Assessment of the effects of municipal wastewater on the heavy metal pollution of water and sediment in Arak Mighan Lake, Iran

Feridon Ghadimi[1,*], Mohammad Ghomi[1]

1- Department of Mining Engineering, Arak University of Technology.

* Corresponding Author: drghadimi@yahoo.com

Received: 23 September 2013 / Accepted: 11 November 2013 / Published online: 15 November 2013

Abstract

Heavy metal concentrations in surface water, wastewater and sediments collected from Mighan Lake in Markazi province, Iran were analyzed, and assessment contamination were evaluated according to the water and sediment quality guidelines. The results showed that the average concentrations of heavy metals in water were ranked as: Ni> Cr> Pb> Fe> Cu> Zn. In comparison with results the background values, the Mighan Lake was polluted by Ni, Cr, Pb and Fe, Most of metals might be mainly from industrial effluent and wastewater around the lake. In the sediments in the Mighan Lake, Fe, Ni, Pb and Cr showed a decreasing trend while Cu and Zn present an increasing trend. The increase of Cu and Zn might due to industrial activity around of Mighan Lake. The analysis of assessment contamination based on quality guidelines suggested that heavy metals in most water and sediments from the Mighan Lake had high toxicity, with Ni, Cr and Pb in water and moderate toxicity, with Zn and Cu in sediment being the highest priority pollutant.

Keywords: Assessment contamination, Heavy metal, Sediment, Mighan Lake, Wastewater.

1–Introduction

Lakes are considered one of the most versatile ecosystems in the world, but they are more sensitive to environmental pollution and anthropogenic impacts (Forghani *et al*., 2009). Heavy metals, such as arsenic (As), mercury (Hg), cadmium (Cd), lead (Pb), and chromium (Cr), are commonly detected in lakes (Anshumali–Ramanathan *et al*., 2009; Ongeri *et al*., 2009). Like other aquatic systems, heavy metals enter lakes through natural sources (e.g. weathering, erosion) and anthropogenic sources (e.g. mining, urban and industrial wastewater) (Zorer *et al*., 2008; Alhas *et al*., 2009; Nasehi *et al*., 2013; Ghomi *et al*., 2013). At present, heavy metal pollution has become a great environmental concern with their toxicity in the food chain (Li *et al*., 2008; Yuan *et al*., 2011; Sarfo *et al*., 2013). Thus, heavy metals in lakes might ultimately have adverse biologic effects on human health through drinking water and consuming aquatic products (Huang *et al*., 2009; Zhang *et al*., 2009). For these reasons, it would be desirable and imperative to investigate their distribution in lakes, which can provide valuable information of heavy metal pollution and help evaluate potential environmental risks (Bu–Olayan and Thomas, 2013; Kapungwe, 2013). Mighan Lake is the largest natural saline lake in Markazi province. The lake covers an area of 110 km2, with an average water depth of 1.5 m. It is mainly used for animals and birds. With rapid development of the local economy large amounts of wastewater from industrial, domestic and agricultural sources from Arak city in Markazi province, Iran was discharged into the lake. As a result, water environment in the Mighan Lake has deteriorated in terms of heavy metal pollution (Bolhasani *et al*., 2010). A number of recent studies have discussed the distribution and sources of heavy metals in various aquatic systems (Yao *et al*., 2009; Kurun *et al*., 2010; Botsou *et al*., 2011). The aims of this study were to: 1) investigate the contamination levels and distributions of heavy metals in surface water, wastewater and surface sediment from the Mighan Lake; 2) compare their concentrations with quality standard; 3) evaluate the contamination of the metal concentrations based on sediment quality guidelines and 4) assessment of contamination source.

2– Materials and method

2.1–Sample collection

In Jun 2012, 13 water samples at 0.5 m below the surface water and wastewater close to the Mighan Lake were collected at sampling locations shown in Figure 1. All of these water samples were obtained using cleaned polyethylene bottles, which were washed with hydrochloric acid and then rinsed with distilled water. Subsequently, water samples were filtered through 0.45 μm millipore filters, acidified to pH<2 with 2 mL 6 N HCl and transported to the laboratory for analysis. During the sample collection, a global positioning system (GPS) was used to locate the sites. A sediment sample for metal analysis was recovered at the central part of the Mighan Lake using a static gravity corer. Total 6 sediment samples were obtained from the sampling site. All the samples were then placed into sealed polyethylene bags and transported to the laboratory for storage at –20°C until analysis. In the laboratory, samples were air–dried at room temperature and sieved through a 100–mesh sieve. For heavy metal analysis, 0.1 g of dry sample was digested using 10 mL HCl–HNO_3–HF. The solution was finally diluted to 25 mL with deionized distilled water.

