focused on heavily urbanized areas such as industrial regions and city agglomerations, as well as on the areas of constant and linear emitters, which include industrial plants, waste landfills and roads. The results confirm degradation of urban and industrial areas are usually higher [6], but sometimes they stay within the norms [7]. The high variations in the content of elements in soil within one urbanized area were also observed [8].

Al-Karrada district within Baghdad City can be one of the residential areas with various anthropogenic activities including commercial (e.g. electrical, clothing, jewelry, furniture shops, supermarkets and different works companies etc.), industrial (e.g. The state company for leather industries, Iraqi flour company, fuel stations, numerous automobile service and repair workshops).

Increased artesian and automobile repairs workshops which may include auto mechanic, auto welding, auto electrician and auto painting units may create many different types of waste during their daily operations. These include used oil and fluids, dirty shop rags, used parts, asbestos from brake pads and waste from solvents used for cleaning parts. All of which are expensive to dispose of and sometimes hazardous. The most dangerous waste

commonly created in auto-repair shops is from the solvents used to clean parts. Many of the chemicals that make up the solvents are extremely dangerous to human and the environment [9].

2. Materials and Methods

2.1 Study Area

Al-Karrada (Figure 1) is an old district situated on the east side of the Tigris river in Risafa side of Baghdad city ($33^{\circ} 17' - 33^{\circ} 19' \text{ N}$, $44^{\circ} 23' - 44^{\circ} 29' \text{ E}$), Iraq. It is characterized by arid to semiarid climate with dry, hot summers and cold winters; the mean annual rainfall is about 151.8 mm [10].

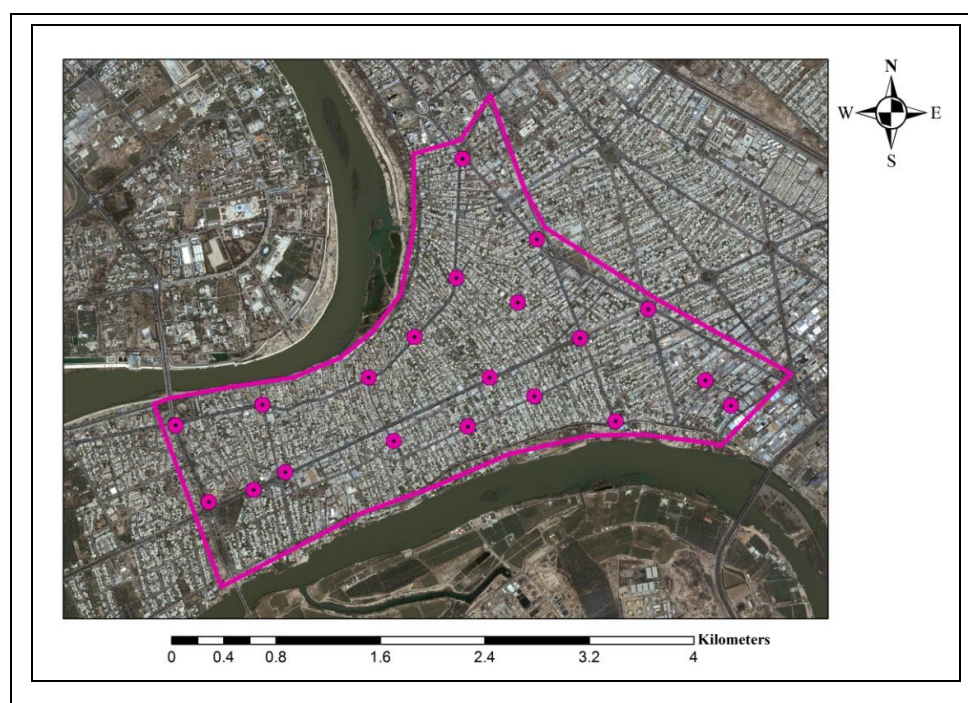


Figure 1: Sampling location in the study site

2.2 Soil Sampling and Analyses

Twenty soil samples were collected in total; each sample representing a composite sample of at least 3 subsamples within Al-Karrada district. The sampling points were randomly distributed to cover the entire study site. All of the sampling sites were recorded using Global Positioning System (GPS) device. The soil samples were collected during December 2013. A bulk sample was prepared by collecting about 1 kg of surface soil (0-20 cm) by hand digging with a stainless steel spatula. After air drying, samples were passed through a 2 mm sieve to remove large debris, stones and pebbles, and then they were stored in plastic bags for further analysis. Samples were wet-digested using a combination of HCl and HNO₃ [11]. Metal determinations were done by Atomic Absorption Spectrometry (AAS 6300, Shimadzu, Japan).

