Ecological Risk Assessment of Ground Water Quality of Two Industrial Zones of Karachi, Pakistan

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

Original Research Article

ABSTRACT

The purpose of this research study is to determine the quality of groundwater in and around the two industrial zones of Karachi such as SITE (Sindh industrial and trading estate) and KITE (Korangi industrial and trading estate) by using EIRA (Environmental Impact and Risk Assessment) method. The environmental researchers find this method easy enough to use for risk assessment and environmental impact. It has estimated the risk and impact associated with measured concentrations of ecological indicators for environmental components examined as a representative in assessment process. There are several mathematical steps being applied in this method. Out of 32 sampling points (18 each) of groundwater analysis, six ecological indicators examined representative for evaluative purpose were assessed. The results of the study indicated that the groundwater quality of both the industrial zones had high pollutant and contaminated due to industrial activities. Therefore, it is certain to implement the plan for remediation to uplift the quality of groundwater and overcome the pollution.

Keywords: Groundwater; Karachi City; industrial zones; effluent; EIRA.

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1. INTRODUCTION

Rapidly growing demand for water and shrinking freshwater resources, especially, in developing countries like Pakistan, the application of marginal quality groundwater has posed a serious threat to environmental management.

The groundwater state is usually more stable than surface water and is more preserved against the risk-factors involved such as water contamination than the surface water. However, there are certainly many risks in terms of its quantity and quality facing underground water resources as a result of adverse human activities, for instance, release of chemical wastes from industrial sectors etc. [1-4].

Numbers of reports of groundwater contamination due to industrial effluent penetrations have been reported Worldwide [5-9].

The industrial effluents are discharged indiscriminately in large number of mega cities of developing countries into the soil and water bodies being indifferent to aftermath adverse impact in future; Karachi is not exceptional to this [10].

One of the most populous and largest city, situated in the south of Pakistan on Arabian Sea's coast is Karachi having 24°51ˈN 67°02ˈE geographical view. As of 2013, it has an estimated population of over 23.5 million people, having an area of 3,527 km^2 approx, resulting in a density of 6000 people per square kilometer. Population within city limit it is the 3rd largest city in the World [11-13].

Karachi is the financial hub and provincial capital of Pakistan generating more than 70% revenue and housing more than 70% of the diverse industries. Multinationals also prefer to locate their industries in Karachi for its deep water seaport and cheap, economical labor in abundance.

Both regulated and unregulated industrial sectors are operating in the city. Most prominently, the largest industrial zones include Korangi Industrial Trading Estate (KITE) and Sindh Industrial Trading Estate (SITE) which have attracted investment from across the country and employed diversified labor force flocked from every corner of Pakistan.
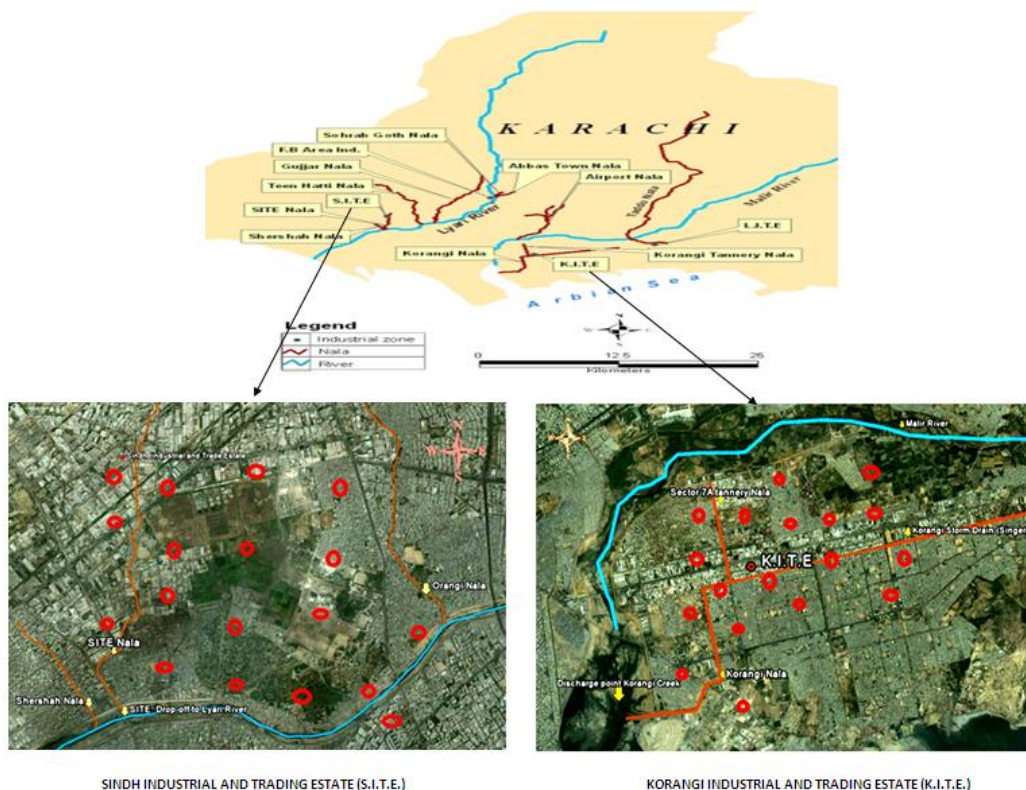

