ORIGINAL ARTICLE

Assess of Environmental and Ecological Risk of Heavy Metals Originated of Reverse Osmosis Desalination Plant Effluents to Coastal Areas in the Persian Gulf

Leila Rezaei[1], PhD candidate; Vali Alipour[2], PhD; Amir Hesam Hassani[3], PhD; Mohsen Dehghani[4], PhD

[1]Department of Environmental Sciences, Qeshm Branch, Islamic Azad University, Qeshm, Iran
[2]Department of Environmental Health Engineering, School of Health, Hormozgan University of Medical Sciences, Iran
[3]Department of Environmental Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[4]Department of Natural Resources and Environmental Sciences, Islamic Azad University, Bandar Abbas Branch, Bandar Abbas, Iran

Correspondence:
Mohsen Dehghani, PhD;
Department of Natural Resources and Environmental Sciences, Islamic Azad University, Bandar Abbas Branch, Bandar Abbas, Iran
Tel: +98 9171613922
Email: dehghni933@gmail.com

Received: 7 January 2022
Revised: 19 February 2022
Accepted: 11 March 2022

Abstract

Background: the Persian Gulf ecosystem is facing degradation, so further degradation must be prevented. The present study was conducted to assess the environmental pollution risk potential of the coastal ecosystem due to heavy metal content in desalination plant's effluent.

Methods: In this cross-sectional study, the researchers selected five stations in the west of Bandar Abbas beach, located at the outlet of desalination effluent canals to the shore, and two stations in the east shore (without effluent discharge) as case and control stations, respectively. The researchers collected 51 Sediment samples and measured heavy metal concentration, using an AA spectrophotometer, and assessed the potential ecological risk. They used SPSS software and the T-test to statistically analyze data.

Results: The concentration means for sediments in case and control stations samples were: 40.63±16.79, 96.64±30.60, 159.74±50.65, 109.22±17.09, 205.35±86.96 mg.kg−1 and 40.15±17.21, 79.16±28.26, 152.43±90.07, 101.82±43.55, and 193.82±112.90 mg.kg−1, respectively for (Pb, Cu, Ni, Cd, and Zn). The ecological risk and Pollution Load Index were (31.72, 35.95, 3.30, 36.96, and 45.61) and (0.62, 0.63, 0.71, 0.68, and 0.9), respectively for metals mentioned order. Individual potential risk for all stations showed a low-risk degree.

Conclusion: Although the heavy metals accumulated in coastal sediments due to the discharge of desalination plant effluents, severe ecological and environmental damage has not occurred. Therefore, there is still time to prevent an environmental catastrophe on the shores receiving desalination effluents. Therefore, it is recommended to all responsible persons to take the necessary measures to monitor and control the plan and reduce the discharge of effluents to the shores.

Please cite this article as: Rezaei L, Alipour V, Hassani AH, Dehghani M. Assess of Environmental and Ecological Risk of Heavy Metals Originated of Reverse Osmosis Desalination Plant Effluents to Coastal Areas in the Persian Gulf. J Health Sci Surveillance Sys. 2022;10(2):203-209.

Keywords: Heavy metal, Ecosystem, Environmental pollution, Persian Gulf, Pollution

Introduction

The growing trend of water consumption, mainly due to population growth and industrial and agricultural activities, increased the tendency to use alternative sources of water supply;[1] hence, seawater desalination has been proposed as an alternative in recent years.[2] There are several technologies for desalinating large amounts of freshwater, mainly based on thermal and membrane methods. These technologies are reliably used for waters with different salinity levels, such as Brackish or Seawater.[3] Among desalination technologies, reverse osmosis, a membrane process based on pressure driving force is growing rapidly as a relatively new technology. In this regard, many desalination plants with different capacities are installed on the shores of Bandar Abbas. They produce thousands of cubic meters of freshwater for two primary purposes, including industrial water (steel, zinc, aluminum, shipbuilding, Oil refineries, etc.) and urban drinking water supply.[4, 5] Finally, the effluent of these desalination plants is discharged to the shores of the Persian Gulf without any post-treatment. However, its environmental effects are not well known, and therefore it is necessary to study the environmental effects of desalination due to the rapid increase in global capacity.[6, 7]