3. Pollution Assessment Method

In the present study, Nemerow (*Ps*) and ecological risk (*Rl*) Indices were used to assess the metal pollution levels in the soil samples. Reference values (Earth crust averages) of the studied metals which were used as background values were taken from Riley and Chester (Table 1), [12].

Table 1: Background values (Earth's crust) Riley & Chester (1971)

Element	Cd	Cr	Cu	Ni	Pb	Zn
Background value	0.2	100	55	75	12.5	70

The composite index method (Nemerow Index) according to [13] can be used to evaluate the quality of the soil of the study area. The composite index method used the Single Pollution Index (P_i), which more directly reflects the pollution of environmental indicators.

$$P_i = \frac{C_i}{C_{ref}} \quad (1)$$

Where P_i is the single pollution index; C_i represents the mean concentrations of heavy metals from at least 5 sampling sites, and C_{ref} indicates the evaluation criteria values [14]. The Nemerow Composite Index (P_s) method takes into account all the individual evaluation factors from (eq. 2) and also highlights the importance of the most contaminated elements.

$$P_s = \sqrt{(P_{ave}^2 + P_{max}^2)/2} \quad (2)$$

Where P_{ave} : the average of the single Pollution Index of all metals, P_{max} : the maximum value of the single pollution index of all metals.

The quality of soil environment is classified into 5 grades from the Nemerow pollution index [15]: ($P_s < 0.7$, safety domain; $0.7 \leq P_s < 1.0$, precaution domain; $1.0 \leq P_s < 2.0$, slightly polluted domain; $2.0 \leq P_s < 3.0$, moderately polluted domain; and $P_s > 3.0$, seriously polluted domain).

The potential ecological risk index method proposed by [14] to evaluate heavy metal contamination from the perspective of sedimentology was applied to evaluate the heavy metal pollution in the soils and also to associate ecological and environmental effects with their toxicology [16]. Although the risk factor is originally used as a diagnostic tool for the purpose of controlling water pollution, it has been successfully used for assessing the quality of sediments and soils in terms of heavy metals pollution [17].

$$RI = \sum_{i=1}^n E_r^i ; \quad E_r^i = T_r^i \times P_i \quad (3)$$

Where E_r : potential ecological risk individual coefficient, T_r : the toxicity response coefficient of metal toxicity.

The toxicity response coefficients of Cd, Cr, Cu, Ni, Pb and Zn were 30, 2, 5, 5, 5 and 1, respectively, while the indices of potential ecological risk are listed in Tables (2) and (3) respectively [14].

Table 2: Single-potential ecological risk (E_r)

E_r	Single-potential ecological risk (E_r)
<40	Low potential ecological risk
$40 \leq E_r < 80$	Moderate potential risk
$80 \leq E_r < 160$	Considerable potential risk
$160 \leq E_r < 320$	High potential risk
≥ 320	Significantly very high

Table 3: Comprehensive-potential ecological risk (RI)

<i>RI</i>	Comprehensive-potential ecological risk (<i>RI</i>)
<90	Low potential ecological risk
$90 \leq RI < 180$	Moderate potential ecological risk
$180 \leq RI < 360$	Strong potential ecological risk
$360 \leq RI < 720$	Very strong potential
≥ 720	Highly – strong potential

4. Results and Discussion

4.1 Distribution of Heavy Metals in Soil

The descriptive statistics of the selected heavy metals data sets relative to soil samples are given in Table (4). High standard deviation reflecting the skewed distribution and a high degree of variation. For Cd, Cr, Cu, and Zn concentrations were not normally distributed, showing a skewed distribution. Therefore, for these elements, medians instead of means were used since they would describe such distributions more precisely.

The order of occurrence of heavy metals measured in study soils followed the sequence of Cr> Ni> Pb> Zn> Cu> Cd. With the exception of Zn, all the measured metals display higher concentrations than the calculated world average of unpolluted soils [18], (Table 4).

Table 4: Basic statistical of heavy metal concentrations (mg/kg)

Element	Minimum	Maximum	Mean	Median	Skewness	Std. Deviation	Mean of Unpolluted Soils [18]
Cd	1.20	5.80	4.18	4.48	-0.94	±1.24	0.53
Cr	43.25	177.85	128.85	134.40	-0.89	±33.62	83
Cu	18.10	77.45	39.05	36.85	0.81	±14.57	24
Ni	46.15	143.85	99.62	113.43	-0.41	±31.78	34
Pb	0.00	164.15	87.12	90.20	-0.36	±47.71	44
Zn	30.80	169.65	79.64	77.53	0.74	±36.64	100

Hot spots of contamination were near to cross roads, bridges, artesian and automobile repair workshops, industrial companies. Although many heavily polluting factories and plants had closed or moved out of the urban area nearly 10 years ago, historic pollution is still a serious. It is a difficult process to remediate contaminated urban soil. At the same time, the contribution of urban traffic to urban soil contamination is underestimated.