Fig. 1.1. Location map and sampling points

Contamination scenario, due to metal ion pollution of Karachi, is quoted as a problem by the earlier researchers [14-16]. However, a major information gap is noted with respect to ecological risk assessment of groundwater of the city. Ecological risk assessment is considered as a technique to govern ecological issues [17-23]. It is the technique that assays the likelihood that adverse ecological effects are taking place, or may occur, due to exposure to one or more stressor. It has been used broadly to interface environmental stressors and their ecological consequences. Risk assessment employed to ecological problem in modernistic [17,24-26]. Risk assessment could be a useful technique and should be used largely in solving ecological issues.

The outcome of this research study is to furnish an overview of the dormant risks of the shallow groundwater resources of both the industrial zones i.e. SITE and KITE. On the basis of this case study, it is envisaged to create a model of potential risks for groundwater and water supply at this aquifer.

1.1 Location Map

Fig. 1.1 shows the location map of the study areas.

2. MATERIALS AND METHODS

2.1 Sampling

All glassware used was NPLA grade and were appropriate certified. Eighteen (18) representative samples of groundwater of each industrial estate were collected during the examining period in sterile 1500 ml polyethylene bottles, the water quality has been analyzed for transition metals such as (Fe, Zn, Cu, Pb, Cr and Ni). In trace metal analysis 50 ml sample was taken and added 5 ml HNO_3 for digestion. The digested samples were filtered and de-ionized water was used to make the volume up to 50 ml after filtration. Then samples were analyzed on Atomic Absorption Spectrophotometer by using appropriate lamp. Standard solutions of known strength were used for calibrating the instrument first for each heavy metal [27].

Process of dilution was necessary in certain cases where concentration of determinants was exceeded to recommend limit for the method employed for the determination. An Accuracy check for chief ions was accomplished for a

considerable interpretation, accuracy and precision of water quality parameters.

2.2 Environmental Impact and Risk Assessment

The method employed herein is an integrated method, which is a combination of significant scale matrix and global pollution index [19,28-30]. The calculation of EIRA (Environmental Impact and Risk Assessment) and significant scale matrix based on method proposed by Robu [28], considering groundwater only in the assessment.

The IM (Impact on environmental component) is the ratio between IU (significant unit) and Q (quality of environmental component), shown in equation 1.

$$IM = IU/Q \tag{1}$$

The Q (quality of environmental component) can be calculated as equation 2.

$$Q = MAC/MC \tag{2}$$

Here;

MAC = Permissible limit of quality indicator
MC = Measured concentration of quality indicator

If Q value is zero, it shows very poor environmental quality (High contamination); if Q value is equal and higher than 1, then the quality of environmental component is very good [31].