The environmental impacts of seawater desalination plants can be classified as water intake, enery consumption, and effluent discharge.[8] The intake section effect is related to chemicals addition and physical impacts. The environmental effects of energy consumption refer to the issue of air pollution. The main critical environmental issues are related to the effluent discharge of plants, where the vast quantities of chemicals and brine are discharged to the sea. These chemicals are added to desalination water in various pretreatment and desalination processes such as chlorination, pH adjustment, coagulation and flocculation, de-chlorination, and descaling, and can adversely affect the environment.[9, 10] Heavy metals are non-biodegradable, toxic, and persistent pollutants due to their high accumulation properties in aquatic elements.[11] High accumulation of (HMs) in sediments can lead to severe ecological changes and ultimately affects human health through bioaccumulation and biomagnification along the food water chain.[12, 13] This event, in turn, can create many problems for the marine ecosystem and human life. The conditions of the coastal ecosystem are more fragile in an industrial coastal area such as the Persian Gulf shores in the west of Bandar Abbas where coastal sediments have a clay content. As Persian Gulf sediments have a high electrical charge because of clay nature and high cation exchange capacity, they have a great power in absorbing pollutants.[14] Thus, such industrial coastal ports chronically exposed to metals have the most polluted sediments.[15, 16]

Assessment of pollution conditions is of great importance in such ecosystems to prevent, control, and warn human communities.[17] Aquatic ecosystems pollution due to HMs can be investigated by evaluation of water, sediments and organisms and a wide range of environmental indices such as ecological risk potential assessment, chemical land accumulation index, pollution factor, and pollution load index.[18-20] However, in the meantime, the ecological risk potential index of toxic metals in aquatic environments is one of the most important indicators because it determines their ecological risk potential according to the concentration and toxicity factor of each metal and the environmental risk of all metals.[21-23] One of the assessment methods is to analyze the sediments, which can be done in different ways, including comparison to reference (background) values of the region, comparison with international standards, and measured values in other areas of the country.[24] Some studies have been conducted on HMs in the Persian Gulf, which indicated the existence of ecological threats related to heavy metals in this water body.[15, 25-28] The Persian Gulf is facing degradation in its coastal and marine ecosystems so preventing further degradation is critical. the environmental effects of chemicals content was important in this study, especially heavy metals (HMs), in reverse osmosis desalination effluents.[29, 30] The present study was conducted to assess the environmental pollution status and ecological risk potential of the Persian Gulf coasts due to effluent discharge, resulting from the rapidly growing desalination plants, with emphasis on HMs effects.

Methods

Study Area

This case-control study was conducted in the Bandar Abbas (south of Iran) beaches; the case region was located in the west beach, where many desalination plants have been installed. There are 5 public canals in this location, selected as case stations of the study; they were natural and artificial canals (estuaries and canals) through which effluent of desalination plants is discharged into the sea. Our control (Blank) beach was the coastal area in the east of Bandar Abbas located at 30 km from the case stations with no municipal and industrial effluent discharge into the sea; (Figure 1, Table 1). A total of 51 samples of sea sediments were taken at 5 sampling stations, and sampling was done randomly along the study beaches, according to a block structure pattern.

Collection of sediment samples was performed by Van Veen sampler in two depths; 0-5 and 5-10 cm in 3 replications from each station.

Heavy Metal Measurement

In the laboratory, the sediments samples were digested in a polytetrafluoroethylene container consisted of a concentrated acid mixture [(5 mL) of HNO3, (1 mL) of HClO4 and HF], then the concentrations of (HMs); (Cd, Fe, Cu, Ni, Zn, and Pb) were measured by Thermo Elemental-SOLAR atomic absorption spectrometer. The hollow cathode lamps were used as instrument lamps, and the air and acetylene mixture was supplied for fuel.

