Original Article

Assessment of Metals (Co, Ni, and Zn) Content in the Sediments of Mighan Wetland Using Geo-Accumulation Index

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Received: 09.05.2015 *Accepted: 22.06.2015*

ABSTRACT

Background: Sediments are inseparable fractions of wetland ecosystems that work as a historical archive in the process of recording heavy metal aggregation changes. This study was carried out for assessing Co, Ni, and Zn in sediment samples of Mighan Wetland using geo-accumulation index in 2013.

Methods: The sediment samples were taken from 11 stations. The samples were subjected to bulk digestion and chemical partitioning and Co, Ni, and Zn concentrations of the sediments were determined by ICP-OES. Geo-accumulation index (I-geo) was used to evaluate the magnitude of contaminants in the sediment profile.

Results: The results showed that Co, Ni, and Zn concentrations in the sediment samples were 10.0±0.65-60.0±3.79, 21.0±1.71-42.0±2.80, and 64.0±6.97-263.0±26.13 μg g^{-1}, respectively. Moreover, according to the I-geo values, the sediments' qualities fell into the unpolluted category.

Conclusion: Although at present, sediments of Mighan Wetland are not polluted with heavy metals, disposal of urban and industrial wastewaters into the wetland as well as the settlement of Iran Mineral Salt Company and the establishment of Arak Refinery in the vicinity of the wetland, can discharge different pollutants especially heavy metals to the wetland and cause irreparable damages in the long run.

Keywords: Chemical Partitioning, Geo-Accumulation Index, Heavy Metals, Mighan Wetland, Sediments.

IJT 2015; 1386-1390

INTRODUCTION

Large amounts of pollutants have been released into marine and estuarine environments over the past several decades. Among these pollutants, heavy metals have long been recognized as major pollutants of marine environments [1]. Heavy metals pollution has been intensively studied in recent years since they are persistent toxins, prone to bioaccumulation, that pose a risk to humanand ecosystems [2]. The accumulation of heavy metals in environmental samples, such as soils and sediments, causes a potential risk to human health due to the transfer of these elements in aquatic media, their uptake by plants, and their subsequent introduction into the food chain [3]. In addition, heavy metals are a cause of concern as contaminants of aquatic systems because of their toxicity at low concentrations. Surface sediments are specific elements of the natural environment. They are a natural sponge adsorbing all kinds of pollutants occurring in water. The structure of sediments together with their developed surfaces makes them a natural sorbent in which the accumulation of all sorts of harmful substances takes place [4]. The occurrence of elevated levels of heavy metals, especially in sediments, can be a good indication of man-induced pollution. High levels of heavy metals can often be attributed to anthropogenic influences rather than natural enrichment of sediments by geological weathering [5].

Human activities in industry, mainly mining and chemical industries, and agriculture , irrigation with polluted water and use of mineral fertilizers (especially phosphates), contaminated manure, sewage sludge, and pesticides containing heavy metals, may lead to the discharge

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oflarge quantities of these chemical compounds into aquatic environments and, ultimately,their entrance into human bodies through food and drinking water [6].

The hazards associated with ingestion of heavy metals lies in their tendency to bioaccumulate through their increased concentration in a biological organism over time. In humans, exposure to heavy metals and radionuclides can result in a wide range of biological effects depending on the level and duration of exposure [6]. Exposure to high levels of heavy metals and radioactive substances causes a number of health effects, such as nausea, vomiting, and diarrhea. Similarly, long-term exposure to heavy metals is associated with renal dysfunction. High exposure to heavy metals can lead to obstructive lung diseases and it has been linked to lung cancer. High doses may also produce bone defects in humans and animals. Long-term exposure can also cause kidney and liver damageand damage to circulatory and nerve tissues [7].

Geochemical studies of sediment cores are helpful in the assessment of pollution, changes in climatic conditions, rate of sedimentation, etc [3].Heat, suspended and dissolved substances are factors that can affect the dispersion of trace elements in waters and accumulation or mobilization of trace elements in the sediments of aquatic environments [8]. The potential of environmental damage might be comparatively small if these metals are ultimately fixed in sediments and pore-water concentrations are limited by their solubility [9]. Information on the total concentrations of metals alone is not sufficient to assess the environmental impact of polluted sediments as heavy metals are present as easily exchangeable metal carbonates, oxides, sulfides, organometallic compounds, and ions in the crystal lattice of minerals which indicates their mobilization capacity and bioavailability. Therefore, it is necessary to identify and quantify the forms in which a metal is present in sediments to gain a more precise understanding of the potential and actual impacts of elevated concentrations and to evaluate processes of downstream transport, deposition, and release under changing environmental conditions [6].Many sequential extraction and chemical partitioning methods have been developed and applied for determination of metal bonding and pollution detection in the particulate phase. It is believed that metals in adsorbed, carbonate, sulfide, and organic bonds are more related to pollution and have a greater risk of bioavailability and contamination of the environment. Forstner and Muller used a sediment pollution index to evaluate heavy metals pollution of rivers in Germany. Many researchers have used sediments to study the behavior of metals over periods of sedimentation [10, 11]. Mighan wetland covers an area of about 10,000 ha, located northeast of Arak in west-central Iran [12]. The aquifer of Mighan playa is developed into the medium to fine phases of the Pleistocene sediments, which occupy a broad graben between mountains of Arak and Ashtian. The bedrock of these formations is composed of crystalline limestone of the zone of low metamorphism rocks [13]. The location of the study area isshown in Figure 1.Because heavy metals pollution in aquatic ecosystems can be harmful to human health, it is necessary to assess the content of pollutants in sediments as an important indicator. Therefore, the present study was carried out to determine Co, Ni, and Zn levels in sediments from Mighan Wetland.