IM_{gw} (Impact on groundwater) can be calculated as

$$IM_{gw} = \sum I_{(gw)i} / n \tag{3}$$

Here;

IM_{gw} = Environmental impact on groundwater due to ecological indicator (i)
i = Ecological indicators (e.g Fe, Co etc)
n = Total number of ecological indicator

$$IM_{gw} = IUgw/Q_{(gw)I} \tag{4}$$

Here;

$Q_{(gw)i}$ = Quality of groundwater due to quality indicator i
IU_{gw} = Significant units obtained by groundwater

The environmental risks are calculated as

$$RM = IM. P \qquad (5)$$

Here;

P = Probability of impact.

The probability was calculated by using the same matrix proposed by Robu [28].

3. RESULTS AND DISCUSSION

The purpose of this research work is to establish groundwater quality of study area by using EIRA technique. Groundwater from 36 sampling point was analyzed for six heavy metals during study period and data obtained, presented in Tables 1.2 and 1.4 and graphically showed in Figs. 1.2 and 1.3, were subjected to EIRA technique.

In SITE the Environmental Impact (IM) values ranges from 161.43 to 7198.2 and Environmental Risk (RM) values ranges from 161.08 to 7176.62 (Tables 1.2 and 1.3), while in KITE the IM values ranges from 315.09 to 1125.8 and RM values ranges from 314.15 to 1122.4 (Tables 1.4 and 1.5). High values for IM and RM underlay the presence of pollutants in environment in very high concentration, because impact directly depends upon the measured concentration of pollutants. In this connection, The higher values of IM and RM of SITE show that the groundwater of this industrial estate is moderately polluted as compare to KITE in term of ecological indicator i.e heavy metal. The higher values for impact and risk induced in groundwater from both study areas showed the industrial activity from these areas was working at its maximum capacity.

Table 1.1. Impact and risk scale [32]

| Range	Description		Action
	Impact	Risk	
100-500	Influence of industrial activities	Moderate risk	Monitoring and prevention measures are required
500-1000	Influence of industrial activities, life forms are in danger	Major risk	Remediation and control are required
Higher than 1000	Highly polluted environment	High risk	All activities must be stopped

Table 1.2. Risk assessment of S.I.T.E. industrial and trading estate

	Concentration mg/l (Ci)							
Sample stations	Fe	Zn	Cu	Pb	Cr	Ni	Mean IM	Mean RM
GW_1	0.089	0.098	0.01	0.004	0.01	0.002	171.79	171.27
GW_2	0.332	0.854	0.019	0.005	0.014	0.008	429.42	428.13
GW_3	0.889	2.079	0.024	0.005	0.016	0.013	854.07	851.51
GW_4	0.129	0.476	0.035	0.001	0.009	0.009	221.9	219.57
GW_5	11.935	1.364	0.018	0.024	0.014	0.004	7198.2	7176.62
GW_6	0.078	0.312	0.016	0.002	0.010	0.004	161.43	161.08
GW_7	0.049	0.029	0.018	0.001	0.079	0.002	325.8	324.8
GW_8	0.080	0.033	0.009	0.001	0.191	0.003	722.27	720.11
GW_9	0.032	0.048	0.001	0.001	0.017	0.003	710.64	708.49
GW_{10}	0.058	0.081	0.008	0.004	0.178	0.004	727.9	725.75
GW_{11}	0.292	2.193	0.02	0.034	0.063	0.009	1133.58	1130.13
GW_{12}	0.202	0.045	0.007	0.019	0.016	0.007	541.92	540.28
GW_{13}	0.310	0.529	0.034	0.053	0.014	0.014	1245.2	1241.48
GW_{14}	4.334	1.292	0.044	0.22	0.008	0.007	6257.5	6238.73
GW_{15}	1.76	0.081	0.022	0.086	0.008	0.007	2499.68	2492.18
GW_{16}	0.286	0.174	0.031	0.044	0.018	0.007	1020	1017
GW_{17}	0.182	4.626	0.041	0.30	0.007	0.008	5482.88	5466.5
GW_{18}	0.346	0.065	0.020	0.33	0.008	0.02	5834.13	5816.62
*WHO (MAC)i	0.3	3	2	0.01	0.05	0.02		