2.2– Sample analysis

Concentrations of Pb, Cd, Ni, Cr, Cu and Zn in all samples were determined using an inductively coupled plasma mass spectrometry (ICP–MS). For quality control, procedural blanks and duplicates were run for 6 samples. The standard deviations were below 10% for all elements. The detection limit for individualmetals was 0.5 to 5 ng/L for a water sample and 0.005 to1 μg/g for a sediment sample.

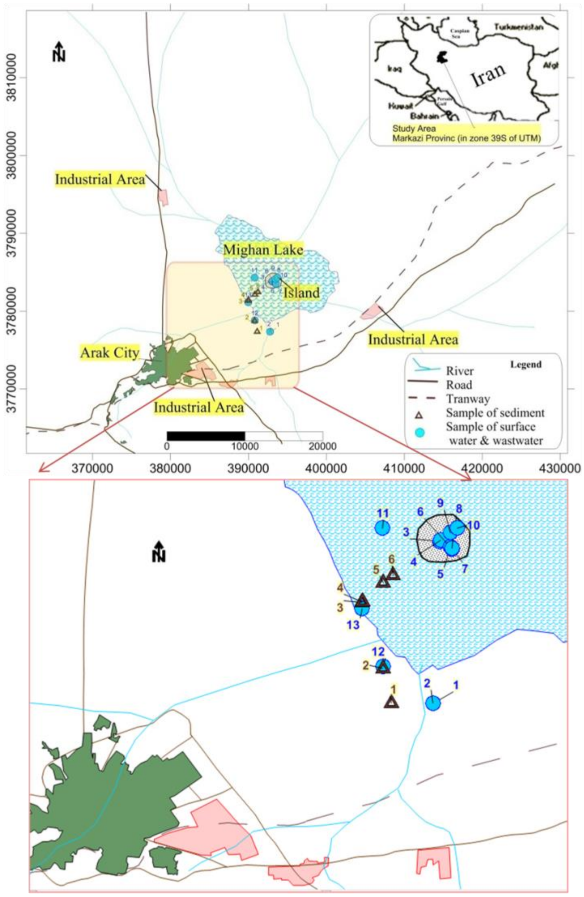

Figure 1) Location map of Mighan Lake and sampling sites of surface water, wastewater and sediment.

2.3–Geoaccumulation index (Igeo)

The geoaccumulation index allows estimation of contamination comparing premining and recent element concentrations. The geoaccumulation index is computed from the following Equation:

$$Igeo = Log_2\left(\frac{C_n}{1.5B_n}\right) \qquad \text{Eq. 1}$$

In the present work, geoaccumulation index was computed from the equation modified by Loska *et al*. (2004), where C_n is the measured concentration of the element in the surface water and wastewater samples and B_n is thepermissible limit of WHO standard (Ogundiran and Afolabi, 2008). Müller divided the geoaccumulation index into seven classes. They are as follows (Müller, 1969):

- Igeo≤ 0: practically uncontaminated
- 0< Igeo< 1: uncontaminated to moderately contaminated
- 1< Igeo< 2: moderately contaminated
- 2<Igeo<3: moderately to heavily contaminated
- 3< Igeo< 4: heavily contaminated
- 4<Igeo<5: heavily to extremely contaminated
- 5≤ Igeo: extremely contaminated

2.4–Contamination degree

The quality of water surface and wastewater can be assessed with the use or calculation of environmental factors and indices, which include a wide range of parameters. Such factors may become valuable tool for the assessment of environmental condition of an area. According to Backman *et al*. (1998), contamination index (Cd) may be considered as such if the measured concentration of parameters and the upper permissible levels of a contaminant are taken into account. According to Backman *et al*. (1998), contamination index is defined as Eq. 2 and Eq. 3:

$$C_d = \sum C_f \qquad \text{Eq. 2}$$

$$C_f = \frac{CA}{CN} \qquad \text{Eq. 3}$$

Where C_d is contamination degree; C_f is contamination factor, CA is analytical value of the component and CN is upper permissible concentration of the component according to WHO (2011). Hakanson (1980) suggested four classes of C_f to evaluate the metal contamination levels as follows (Loska *et al*., 2004): low (C_f<1), moderate (1≤C_f<3), considerable (3≤C_f<6), and very high (6≤C_f) contamination. The degree of contamination (C_d) is the sum of contamination factors for all of the elements. Contamination degree (C_d) is calculated individually for each water sample, as a sum of the contaminant factors of single component that exceed the maximum contaminant levels (Ramos *et al*., 2004). Hence, contamination degree summarized the combinational effects of several quality parameters that may have harmful consequences to health/the environment. The value scale for contamination degree consists of 4 ranges as (Edet and Offiong, 2002):

- C_d< n: low degree of contamination
- *n*<C_d<2*n*: moderate degree of contamination
- 2*n*< C_d< 3*n*: high degree of contamination
- C_d> 3*n*: very high degree of contamination