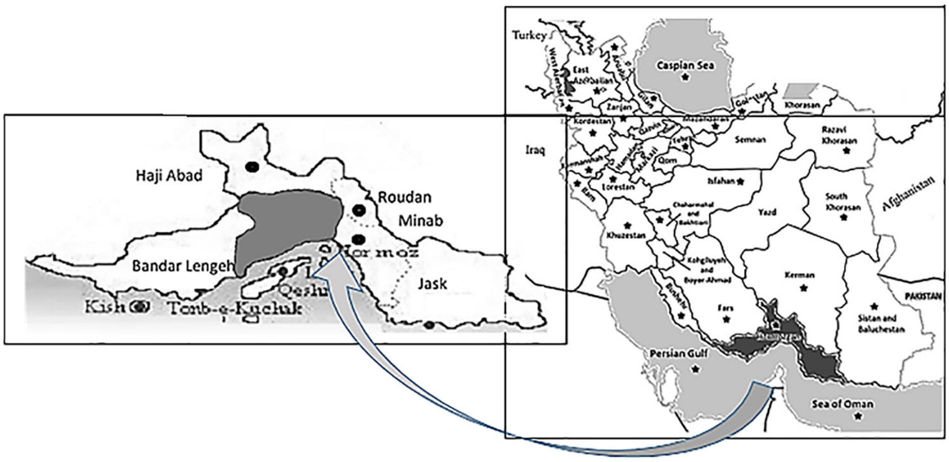

Figure 1: Study area and sampling station location

Table 1: Sampling station Geographical Coordinate (UTM)

Sampling station	X	Y
1	409961.13	2999595.8
2	410093.8	2999943.92
3	411536.62	3001603.03
4	410282.21	3000185.31
5	409775.12	2998852.4
Control 1	452407.17	3002476.53
Control 2	454887.78	3002059.15

UTM: Universal Transverse Mercator

Sediment Contamination and Risk Assessment Indices

Contamination factor (CF), Geo-accumulation Index (Igeo), Potential ecological risk index (PERI), and Modified degree of contamination (mCd) were the risk assessment indices for coastal sediments.

Contamination Factor (CF)

Pollution coefficient values (Eq. 1) can describe the environmental pollution related to the HMs. The pollution coefficient is obtained by dividing the sample's metal concentration by the reference value's concentration (Table 2). The level of HMs is normalized to a base metal such as iron, aluminum, or manganese, that is why the concentration of these metals in the soil is thought to be independent of the concentrations of other metals, and therefore it is not affected by other metals.[31]

$$CF=Mx/Mb \qquad \text{(Eq. 1)}$$

Where (Mx) is for the concentration of the element in the sample, (Mb) is the concentration of the same contaminant in the reference material (sediment). In the present study, the mean concentration of the HMs measured in the control stations was selected as the reference values. After calculating the (CF), interpretation of contamination values was done, using Hakanson Classification (Table 2).

Geo-accumulation Index (Igeo)

Geo-accumulation Index (Igeo) (Eq. 2) is an index to assess the intensity of anthropogenic (HMs) deposition on sediments. This potential contamination index is calculated by normalizing one metal concentration in the case samples to the concentration of a reference element.[32]

$$Igeo=\ln Cn/1.5*Bn \qquad \text{(Eq. 2)}$$

In this equation: (Cn) is the HM concentration in sediments of study stations, (Bn) is the HM concentration in sediments of blank beaches, which is the background value, and the constant 1.5 is to analyze natural fluctuations in the content of sediments in the environment and to detect minimal anthropogenic influence.[33] Table 3 presents the different classes of Muller values.[13, 34]

Table 4 presents the reference values for (HM) which were measured values in the blank beaches (the vales for Control).