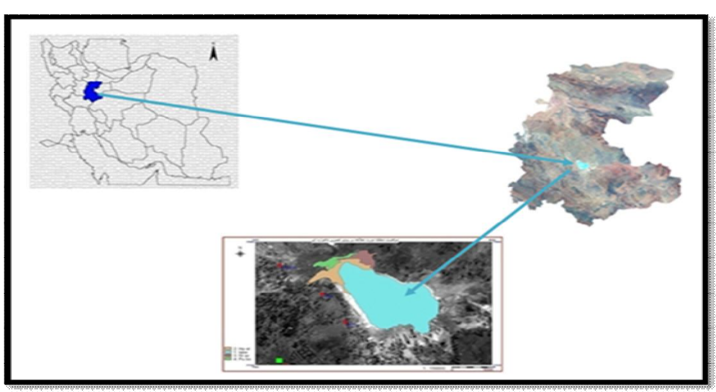

Figure1. The location of the study area.

MATERIALS AND METHODS

Sampling

Thirty three surface sediment samples were collected using Piterson grab from eleven stations along Mighan Wetland as shown in Figure 2 in February 2013. These samples were subjected to simultaneous determination of heavy metals (Co, Ni, and Zn). The geographical coordinates (latitude and longitude) for each station are shown in Table 1. The samples were carried by polythene bag and transported to the laboratory.They werefirst stored at temperature of 4 ºC and then the sediment samples were air-dried for two weeks in the Chemistry Laboratory of Islamic Azad University of Hamadan and sieved through a 60-µm mesh to remove debris.After that, they underwent homogenization for analysis of the metals [14].

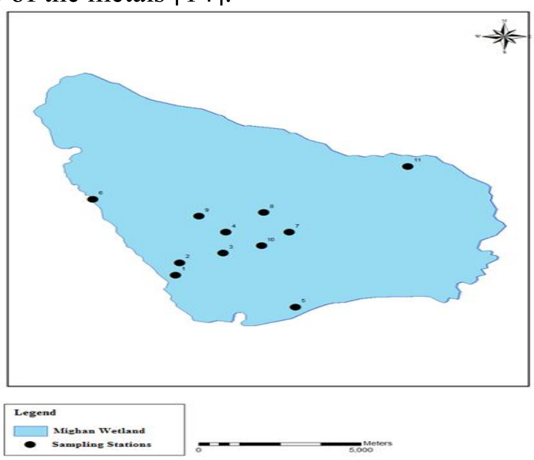

Figure2. Map of the sampling stations in Mighan Wetland.

Table 1. Location of the sampling stations.

Station	Longitude	Latitude
1	49^0 48′ 40.71″	34^0 10′ 11.83″
2	49^0 48′ 46.66″	34^0 10′ 31.90″
3	49^0 49′ 38.71″	34^0 10′ 48.18″
4	49^0 49′ 41.76″	34^0 11′ 23.79″
5	49^0 51′ 16.90″	34^0 09′ 04.37″
6	49^0 47′ 00.31″	34^0 12′ 17.73″
7	49^0 50′ 57.89″	34^0 11′ 24.46″
8	49^0 50′ 26.44″	34^0 11′ 57.35″
9	49^0 49′ 08.32″	34^0 11′ 50.35″
10	49^0 50′ 24.45″	34^0 11′ 01.41″
11	49^0 53′ 19.46″	34^0 13′ 16.60″

Analytical Methods

Sediments were analyzed for heavy metals (Co, Ni, and Zn). For the total heavy metal content analysis, all of the samples were powdered in Teflon tubes for chemical analysis [15]. The total metal content was determined by digesting the samples with a mixture of HNO_3–$HClO_4$ in a microwave oven. Then the solution was filtered through Whatman No. 42 filter paper [14, 16, and 17]. Finally, all samples were fully analyzed using ICP-OES (710-ES, Varian).