Where n is the number of contaminants involved in the C_d determination**.**

2.5–Statistical analysis

To identify relationship among metal data in surface water and wastewater and their possible sources, cluster analysis (CA) were performed using statistics software package

Statistica Version 8 for windows. CA is the most common multivariate statistical methods used in environmental studies (Lambrakis *et al*., 2004; Liu *et al*., 2003; Love *et al*., 2004). CA classifies a set of observations into two or more mutually exclusive unknown groups based on combination of internal variables. CA often group individual parameters and variables (Colby, 1993). The purpose of CA is to discover a system of organizing observations where a number of groups/variables share observed properties. A dendogram is the most commonly used method of summarizing hierarchical clustering. In the current study, CA was used to evaluate the sources similarities metal data in water and sediments.

3–Results and discussion

3.1–Characterization of surface water and wastewater

3.1.1–Hydrochemical data

The level of the detected constituents in water and wastewater samples (Table 1 and Fig. 2) shows that in all the sampling locations, Zn and Cu are low relative to the WHO standard limit. Cr, Pb, Ni and Fe were found to be above the maximum permissible limit of standard in all locations.

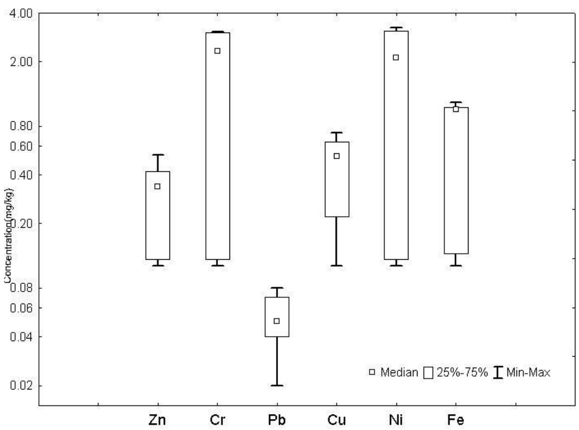

Figure 2) Concentrations for constituents in surface water and wastewater samples in Mighan Lake.

Table 1) Heavy metal data of surface water and wastewater samples (concentration is mg/kg).

Sample No.	Zn	Cr	Pb	Cu	Ni	Fe
1	0.11	0.11	0.02	0.11	0.12	0.11
2	0.11	0.12	0.07	0.12	0.11	0.12
3	0.21	3.02	0.05	0.73	3.21	1.12
4	0.53	3.01	0.06	0.71	3.23	1.02
5	0.42	3.04	0.04	0.61	2.21	1.01
6	0.51	3.03	0.03	0.64	3.11	1.04
7	0.42	3.01	0.05	0.62	3.21	1.05
8	0.42	2.56	0.07	0.72	3.05	1.01
9	0.34	2.23	0.08	0.52	2.06	1.03
10	0.43	2.33	0.08	0.41	2.11	1.11
11	0.12	0.11	0.06	0.22	0.11	0.13
12	0.13	0.12	0.05	0.11	0.12	0.12
13	0.11	0.96	0.04	0.23	1.11	1.01
Max.	0.53	3.04	0.08	0.73	3.23	1.12
Min.	0.11	0.11	0.02	0.11	0.11	0.11
Mean	0.30	1.82	0.05	0.44	1.83	0.76
Reference Value*	3	0.05	0.01	2	0.02	0.3

Figure 2 and Table 1 present the statistics of elemental constituents in water and wastewater of the study area. The result shows that the mean concentration of the examined parameters Zn, Cr, Pb, Cu, Ni and Fe included 0.03, 1.82, 0.05, 0.44, 1.83 and 0.76 mg/kg respectively. Among the examined heavy metal constituents Cr, Pb, Ni and Fe have the highest mean while Zn and Cu remained the least. Further, the World Health Organization (WHO) standard limit for drinking water quality adopted to adjudge the suitability of surface water and waste water for drinking in the study area showed that only the parameters examined of Cr, Pb, Ni and Fe was found to be above the maximum permissible limit for drinking water standard. High Cr, Pb, Ni level noticed in water samples is characteristic of water in the around the industrial area which is due to the local wastewater treatment plant.

3.1.2–Geoaccumulation index (Igeo)

Contamination assessment showed that geoaccumulation index of Zn and Cu in all locations is practically uncontaminated (Fig. 3).