Table 2: Hakanson Classification for Contamination Factor (CF)

Sediment contamination coefficient	Contamination rate coefficient
Low pollution coefficient	$CF<1$
Medium contamination coefficient	$3>CF\geq1$
Significant contamination coefficient	$6>CF\geq3$
Very high pollution factor	$CF\geq6$

Table 3: The different classes of Muller values for Geo-accumulation of heavy metals[35]

Class	Igeo value	Sediments quality
0	0	Uncontaminated
1	0-1	Uncontaminated to moderately contaminated
2	1-2	moderately contaminated
3	2-3	Moderately to heavily contaminated
4	3-4	Heavily contaminated
5	4-5	Heavily to extremely contaminated
6	>5	Extremely contaminated

Table 4: The concentrations ($mg.kg^{-1}$) of measured heavy metals in the case and control stations

Station	Pb	Cu	Ni	Cd	Zn
1	21.09	115.77	200.34	85.65	116.63
2	19.8	133.21	209.14	101.46	97.13
3	56.15	65.46	86.19	102.48	291.04
4	48.34	55.16	111.56	122.20	212.54
5	57.75	113.58	191.49	134.32	309.43
Control	40.15	79.16	152.43	101.82	193.82

Table 5: The ecological and environmental risk level of the studied heavy metals

EI	Ecological risk of any metal	IR risk index	Ecological and environmental risk
40≥EI	Low risk	RI>150	Low risk
80≥EI≥40	Medium risk	300<RI≥150	Medium risk
160≥EI≥80	Substantial risk	600<RI≥300	Substantial risk
320≥EI≥160	High risk	600≥RI	High risk
320≥EI	Too much risk	-	-

Potential Ecological Risk Index (RI)

The potential ecological risk index (PERI) was used to assess the potential risk of (HMs) contamination in sediments; a modification index which considers the synergy, toxic level, concentration of the HMs and ecological sensitivity of (HMs).[36] Equations 3 and 4 determine the ecological risk assessment index.

$$Ei = Ti \times CF \qquad \text{(Eq. 3)}$$

$$RI = \sum_{i=1}^{m} Ei \qquad \text{(Eq. 4)}$$

Where (Ei) is the individual potential risk, (Ti) is the response factor for toxicity that related values are, Pb=Cu=Ni=5, Cd=30, and Zn=1.

(RI) is the ecological risk of HMs in sediments. The (EI) and (RI) values of the HMs were categorized into five levels, as shown in Table 5.

Pollution Load Index (PLI)

The pollution load index is used extensively in assessing sediment pollution by (HMs).[12, 37] PLI_{zone} is the (HMs) pollution load index of all stations.

$$PLI = \sqrt[4]{CF_{Pb} \times CF_{Cr} \times CF_{Zn} \times CF_{Cu} \times Ni} \qquad \text{(Eq. 5)}$$

$$PLI_{zone} = (PLI_1 * PLI_2 * PLI_3 * PLI_4 * PLI_5)^{1/5} \qquad \text{(Eq. 6)}$$

If PLI Classification >1, pollution occurs and sediments are less polluted and/ or not polluted if the PLI value is less than 1.

Results

Concentrations of Heavy Metals

Table 4 presents the concentrations of measured heavy metals in the case and control stations of the study.

The mean concentrations of Pb, Cu, Ni, Cd, and Zn for sediments for all station of case area and control stations samples were: 40.63±16.79, 96.64±30.60, 159.74±50.65, 109.22±17.09, 205.35±86.96 $mg.kg^{-1}$ and 40.15±17.21, 79.16±28.26, 152.43±90.07, 101.82±43.55, and 193.82±112.90 $mg.kg^{-1}$, respectively.

Contamination Factor (CF)

Table 6 presents the calculated contamination factor (CF) for measured heavy metals in all stations of the case and control.

The concentration of Cu in the sediment of stations 1, 2, and 5 was in the medium contamination category range, and low contamination was calculated for Cd in this station. The contamination factor for Zn metal at stations 3 and 5 was also in the range of medium contamination.

Geo-accumulation Index (Igeo)

Table 7 presents the mean and calculated values of the Geo-accumulation index (Igeo) for measured heavy metals in all case and control stations.