4.2 Pollution Level Assessment and Potential Ecological Risk

Results of Nemerow index (P_s) (Table 5) of study area fall in the seriously polluted domain with the soil environment quality classification of ($P_s > 3.0$), pointing to the significant of the human interference on the occurrence of heavy metals pollution in the soils of this district. Wide range of metals pollution from different industrial and commercial could release a range of heavy metals. In addition, vehicle emissions were also a major source of heavy metals in this highly urbanized area with heavy traffic [19].

Table 5: Nemerow composite pollution index (P_s) values

P_i						P_s
Cd	Cr	Cu	Ni	Pb	Zn	
22.4	1.34	0.67	1.33	6.97	1.11	16.33

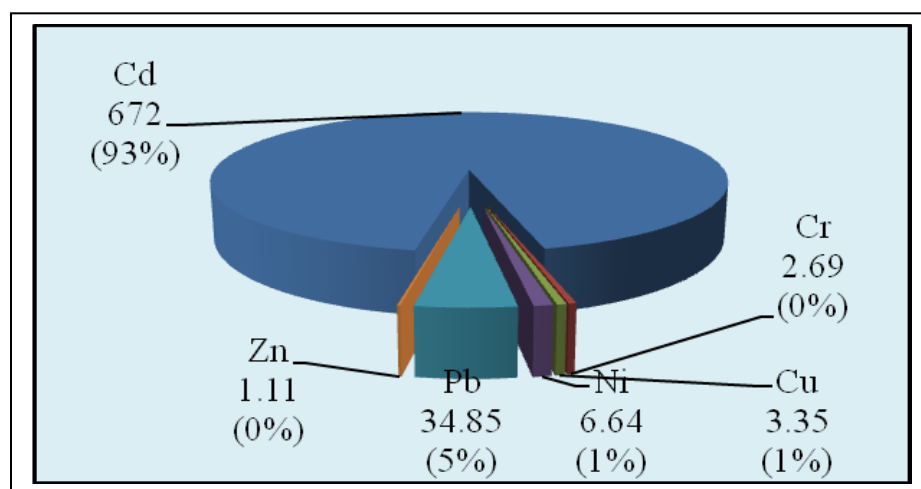
Table (6) presents the ecological risk (RI) Index. Figure (2) shows the single ecological risk factors (Er) of different heavy metals and their contributions to the comprehensive potential ecological risk (RI) of the soils. With single risk factor (Er) of 672, Cd posed the highest level of potential ecological risk, while the other heavy metals had much lower levels of risk with risk factors values of less than 35. The input of Cd into the soils of the study area is of great concern because of its high toxic-response factor. This feature (Cd) is attributed to the wear and tear of tires and the greater traffic density on the busy roads. Also cadmium can travel for long distances from the source of emission by atmospheric transport [20]. Moreover, furniture, cars, trucks, industrial tools and various kinds of fasteners including bolts, nuts, wrenches and nails have cadmium covering [21]. Also, as one of many other compositions of the explosive materials, cadmium could be released into the environment via bombs and explosive cars which recently increased in the last ten years in Baghdad city. Explosions can lead to fuel burning, wear out of tires, leakage of oils, corrosion of batteries and metallic parts such as radiators, spread and accumulation of small parts of the cars which are covered with Cd in the surrounding soils [22].

These results agree with the findings of other authors. [13] and [23] reported that significantly high potential ecological risks were recorded in their studies, which mainly were products of high Cd load in the soils.

The value of the comprehensive potential ecological risk index (RI) was 720.63 indicating an overall (highly – strong potential) posed by the heavy metals, which was the translation of the high Nemerow composite index recorded due to the various operations/activities at this district.

Table 6: Single (Er) and comprehensive (RI) potential ecological risk factors

Er						RI
Cd	Cr	Cu	Ni	Pb	Zn	
672	2.69	3.35	6.64	34.85	1.11	720.63

**Figure 2: Makeup of the potential ecological risk index**

5. Acknowledgements

We cordially thank Mrs. Athmar Al-Mashhady, Environmental Research Centre, University of Technology, Baghdad, Iraq, for her *help in carrying out the laboratory analysis*.