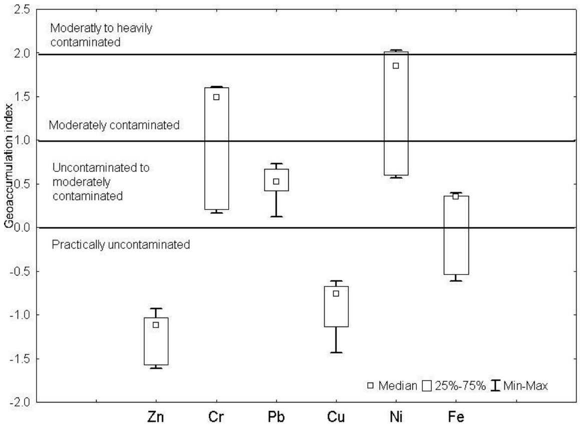

Figure 3) Geoaccumulation index for constituents in surface water and wastewater samples in Mighan Lake.

The mean concentration of Pb and Fe change from uncontaminated to moderately contaminated but Cr and Ni depict moderately contaminated. Based on Figure 3, the geoaccumulation index of Cr and Ni changes from uncontaminate to moderately contaminate in some of samples. Therefore, it is possible, there are three sources: Zn and Cu are of natural source; Pb and Fe are of natural and anthropogenic; Cr and Ni are of anthropogenic origin.

3.1.3–Contamination degree

The following terminology is adopted to describe the contamination degree (C_d values) for seven substances indicating serious anthropogenic pollution:

- $C_d < 6$: low degree of contamination
- $6 \leq C_d < 12$: moderate degree of contamination
- $12 \leq C_d < 18$: high degree of contamination
- $C_d \geq 18$: very high degree of contamination

The computed contamination factor (Fig. 4 and Table 2) for the sampling shows that samples are very high contamination of Cr and Ni and are considerable contamination of Pb and Fe while, are low contamination of Zn and Cu.

Based on Cd values calculated for six elements (Zn, Cr, Pb, Cu, Ni and Fe) (Table 2), Mighan Lake generally presents contamination varying from a moderate degree of contamination to very high degree of contamination; the very high and high degree of contamination belong to the most of samples in the surface water lake and wastewater of Arak city. In the study area, pollution can be related to wastewater of industrial activities.

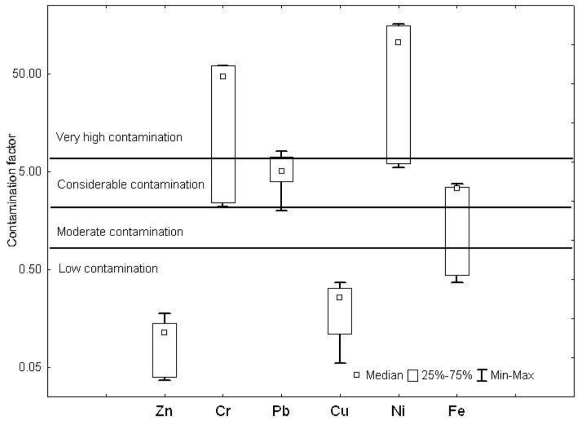

Figure 4) Contamination factor for constituents in surface water and wastewater samples in Mighan Lake.

Table2) Contamination factors (C_f) and contamination index (C_d) in surface water and wastewater samples in Mighan Lake.

Sampling No.	C_f						C_d	Contamination degree
	Zn	Cr	Pb	Cu	Ni	Fe		
1	0.04	2.2	2	0.05	6	0.36	10	Moderate
2	0.04	2.4	7	0.06	5.5	0.40	15	High
3	0.07	60.4	5	0.36	160	3.73	230	Very high
4	0.17	60.2	6	0.35	161	3.40	231	Very high
5	0.14	60.8	4	0.30	110	3.36	179	Very high
6	0.17	60.6	3	0.32	155	3.46	223	Very high
7	0.14	60.2	5	0.31	160	3.50	229	Very high
8	0.14	51.2	7	0.36	152	3.36	214	Very high
9	0.11	44.6	8	0.26	103	3.43	159	Very high
10	0.14	46.6	8	0.21	105	3.70	164	Very high
11	0.04	2.2	6	0.11	5.5	0.43	14	High
12	0.04	2.4	5	0.05	6	0.40	14	High
13	0.04	19.2	4	0.12	55	3.36	82	Very high

3.1.4–Cluster analysis

The heavy metal data concentrations (the variables) were chosen to calculate for similarities in the variable. Then hierarchical clustering by applying single method was performed on the data set. The CA results for heavy metal data studied are shown in Figure 5 as a dendogram. Figure 5 displays three clusters: (1) Ni–Cr; (2) Fe; (3) Pb–Cu–Zn. It is observed, however, that clusters 2 and clusters 3 join together at a relatively higher level, possibly implying a common source. The results imply that some different anthropogenic activities occurred in the surface water and wastewater that illustrated as a dendogram in Figure 5 from the study area. Cluster 1 is composed of the Ni and Cr was mainly derived from anthropogenic inputs.