Table 6: Values of calculated contamination factor (CF) for different stations studied based on the reference amount of heavy metal concentration in control stations

Station	Pb	Cu	Ni	Cd	Zn
1	0.31	1.19	0.92	0.64	0.42
2	0.29	1.37	0.96	0.75	0.35
3	0.82	0.67	0.40	0.76	1.05
4	0.70	0.57	0.51	0.91	0.76
5	0.85	1.17	0.88	1.00	1.11

Table 7: The mean and calculated values of Geo-accumulation index (Igeo) for different stations studied based on the reference amount of heavy metal concentration in control stations

Station	Pb	Cu	Ni	Cd	Zn
1	1.05	0.03	0.13	0.58	9.62
2	1.11	0.11	0.09	0.41	9.44
3	0.07	0.60	0.98	0.40	10.53
4	0.23	0.77	0.72	0.22	10.22
5	0.04	0.04	0.18	0.13	10.59
Mean	0.50	0.31	0.42	0.35	10.08

Table 8: Individual potential risk EI for all HMs in the study stations

Station	Pb	Cu	Ni	Cd	Zn
1	1.55	5.95	4.6	19.2	0.42
2	1.45	6.85	4.8	22.5	0.35
3	4.1	3.35	2	22.8	1.05
4	3.5	2.85	2.55	27.3	0.76
5	4.25	5.85	4.4	30	1.11

Based on the mean heavy metal concentrations analysis, Station 1 and 3 had the highest and lowest heavy metal concentration values, respectively.

Potential ecological risk index (RI)

For all stations and metals, RI was calculated using the TI of mentioned in 2.3. and 4 sections and the individual potential risk EI presented in Table 8.

Regarding HMs, all stations were in a low-risk range, based on calculated EI. According to our calculations, the value of RI for (Pb, Cu, Ni, Cd, and Zn) were (31.72, 35.95, 3.30, 36.96, and 45.61), respectively. Given that the calculated RI value for all stations is less than the risk threshold (150), it can be concluded that the measured stations are in the low-risk range.

Pollution Load Index PLI

According to the calculations related to PLI, the pollution index of all metals is less than one in all stations; (PLI values of: 0.62, 0.63, 0.71, 0.68, and 0.9 were calculated for stations 1 to 5, respectively); according to this index, all stations were in a grade of "non-polluted and/or less polluted".

Discussion

The mean concentrations of Pb, Cu, Ni, Cd, and Zn in sediments for all case station and control stations samples were: 40.63±16.79, 96.64±30.60, 159.74±50.65, 109.22±17.09, 205.35±86.96 mg.kg^{-1} and 40.15±17.21, 79.16±28.26, 152.43±90.07, 101.82±43.55, and 193.82±112.90 mg.kg^{-1}, respectively (Table 3). Thus the sequence of total concentrations of heavy metals in different stations was obtained as (Zn>Cd>Cu>Pb>Ni), respectively. The result of the T-test for comparison of the measured HMs in case and control stations showed that there is no significant difference between case and control beaches for metals of Pb, Ni, and Cd (P>0.05), while this test confirmed the significant difference for metals of Cu and Zn between case and control beaches (P<0.05). Therefore, higher Zn concentrations can be caused by two factors: a) in desalination plants, copper sulfate is used as an algaecide,[38] B) the use of Zn salts to improve the capacity of anti-scaling in reverse osmosis membrane.[39] Therefore, it can be concluded that the significant difference between receiving effluent and control beaches can be due to desalination plants. These findings were in line with the results of Ghasemzade et al.[40] and Arfaeinia et al.[27]

Due to the significant differences for some of the measured metals concentrations between the case and control stations, it became more important to investigate whether the presence of these metals in coastal sediments has the potential to create ecological and environmental risks. Therefore, the indices of potential ecological and environmental risk were analyzed in this study.

The (Igeo) for the lead metal in stations 1 and 2 was "moderately contaminated"; in other stations, the interpretation of the index was "uncontaminated to moderately-contaminated". This index for Cu and Cd in all stations was "uncontaminated to moderately-contaminated" and for nickel in stations 3 and 4 was "moderately contaminated". On average, the calculated Geo-accumulation only for Pb was moderately contaminated and uncontaminated to moderately contaminated for other metals.