I-Geo Accumulation Index Calculation

To evaluate the magnitude of the contaminants in the sediment profile, I-geo was computed according to the abundance of the species in source material to that found in the Earth's crust and equation 1 was used to calculate I-geo [18]. I-geo is a common criterion for assessment the heavy and toxic metal pollution in sediments and is classified in seven grades (0-6) ranging from unpolluted to extremely polluted (Table 2):

Equation 1. I-geo= log 2 [Cn/(1.5 Bn)]

Where Cn and Bn are the concentration of the element and world surface rock average, respectively [19]. Factor 1.5 is incorporated in the relationship to account for possible variation in background data due to lithogenic effect.

Table2. Muller's classification for I-geo.

I-geo Value	Class	Sediment Quality
≤0	0	unpolluted
0-1	1	unpolluted to moderately polluted
1-2	2	moderately polluted
2-3	3	moderately to strongly polluted
3-4	4	strongly polluted
4-5	5	strongly to extremely polluted
>6	6	extremely polluted

Statistical Analysis

Correlation analysis was conducted using the SPSS 19.0 statistical package.

RESULTS

The descriptive statistics for the sediment samples are shown in Table 3. The results indicate that Co, Ni, and Zn concentrations in sediment samples were 10.0±0.65-60.0±3.79, 21.0±1.71-42.0±2.80, and 64.0±6.97-263.0±26.13 µg g^{-1}, respectively. The results of Pearson correlation coefficient between the elements indicated that there were significant correlations between Co/Zn and Ni/Zn (Table 4). In addition, according to the I-geo values, the sediments' qualities were classified as unpolluted (Table 5).

Table3. Mean concentrations of metal in sediment samples (μg g^{-1} DW).

Station	Co	Ni	Zn
1	17±1.12	23±1.77	109±10.1
2	33±2.01	41±3.05	135±14.35
3	13±1.01	23±1.89	116±10.98
4	60±3.79	36±2.59	263±26.13
5	27±1.88	31±2.26	132±13.99
6	32±2.10	36±2.44	145±15.01
7	10±0.65	26±1.90	130±13.48
8	17±1.19	21±1.71	64±6.97
9	10±0.71	38±2.49	161±15.81
10	10±0.68	30±2.03	106±10.02
11	10±0.70	42±2.80	142±14.35
Mean Concentration±SD	19.45±15.48	31.54±7.55	136.63±49.12
Mean World Sediments [11]	14	52	95

Table4. Pearson correlation coefficient matrix for heavy metals.

Element	Co	Ni	Zn
Co	1	0.316	0.739*
Ni	0.316	1	0.556*
Zn	0.739*	0.556*	1

* Correlation is significant at the 0.05 level (one-tailed).

Table5.I-geo for metal in sediment samples of Mighan Wetland.

Heavy Metals	I-geo Value	Class	Sediment Quality
Co	-0.11	0	unpolluted
Ni	-1.31	0	Unpolluted
Zn	-0.071	0	unpolluted

DISCUSSION

Cobalt is beneficial for humans because it is part of vitamin B_{12}. Exposure to high levels of cobalt can result in lung and heart effects and dermatitis [20]. Nickel acts as an activator of some enzyme systems at trace levels, but its toxicity at higher levels is a cause of concern. It accumulates in the lungs and frequently causes bronchial failure [21]. Zinc, on the other hand,is an essential functional and structural element in biological systems often catalyzing reactions by binding to substrates by favoring various reactions, such as the mediation of oxidation–reduction reactions, or redox reactions, through reversible changes in the oxidation state of the metal ions [22, 23]. The results of the present study showed the ranking of the mean concentration of metals in the study area as Zn> Ni> Co. In this study, numerical sediment quality guidelines (SQGs),threshold effect concentration (TEC), and probable effect concentration (PEC) were used for assessment of metal concentrations in the sediment samples. The results indicated that the mean concentrations of Ni and Zn in the sediment samples of Mighan Wetland are higher than TEC (n.d. for Co, 22.70 μg g^{-1} for Ni, and 121.0 μg g^{-1} for Zn) [5, 19, 24]. This means that these metals may have adverse effects.Table 4 shows that elemental pairs Co/Zn (R= 0.739, P< 0.05) and Zn/Ni, (R= 0.556, P< 0.05) significantly correlated with each other.

CONCLUSION

The content of metals in sediments can be a secondary source of water pollution, once the environmental situation is changed. Therefore, evaluation of metal contamination in sediments is an essential tool to assess the risk in an aquatic ecosystem [25-27]. According to the I-geo values, the sediments quality was classified as unpolluted. Therefore,considering the existing I-geo values, it can be stated that although, at present, the sediments of Mighan Wetland are not polluted with heavy metals, entrance of urban and industrial wastewaters to the wetland, the settlement of Iran Mineral Salt Company, and the establishment of Arak Refinery in the vicinity of the wetland can discharge different pollutants,especially heavy metals into the wetland cause irreparable damages in the long run.

ACKNOWLEDGEMENTS

The authors are grateful to Islamic Azad University of Hamadan for providing facilities to conduct and complete this study. The authors declare that there is no conflict of interests.

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