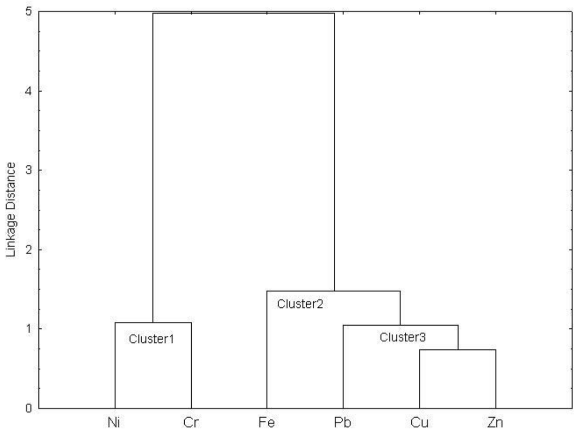

Figure 5) Dendogram results single method of hierarchical cluster analysis for 6 variables.

Metal industrial activities (such as Aluminum Navard plant and Avangan plant) are the most important sources of heavy metals in wastewater (Table 3).

Table 3) Wastewater composition of metal plants in Arak city next to the Mighan Lake (concentration in mg/kg).

Metal plant name*	Zn	Cr	Pb	Cu	Ni	Fe
Vagon -Pars	1.24	0.00	0.00	0.03	0.00	1.57
Avangan	8.47	0.10	1.33	0.61	0.22	66
Mashinsazi	0.03	0.00	0.05	0.00	0.00	0.32
Combain	2.55	0.02	0.21	0.16	0.07	16
Azarab	0.44	0.01	0.00	0.04	0.00	1.35
Alemerol	0.86	0.02	0.05	0.04	0.05	6.14
Al- Navard	12.81	0.27	0.57	0.90	0.42	117

Cluster 2 includes Fe was controlled by anthropogenic activity in the study area (such as Aluminum Navard plant, Avangan plant, Combain plant, Alemerol plant and Vagon Pars plant) (Table 3). Cluster 3 includes Pb, Cu and Zn appeared to be affected by both anthropogenic (wastewater of traffic activities, Aluminum Navard plant and Avangan plant) and natural sources (especially Cu and Zn) (Solgi *et al.*, 2012; Kiham, 2013).

3.2–Characterization of sediments

3.2.1–Heavy metal concentrations of sediment samples

Summary of descriptive statistics such as minimum, mean, maximum for six elements used in this study are shown in Figure 6. Reference values of the studied metals (Caritat and Reimann, 2012; Taylor and McLennan, 1995) are also included Zn=52; Cr=35; Pb=17; Cu=14; Ni=19 and Fe=35000. Most of the elements have a wide range of variations of several magnitudes. This was evident for Zn, whose concentrations vary from 26 to 642 mg/kg with a mean of 174 mg/kg; for Cr from 15 to 80 with a mean of 29 mg/kg; for Pb from 8 to 17 with a mean of 12.43 mg/kg; for Cu from 10 to 33 with a mean of 18 mg/kg; for Ni from 14 to 19 with a mean of 17.43 mg/kg and for Fe from 3620 to 35000 with a mean of 12284 mg/kg (Fig. 6).

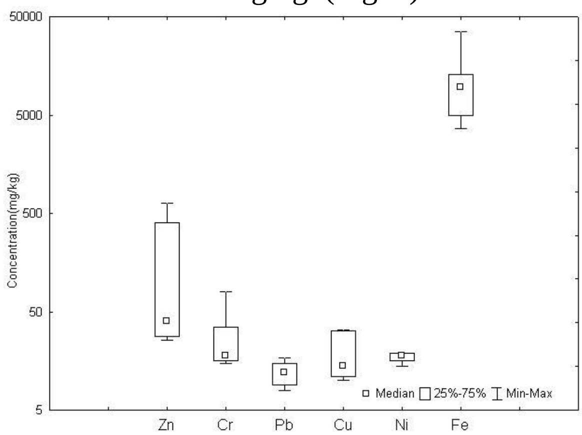

Figure 6) Concentration of metals (mg/kg) in sediment of Mighan Lake.

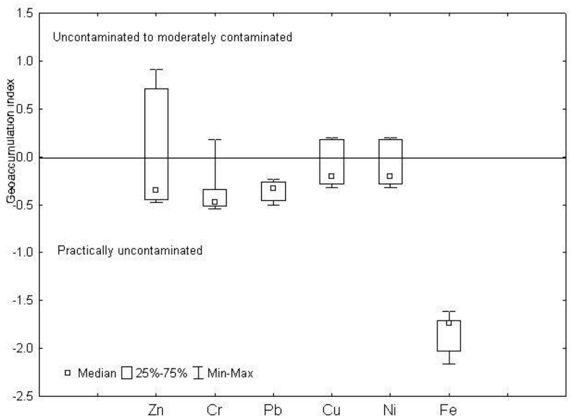

Figure 7) Geoaccumulation index for constituents in surface water and wastewater samples in Mighan Arak.