The ecological risk assessment of studied HMs indicates that most of the studied stations are in the "low risk" category. The highest and lowest risks are related to zinc and Ni, respectively. Also, the findings of the environmental risk index of these metals showed that according to the values obtained (less than 150 environmental hazards of these metals were low). The zone PLI was also calculated, which showed the area is "slightly polluted to non-polluted" (PLI_{zone}=0.71).

Conclusion

This study was conducted to provide data on the concentration level of heavy metals originated in the sediments of Bandar Abbas west Beaches in the Persian Gulf, where a huge capacity of RO desalination plants discharge their brine effluents to the coastal water. In addition, assessing potential ecological risk was done.

As most of the studied indices showed "low pollution degree" in the studied shoreline, it can be concluded that despite the accumulation of some heavy metals in coastal sediments due to the discharge of desalination plant effluents, fortunately, the beaches have not yet reached the breakpoint of severe ecological and environmental condition. This finding means we still have time to prevent an environmental catastrophe on the shores receiving desalination effluents. Therefore, it is recommended to all responsible persons to take the necessary measures to monitor and control and reduce the discharge of effluents to the shores.

Acknowledgment

The authors are sincerely grateful of the Persian Gulf Mining and metal industries special economic zone for their help with the project.

Conflict of interest: None declared

References

1 Boelee E, Janse J, Le Gal A, Kok M, Alkemade R, Ligtvoet W. Overcoming water challenges through nature-based solutions. Water Policy. 2017;19(5):820-36.

2 Ghernaout D, Gabes Z. Desalination in the Context of Water Scarcity Crisis: Dares & Perspectives. Open Access Library Journal. 2020;7(11):1.

3 Manchanda H, Kumar M. Study of water desalination techniques and a review on active solar distillation methods. Environmental Progress & Sustainable Energy. 2018;37(1):444-64.

4 Rezaei L, Dehghani M, Hassani AH, Alipour V. Seawater reverse osmosis membrane fouling causes in a full scale desalination plant; through the analysis of environmental issues: raw water quality. Environmental Health Engineering and Management Journal. 2020;7(2):119–26.

5 Mehrgan M, Mahdiraji H, Binaee S, Alipour V, Agha SRH. Modeling of environmental aspects related to reverse osmosis desalination supply chain. Environmental Health Engineering and Management Journal. 2020;7(1): 31–40.

6 Darre NC, Toor GS. Desalination of water: a review. Current Pollution Reports. 2018;4(2):104-11.

7 Thimmaraju M, Sreepada D, Babu GS, Dasari BK, Velpula SK, Vallepu N. Desalination of water. Desalination and Water Treatment. 2018:333-47.

8 Missimer T, Maliva R. Environmental issues in seawater reverse osmosis desalination: intakes and outfalls Desalination 2018;434:198-215.

9 Caldera U, Breyer C. Learning curve for seawater reverse osmosis desalination plants: capital cost trend of the past, present, and future. Water Resour Res. 2017;53(12):10523-38.

10 Petersen KL, Frank H, Paytan A, Bar-Zeev E. Impacts of seawater desalination on coastal environments. Sustainable desalination handbook: Elsevier; 2018. p. 437-63.

11 Saadati M, Soleimani M, Sadeghsaba M, Hemami MR. Bioaccumulation of heavy metals (Hg, Cd and Ni) by sentinel crab (Macrophthalmus depressus) from sediments of Mousa Bay, Persian Gulf. Ecotoxicology and environmental safety. 2020;191:109986.

12 Kabir MH, Islam MS, Hoq ME, Tusher TR, Islam MS. Appraisal of heavy metal contamination in sediments of the Shitalakhya River in Bangladesh using pollution indices, geo-spatial, and multivariate statistical analysis. Arabian Journal of Geosciences. 2020;13(21):1-13.