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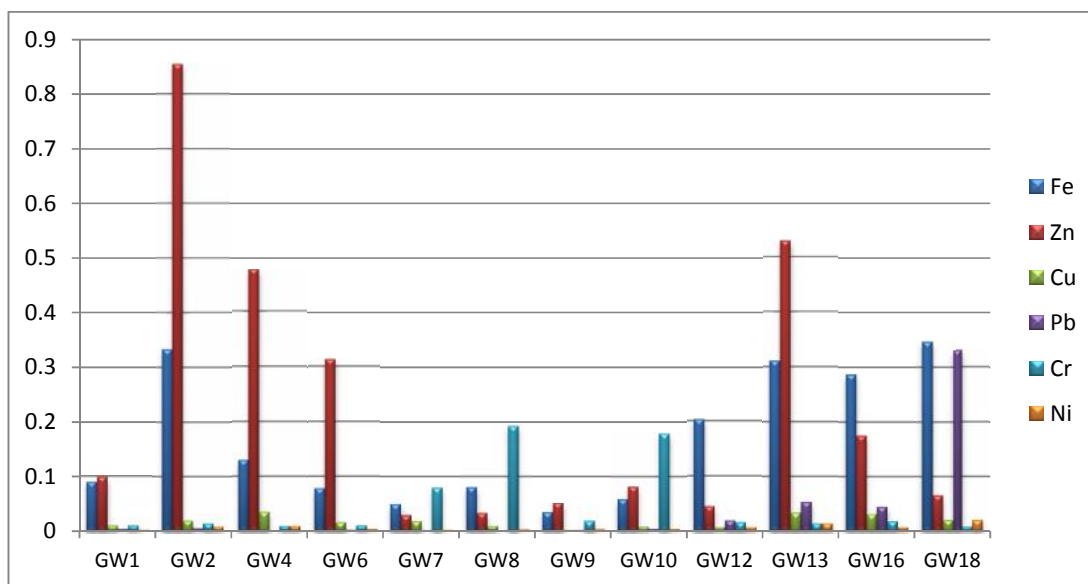
Fig. 1.2. Heavy metals concentration (SITE)
Sample No. 5, 14&15 having high Fe Concentration was not including in the graph, similarly sampling point 3,11& 17 having high concentration for Zn. Therefore, these points were excluded from the graph to make the graph presentable
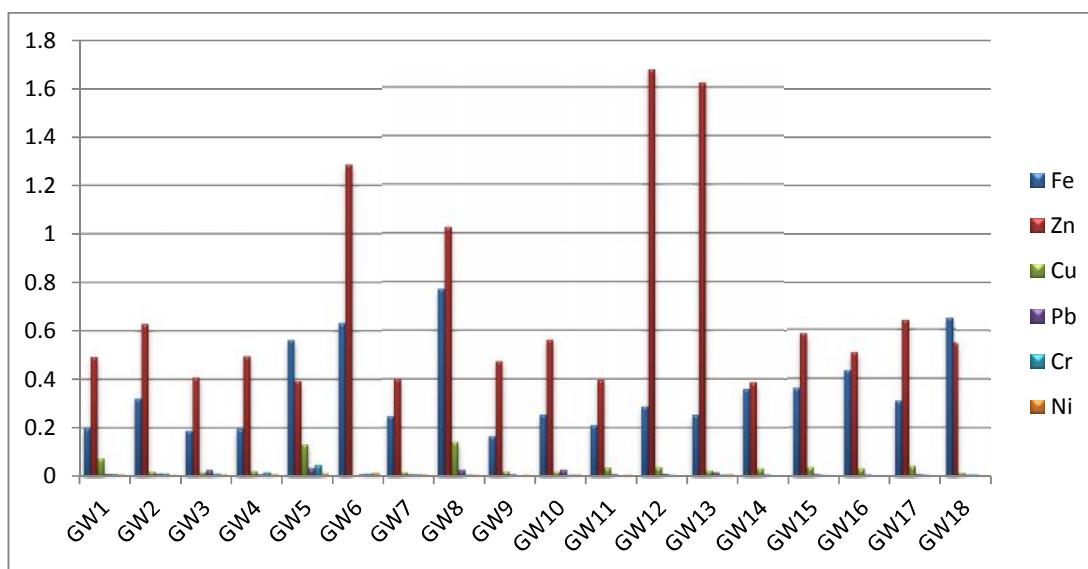
Fig. 1.3. Heavy metals concentration (KITE)