Cr, Pb and Fe concentrations in sediments of Mighan Lake are lower than values reported in the literature (Taylor and Mc Lennan, 1995), but the concentrations of Zn, Cu and Ni are higher than of upper continental crust. The anthropogenic sources of Zn, Cu and Ni are related to the metal industry activities around of Mighan Lake (Kabata–Pendias, 2000).

3.2.2–Assessment of contamination

Assessment of contamination showed that Igeo of total elements are practically uncontaminated in most of locations (Fig. 7). In some of locations, Zn, Cu and Ni are uncontaminated to moderate contaminated. Therefore, it is possible that Cr, Pb and Fe are natural source and Zn, Cu and Ni are anthropogenic origin. The computed contamination factor (Fig.8 and Table 4) for the sampling shows that samples are low contamination for total of elements. While some of the samples show moderately to very high contamination for Zn and Cu (Fig. 8).

Table 3) Wastewater composition of metal plants in Arak city next to the Mighan Lake (concentration in mg/kg).

Metal plant name*	Zn	Cr	Pb	Cu	Ni	Fe
Vagon -Pars	1.24	0.00	0.00	0.03	0.00	1.57
Avangan	8.47	0.10	1.33	0.61	0.22	66
Mashinsazi	0.03	0.00	0.05	0.00	0.00	0.32
Combain	2.55	0.02	0.21	0.16	0.07	16
Azarab	0.44	0.01	0.00	0.04	0.00	1.35
Alemerol	0.86	0.02	0.05	0.04	0.05	6.14
Al- Navard	12.81	0.27	0.57	0.90	0.42	117

Based on Table 4 sediments of Mighan Lake generally present contamination varying from a low degree of contamination to high degree of contamination; the high degree of contamination is belong to sample 1 and sample 2. Pollution can be related to a industrial activities (such as Aluminum Navard plant, Avangan plant, Combain plant, Alemerol plant and Vagon Pars plant).

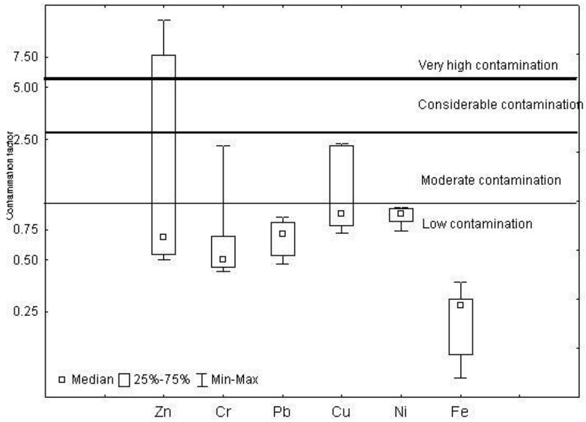

Figure 8) Contamination factor for constituents in surface water and wastewater samples in Mighan Arak.

3.2.3–Cluster analysis

Using single–linkage and Pearson's correlation coefficients cluster analysis (hierarchical cluster analysis) was carried out and the results are given in a dendogram (Fig. 9).

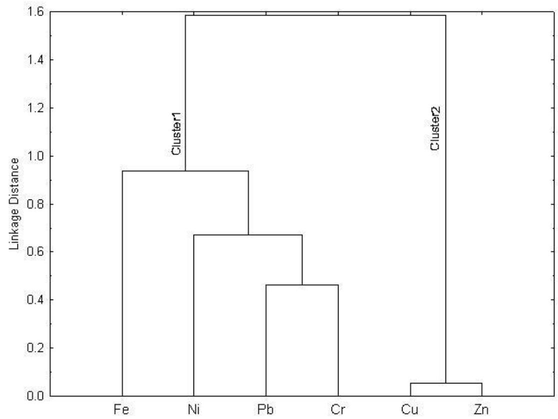

Figure 9) Dendogram results of hierarchical cluster analysis for 6 variables.

Results of cluster analysis indicate that the elements comprise two groups. The first group is consisting of Fe, Ni, Pb and Cr. The second group consisting of Cu and Zn. Cu and Zn source clearly represents the anthropogenic contribution, such as metal industrial activities (Ozsoy and Ornektekin, 2009; Song and Gao, 2009). These elements were enriched in comparison with crustal materials in some of the samples as shown in Figure 8. The cluster is usually showed from crustal sources or natural origins in sediments.