References

- [1] Chakraborty, R., Zaman, S., Mukhopadhyay, N., Banerjee, K., and Mitra, A. (2009). Seasonal Variation of Zn, Cu and Pb in the Estuarine Stretch of West Bengal, *Indian Journal of Marine Science*, 38(1), 104-109.
- [2] Smith, D.G. (1986). Heavy Metals in the New Zealand Aquatic Environment: A Review, Water Quality Centre, Ministry of Works and Development, Wellington, New Zealand.
- [3] Lee, C.S., Li, X., Shi, W., Cheung, S.C. and Thornton, I. (2006). Metal Contamination in Urban, Suburban, and Country Park Soils of Hong Kong: A Study Based on GIS and Multivariate Statistics, *Science of the Total Environment*, 356, 45-61.
- [4] Al Obaidy, A.H.M.J. and Al Mashhadi, A.A.M. (2013). Heavy Metal Contaminations in Urban Soil within Baghdad City, Iraq, *Journal of Environmental Protection*, 2013, 4(1), 72-82.
- [5] Davydova, S. (2005). Heavy Metals as Toxicants in Big Cities, *Microchemical Journal*, 79, 133-136.
- [6] Onder, S., Dursun, S., Geyzgin S. and Demirbas, A. (2007). Determination of Heavy Metal Pollution in Grass and Soil of City Centre Green Areas (Konya, Turkey), *Polish Journal of Environmental Studies*, 16(1), 145-154.
- [7] Jankiewicz, B. and Ptaszyński, B. (2005). Determination of Chromium in Soil of Łódź Gardens, *Polish Journal of Environmental Studies*, 14(6), 869.
- [8] Boszke, L. and Kowalski, A. (2006). Spatial Distribution of Mercury in Bottom Sediments and Soils from Poznań, Poland, *Polish Journal of Environmental Studies*, 15(2), 211.
- [9] Imevbore, A.A.A. and Adeyemi, S.A. (1981). Environmental Monitoring in Relation to Pollution and Control of Oil Pollution, Inc. Proc. Seminar on the petroleum industry and the Nigerian environment, 6, 135-142.
- [10] Al-Adili, A. S. (1998). Geotechnical Evaluation of Baghdad Soil Subsidence and Their Treatments, Thesis, University of Baghdad
- [11] Page, A.L. Miller, R.H. and Keeney, D. R. (1982). Methods of Soil Analysis, Part 2, 2nd Edition, Agron. Monogr, ASA and SSSA, Madison
- [12] Riley, J.P. and Chester, R. (1971). Introduction to Marine Chemistry, Academic Press, London, 1971
- [13] Liang, J., Chen, C., Song, X., Han, Y. and Liand, Z. (2011). Assessment of Heavy Metal Pollution in Soil and Plant from Dunhua Sewage Irrigation Area, *International Journal of Electrochemical Science*, 6, 5314-5324.
- [14] Hakanson, L. (1980). An Ecological Risk Index for Aquatic Pollution Control: A Sedimentological Approach, *Water Research*, 14, 975-1001.
- [15] Cheng, J.L., Shi, Z. and Zhu, Y.W. (2007). Assessment and Mapping of Environmental Quality in Agricultural Soils of Zhejiang Province, China, *Environmental Sciences*, 19, 50-54.
- [16] Qu, J., Yuan, V., Wang, X., Shao, P. and Cong, Q. (2004). Distribution of Heavy Metals, Chemical Fractions and Ecological Risks Around a Molybdenum Mine in Liaoning Province, China, *Vitamins and Trace Elements*, 1(3), 1-6.
- [17] Qingjie, G., Jun, D., Yunchuan, X., Qingfei, W. and Liqiang, Y. (2008). Calculating Pollution Indices by Heavy Metals in Ecological Geochemistry Assessment and A Case Study in Parks of Beijing, *Journal of China University of Geosciences*, 19(3), 230-241.
- [18] Kabata-Pendias, A. and Pendias, H. (2001). Trace Element in Soils and Plants, CRC Press, London.
- [19] Hu, J.L., Wu, F.Y, Wu, S.C., Sun, X.L., Lin, X.G. and Wong M.H. (2013). Phytoavailability and Phytovariety Codetermine the Bioaccumulation Risk of Heavy Metal from Soils, Focusing on Cd-Contaminated Vegetable Farms around the Pearl River Delta, China, *Ecotoxicology and Environmental Safety*, 91, 18-24.
- [20] WHO, (2001). Environmental Health Criteria 221. Zinc, WHO, Geneva.
- [21] Adriano, D.C. (2001). Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability and Risks of Metals, 2nd Edition.
- [22] Dolan, L.M.J., Van Bohemen, H., Whelan, P., Akbar, K.F., Malley, V.O., Leary, G.O. and Keizer, P.J. (2006). Towards the Sustainable Development of Modern Road Ecosystem, In *The Ecology of Transportation: Managing Mobility for the Environment*, J. Davenport and J. L. Davenport, Eds., 275-331, Springer.
- [23] Qiu, H. (2010). Studies on the Potential Risk and Homology Correlation of Heavy Metal in the Surface Soil, *Agricultural Science*, 2(2), 194-201.