Table 1.3. Calculation of IM and RM for groundwater sample GW_1 of SITE

Parameters	MAC	Cm	Q	IM	RM	Mean IM	Mean RM
Fe	0.3	0.089	3.37	295.69	294.8		
Zn	3	0.098	20.61	32.55	32.45		
Cu	2	0.01	200	4.98	4.96	171.79	171.27
Pb	0.01	0.004	2.5	398.59	397.39		
Cr	0.05	0.01	5	199.29	198.69		
Ni	0.02	0.002	10	99.65	99.35		

Table 1.4. Risk assessment of Korangi industrial and trading estate

Sample stations	Concentration mg/l (Ci)						Mean IM	Mean RM
	Fe	Zn	Cu	Pb	Cr	Ni		
GW_1	0.199	0.492	0.073	0.009	0.009	0.007	380.9	379.8
GW_2	0.320	0.628	0.019	0.01	0.011	0.005	446.29	444.95
GW_3	0.187	0.407	0.016	0.026	0.011	0.007	652.7	650.8
GW_4	0.196	0.495	0.021	0.008	0.015	0.008	383.47	382.33
GW_5	0.562	0.392	0.131	0.033	0.046	0.011	1125.8	1122.4
GW_6	0.631	1.285	0.0006	0.008	0.011	0.013	698.2	696.1
GW_7	0.246	0.399	0.015	0.008	0.008	0.007	377.14	376
GW_8	0.77	1.023	0.141	0.026	0.007	0.006	989.24	996.8
GW_9	0.165	0.473	0.019	0.008	0.004	0.006	315.09	314.15
GW_{10}	0.253	0.561	0.018	0.027	0.006	0.007	699.5	697.41
GW_{11}	0.209	0.396	0.035	0.008	0.004	0.006	336.54	325.03
GW_{12}	0.286	1.672	0.037	0.009	0.006	0.004	456.6	455.2
GW_{13}	0.253	1.617	0.023	0.015	0.007	0.008	570.5	568.8
GW_{14}	0.358	0.385	0.032	0.007	0.004	0.002	368.35	367.24
GW_{15}	0.361	0.583	0.038	0.008	0.005	0.004	417.8	416.6
GW_{16}	0.433	0.506	0.031	0.007	0.004	0.003	424.7	423.46
GW_{17}	0.308	0.638	0.043	0.008	0.006	0.003	387	385.9
GW_{18}	0.647	0.546	0.013	0.007	0.007	0.004	562	560
*WHO (MAC)i	0.3	3	2	0.01	0.05	0.02		

Table 1.5. Calculation of IM and RM for groundwater sample GW_1 of KITE

Parameters	MAC	Cm	Q	IM	RM	Mean IM	Mean RM
Fe	0.3	0.199	1.508	660.79	658.81		
Zn	3	0.492	6.098	163.41	162.92		
Cu	2	0.073	27.397	36.37	36.26	380.9	379.8
Pb	0.01	0.009	1.111	896.92	894.23		
Cr	0.05	0.009	5.555	179.38	178.84		
Ni	0.02	0.007	2.857	348.78	347.73		