4–Conclusions

The study of the distribution of heavy metals in surface water, wastewater and the sediment from the Mighan Lake suggests that the lake is facing heavy metal pollution. In surface water and wastewater, abundances of heavy metals in water were ranked as: Ni> Cr> Pb> Fe> Cu> Zn. Some heavy metals exceeded background values, indicating that the Mighan Lake is polluted with some heavy metals. The spatial distribution of these metals indicated that they might be related to industrial effluent and wastewater around the lake. In the sediments, increase of Cu and Zn concentration reflected that this metal in the sediments might originate from the anthropogenic activities. Decrease in concentration of Cr, Pb, Ni and Fe was likely associated with the natural sources. Lake should be of high concern, and Cr, Ni in surface water and Cu, Zn in sediments were the highest priority pollutants.

Acknowledgements

The authors would like to thank Dr. M. Yousefi–Rad and an anonymous reviewer for their kind and careful comments that made the manuscript improved. This study was financially supported by the Scientific Research Project Commission of Department of Mining Engineering of Arak University of Technology.

References:

Alhas, E., Oymak, S. A., Karadede–Akin, H. 2009. Heavy metal concentrations in two barb, Barbus xanthopterus and Barbus rajanorum mystaceus from Atatürk Dam Lake, Turkey. Journal of Environmental Monitoring and Assessment: 148, 11–18.

Anshumali–Ramanathan, A. L., Singh, G., Ranjan, R., Tripathi, P. 2009. Chemodynamics of trace metalfractions in surface sediments of the Pandoh Lake, Lesser Himalaya, India. Journal of Environmental Geology: 57,1865–1879.

Backman, B., Bodis, D., Lahermo, P., Rapant, S., Tarvainen, T. 1998. Application of a groundwater contamination index in Finland and Slovakia. Journal of Environmental Geology, 36, 55–64.

Bolhasani, A., Azimi, R., Mohammadi, M., Mardian, M. 2010. Identification of pollution sources of water pollution potential in the lagoon Mighan, Proceedings of The first national conference on combating desertification and sustainable development of Iran Desert Wetlands (Relying on Meighan Desert Wetland).

Botsou, F., Karageorgis, A. P., Dassenakis, E., Scoullos, M. 2011. Assessment of heavy metalcontamination and mineral magnetic characterization of the Asopos River sediments (Central Greece). Mar Pollution Bulletin: 62, 547–563.

Bu–Olayan, A. H., Thomas, B. V. 2013. Effect of Trace Metals Levels in Waste water Discharges, Sediment and Euchelus Asper in Kuwait Marine Environment. International Journal Environment Research: 7, 779–784

Caritat, P. D., Reimann, C. 2012. Comparing results from two continental geochemical surveys to worldsoil composition and deriving Predicted Empirical Global Soil (PEGS2) reference values. Earth and Planetary Science Letters: 319–320, 269–276.

Colby, N.D. 1993. The use of 2–way cluster analysis as a tool for delineating trends inhydrogeologic units and development of a conceptual model. 1993 Ground watermodeling conference, IG WMC, Colorado School of Mines, Golden Co.

Edet, A. E., Offiong, O. E. 2002. Evaluation of water quality indices for heavy metal contamination monitoring. A study case from Akpabuyo–Odukpani area, Lower cross River Basin (southeastern Nigeria). GeoJournal: 57, 295–304.

Forghani, G., Moore, F., Lee, S., Qishlaqi, A. 2009. Geochemistry and speciation of metals in sediments of the Maharlu Saline Lake, Shiraz, SW Iran. Environmental Earth Science: 59, 173–184.

Ghomi, M., Ghadimi, F., Hajati, A. 2013. Evolution of soil contamination in the abandoned Lakan Lead and Zinc mine by heavy metals, Iran. Journal of Tethys: 1, 12-28.

Hakanson, L. 1980. An ecological risk index for aquatic pollution control, a sedimentological approach. Journal of Water Research: 14, 975–1001.

Huang, X., Hu, J., Li, C., Deng, J., Long, J., Qin, F. 2009. Heavy–metal pollution and potentialecological risk assessment of sediments from Baihua Lake, Guizhou, China." Int. Journal of Environmental Health Research: 19, 405– 419.

Kabata–Pendias, A. 2000. Trace Element in Soils and Plants. 3td. Ed. CRC Press, 413p

Kapungwe, E. M. 2013. Heavy Metal Contaminated Water, Soils and Crops in Peri Urban Wastewater Irrigation Farming in Mufulira and Kafue Towns in Zambia. Journal of Geography and Geology: 5, 55.

Kiham, C. 2013. Heavy metal contamination in water and sediment downstream of municipal wastewater treatment plants, Dares Salaam, Tanzania. Intrnational Journal of Environmental Science: 3, 1407–1415.

Kurun, A., Balkis, N., Erkan, M., Balkis, H., Aksu. A., Erşan, M. S. 2010. Total metal levelsin crayfish Astacus leptodactylus (Eschscholtz, 1823), and surface sediments inLake Terkos, Turkey. Journal of Environmental Monitoring Assessment: 169, 385–395.

Lambrakis, N., Antonakos, A., Panagopoalos, G. 2004. The use of multi component statisticalanalysis in hydrogeological environmental research. Journal of Water Research: 38, 1862–1872.

Li, S. Y., Xu, Z. F., Cheng, X. L., Zhang, Q. F. 2008. Dissolved trace elements and heavy metals in the Danjiangkou Reservoir, China. Journal of Environmental Earth Sciences: 6, 39–47.

Liu, C.W., Lin, K. H., Kuo, Y. M. 2003. Application of factor analysis in the assessment of groundwater quality in a black foot disease area in Taiwan. Journal of Science of the Total Environment: 313,77–89.

Loska, K., Wiechula, D., Korus, I. 2004. Metal contamination of farming soils affected by industry. Journal of environmental International: 30,159–165.

Müller, G. 1969. Index of geo–accumulation in sediments of the Rhine River. GeoJournal: 2, 108–118.

Love, D., Hallbauer, D., Amos, A., Hranova, R. 2004. Factor analysis as a tool in groundwater quality management; two southern African case studies. Journal of Physics and Chemistry ofthe Earth: 29,15–18, 1135–1143.

Moghimi, S. 2008. An investigation on environment impact of Arak City wastewater treatment plantoutfall on water body of Meighan wetland. Wetland, Research office of Department of Environment of Markazi Province, Arak, Iran, 2008-2009 (~13300 EU).

Nasehi, F., Monavari, M., Naderi Gh., Vaezi, M. A., Madani, F. 2013. Investigation of heavymetals accumulation in the sediment and body of carp fish in Aras River. Iranian

Journalof Fisheries Sciences: 12, 398–410.

Ogundiran, O., Afolabi, T. A. 2008. Assessment of the physicochemical parameters and heavymetal toxicity of leachates from municipal solid waste open dumpsite. International Journal Environmental Sciences Technology: 5, 243–250.

Ongeri, D. M. K., Lalah, J. O., Wandiga, S. O., Schramm, K. W., Michalke, B. 2009. Levelsof toxic metals in multi sectoral samples from Winam Gulf of Lake Victoria. Bulletin Environmental Contammination Toxicology: 82, 64–69.

Ozsoy, T., Ornektekin, S. 2009. Trace elements in urban and suburban rainfall,Mersin, Northeastern Mediterranean. Journal of Atmospheres Research: 94, 203–219.

Ramos, J. A. L., Barrón, L. E. R., Sandoval, I. M. 2004. Combined use of aquifer contamination risk mapsand contamination indexes in the design of water quality monitoring networks in Mexico. Journal of Geofísica International: 43, 641–650.

Sarfo, D.K., Anim, A.K., Baidoo, I. K., Opata, N.S., Kwarteng, I., Ameyaw, F, Serfor–Armah, Y.2013. Sewage impact on metal accumulation in sediments and fish Clarias gariepinus from the University of Cape Coast community and its environs. Journal of Environmental Science and Water Resources: 2, 191–197.

Solgi, E., Esmaili, A., Riahi–Bakhtiari, A. R., Hadipour, M. 2012. “Soil contamination of metals in thethree industrial Estate, Arak. Bulletin of Environmental Contamination and Toxicology: 88, 634–638.

Song, F., Gao, Y. 2009. Chemical characteristics of precipitation at metropolitan Newark in the US East Coast. Journal of Atmospheres Environmental: 43, 4903–4913

Taylor, S. R., McLennan, S. M. 1995. The geochemical evolution of the continental crust. Review Journal of Geophysics: 33, 165–241.

Yao, S. C., Xue, B., Xia, W. L., Zhu, Y. X., Li, S. J. 2009. Lead pollution recorded in sediments of three lakes located at the middle and lower Yangtze River basin, China. Quaternary International: 208, 145-150.

Yuan, H. Z., Shen, J., Liu, E. F., Wang, J. J., Meng, X. H. 2011. Assessment of nutrients and heavy metals enrichment in surface sediments from Taihu Lake, a eutrophic shallow lake in China. Environmental Geochemical Health: 33,67–81.

WHO. 2011. Guidlines for drinking water quality. 4th. Ed.

Zhang, M., Cui, L., Sheng, L., Wang, Y. 2009. Distribution and enrichment of heavy metals among sediments, water body and plants in Hengshuihu Wetland of North China. Journal of Ecology Engineering: 35, 563–569.

Zorer, O. S., Ceylan, H., Doğru, M. 2008. Assessment of some trace heavy metals and radioactivity concentration in water of Bendimahi River Basin (Van, Turkey). Environmental Monitoring Assessment: 147, 183–190.