In addition, six heavy metals namely; Fe, Zn, Pb, Cu, Cr and Ni in ground water samples from shallow aquifer in and around Industrial areas were analysed and found to have anomalously high concentration of Fe 1.187 mg/l (0.032-11.93), Zn 0.798 mg/l (0.029-4.626), Cu 0.02 mg/l (0.001-0.044), Pb 0.063 mg/l (0.001-0.33), Cr 0.037 mg/l (0.007-0.191), Ni 0.007 (0.002-0.02) in SITE and Fe 0.354 mg/l (0.165-0.77), Zn 0.694 mg/l (0.385-1.672), Cu 0.039 mg/l (0.0006-0.141), Pb 0.0129 mg/l (0.007-0.033), Cr 0.009 mg/l (0.004-0.046), Ni 0.006 (0.002-0.013) in KITE as compare to the reported by Alvi, et al., 2006 and Mahmood, et al., 1998. The majority samples collected from the SITE area showed higher concentration of Fe, Pb and Cr than permissible limit (Threshold value of WHO), whereas the concentration of Fe and Pb were found significantly higher than WHO permissible limit in KITE area, probable due to:

- The concentration of Fe is particularly high in both the industrial estates. May be due to geological origin as well as number of industries such as steel industry, rusting of iron scraps and corrosion of iron containing metals are responsible for the same.
- The higher value of Pb may be attributed as fuel additive and also present in coal which is used as fuel in industries.
- Significant higher value of Cr is found in the samples which were near to the leather tanneries.

It can be accomplished with the help of experimental result that the ground water of the study areas is moderatly polluted due to the presence of heavy metals.

4. CONCLUSION

The data obtained from both the study areas were subjected EIRA technique. According to experimental result the ground water of SITE moderately polluted as compared to heavy

metals observed in KITE, which acts as ecological indicators. These ecological indicators may cause disastrous effects upon public health and environment if consumed directly without any treatment and recommended that possible solution for remedy is combined effluent treatment plant. It is further concluded that to reduce the health risk and the extent of heavy metal contamination, steps must be taken for effluent treatment of industrial effluent. Regular monitoring of heavy metal in and around industrial estates is also necessary.

This study further demonstrates the application of EIRA technique in assessing the ecological risk assessment of the groundwater and also to provide preliminary assessment of the groundwater quality that will serve as a database for future investigations and monitoring of groundwater quality in the study zones.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Akinbile CO, Yusuf MS. Environmental impact of leachate pollution on groundwater supplies in Akure, Nigeria. International Journal of Environmental Science and Development. 2011;2(1):81-89.
2. Nasrullah NR, Bibi H, Iqbal M, Durrani MI. Pollution loads in industrial effluent and groundwater of Gadoon Amazai Industrial Estate (GAIE) Swabi, NWFP. Journal of Agriculture and Biological Science. 2006;1:18-24.
3. Yousuf I, Sultan A, Shomaila S, Ishaq M, Nisar A. Investigation of pollution in the industrial effluent. Journal of the Chemical Society of Pakistan. 2000;22(4):239-244.
4. Ravinder G, Ch Ravinder RK Viyaya. Ground water pollution due to dumping of Municipal Solid Water at Warangal. Indian Journal of Environment Protection. 2005;25(6):523-526.
5. Siddiqui WA, Sharma RR. Assessment of the impact of industrial effluents on groundwater quality in Okhla industrial area, New Delhi, India.E-journal of chemistry. 2009;6(S1):S41-S46. Available:http://dx.doi.org/10.1155/2009/525707

6. Madhavi A, Prasad R. Effect of industrial effluent on properties of groundwater. Journal of Environmental Biology. 2003;24(2):187-192.
7. Nubi OA, Ajuonu N. Impacts of industrial effluent and Dumpsite leachate discharges on the quality of groundwater in Oyo state, Nigeria. Journal of Biodiversity and Environmental Sciences (JBES). 2011; 1(3):13-18.
8. Kumar DS, Kumar PS, Gopalakrishnan P. Ground water quality assessment in paper mill effluent irrigated area - using multivariate statistical analysis. World Applied Sciences Journal. 2011;13(4):829-836.
9. Shakeri A, Moore F, Mohammadi Z, Raeisi E. Heavy metal contamination in the shiraz industrial complex zone groundwater, South Shiraz, Iran. World Applied Sciences Journal. 2009;7(4):522-530.
10. WWF. Pakistan's waters at risk, Water and health related issues in Pakistan and key recommendations, A special report, WWF-Pakistan, Ferozepur Road, Lahore-54600, Pakistan. 2007;1-33.
11. Khattak MI, Khattak IM. Ground water analysis of Karachi with reference to adverse effect on human health and its comparison with other cities of Pakistan. Journal of Environmental Science and Water Resources. 2013;2(11):410–418.
12. CDGK. Geography and demography of Karachi City District Government Karachi; 2011.
13. Rahman A, Lee K, Khan A. Domestic water contamination in rapidly growing mega cities of Asia: A case of Karachi, Pakistan. Environmental Monitoring and Assessment. 1997;44:339-360. DOI: 10.1023/A:1005747732104
14. Haq N, Arain MA, Haque Z, Badar N, Mughal N. Drinking water contamination by Chromium and Lead in Industrial Lands of Karachi. Journal of Pakistan Medical Association. 2009;59:270-274.
15. Alvi SK, Khan FA, Siddiqui I, Asghar U, Usmani TH. Trace metals contamination in groundwater of SITE area Karachi. Journal of the Chemical Society of Pakistan. 2006;28(3):223-229.
16. Mahmood SN, Naeem S, Siddiqui I, Khan FA. Metal contamination in groundwater of Korangi Industrial area, Karachi. Journal of the Chemical Society of Pakistan. 1998;20(2):125-131.

17. Barnthouse LW, Wayne R, Munns Jr, Sorensen MT. Population-level ecological risk assessment. Taylor and Francis Group, NewYork. 2008;337.

18. Suter II GW. Ecological risk assessment. 2nd edn., CRC Press, New York; 2007.

19. Macoveanu M. Methods and techniques for environmental impact assessment. 2nd Edition. Eco-Zone Press, Iasi; 2005.

20. Horaicu C. The integrated monitoring of the environment, (in Romanian). Tipo Moldova Publishing House, Iaşi, Romania; 2004.

21. Varduca A. Integrated monitoring of water quality, (in Romanian), H.G.A. Publishing House, Bucharest, Romania; 1999.

22. EPA. Guidelines for ecological risk assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC. EPA/630/R095/002F; 1998.

23. Rojanschi V. Global assessment possibilities of pollution impact on ecosystems quality, Environment. 1991;2: 1-2.

24. Jafari J, Nematullah K, Afshin D. Ecological risk assessment of lead (Pb) after waste disposal from metallurgical industries. Research Journal of Environmental and Earth Sciences. 2010;2(3):139-145.

25. Robu B, Bulgariu L, Bulgariu D, Macoveanu M. Quantification of impact and risk induced in surface water by heavy metals: Case Study – Bahlui River Iasi. Environmental Engineering and Management Journal. 2008;7:263-267.

26. Horaicu C, Florea GC, Robu B. The management of environmental risk in the extractive industry. (in Romanian), Tipo Moldova Publishing House, Iaşi, Romania; 2007.

27. APHA. Standard methods for the examination of water and waste water. American Public Health Association, Washington DC. 21st edn; 2005.

28. Robu B. Environmental impact and risk assessment for industrial activities, (in Romanian). Eco-Zone Publishing House, Iaşi, Romania; 2005.

29. Gavrilescu M. Risk assessment and management, Eco-zone Press, Iasi, Romania; 2003.

30. Carlig E, Brindusa R, Matei M. Quantification of environmental impact and risk induced by industrial activities on groundwater quality: Case study Cordun - Roman area, Romania. Environmental Engineering and Management Journal. 2008;7:791-804.

31. Goyal SK, Deshpande VA. Comparison of weight assignment procedures in evaluation of environmental impacts. Environmental Impact Assessment Review. 2001;21:553-563.
DOI: 10.1016/S0195-9255(01)00086-5

32. Pearce F. Rivers of doubt. New Scientist, London, UK; 1999.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/12916