13 Joksimović D, Perošević A, Castelli A, Pestorić B, Šuković D, Đurović D. Assessment of heavy metal pollution in surface sediments of the Montenegrin coast: a 10-year review. Journal of Soils and Sediments. 2020;20(6):2598-607.

14 Pourang N, Bahrami A, Nasrolahzadeh Saravi H. Shells of Bufonaria echinata as biomonitoring materials of heavy metals (Cd, Ni and Pb) pollution in the Persian Gulf: with emphasis on the annual growth sections. Iranian Journal of Fisheries Sciences. 2019;18(2):256-71.

15 Sharifinia M, Taherizadeh M, Namin JI, Kamrani E. Ecological risk assessment of trace metals in the surface sediments of the Persian Gulf and Gulf of Oman: evidence from subtropical estuaries of the Iranian coastal waters. Chemosphere. 2018;191:485-93.

16 Rezaei M, Kafaei R, Mahmoodi M, Sanati AM, Vakilabadi DR, Arfaeinia H, et al. Heavy metals concentration in mangrove tissues and associated sediments and seawater from the north coast of Persian Gulf, Iran: Ecological and health risk assessment.

Environmental Nanotechnology, Monitoring & Management. 2021;15:100456.

17 Tian K, Wu Q, Liu P, Hu W, Huang B, Shi B, et al. Ecological risk assessment of heavy metals in sediments and water from the coastal areas of the Bohai Sea and the Yellow Sea. Environment international. 2020;136:105512.

18 Ahmadov M, Humbatov F, Mammadzada S, Balayev V, Ibadov N, Ibrahimov Q. Assessment of heavy metal pollution in coastal sediments of the western Caspian Sea. Environmental Monitoring and Assessment. 2020;192(8):1-18.

19 Rodríguez-Espinosa P, Shruti V, Jonathan M, Martinez-Tavera E. Metal concentrations and their potential ecological risks in fluvial sediments of Atoyac River basin, Central Mexico: Volcanic and anthropogenic influences. Ecotoxicology and Environmental Safety. 2018;148:1020-33.

20 Ogundele LT, Ayeku PO, Adebayo AS, Olufemi AP, Adejoro IA. Pollution Indices and Potential Ecological Risks of Heavy Metals in the Soil: A Case Study of Municipal Wastes Site in Ondo State, Southwestern, Nigeria. Polytechnica. 2020:1-9.

21 Tokatli C. Sediment quality of Ergene River Basin: bio–ecological risk assessment of toxic metals. Environmental monitoring and assessment. 2019;191(11):1-12.

22 Xu Y, Wu Y, Han J, Li P. The current status of heavy metal in lake sediments from China: Pollution and ecological risk assessment. Ecology and evolution. 2017;7(14):5454-66.

23 Liu J-J, Ni Z-X, Diao Z-H, Hu Y-X, Xu X-R. Contamination level, chemical fraction and ecological risk of heavy metals in sediments from Daya Bay, South China Sea. Marine pollution bulletin. 2018;128:132-9.

24 Asheghi R, Hosseini SA, Saneie M, Shahri AA. Updating the neural network sediment load models using different sensitivity analysis methods: a regional application. Journal of Hydroinformatics. 2020;22(3):562-77.

25 Bastami KD, Afkhami M, Mohammadizadeh M, Ehsanpour M, Chambari S, Aghaei S, et al. Bioaccumulation and ecological risk assessment of heavy metals in the sediments and mullet Liza klunzingeri in the northern part of the Persian Gulf. Marine pollution bulletin. 2015;94(1-2):329-34.

26 Janadeleh H, Jahangiri S, Kameli MA. Assessment of heavy metal pollution and ecological risk in marine sediments (A case study: Persian Gulf). Human and Ecological Risk Assessment: An International Journal. 2018;24(8):2265-74.

27 Arfaeinia H, Dobaradaran S, Moradi M, Pasalari H, Mehrizi EA, Taghizadeh F, et al. The effect of land use configurations on concentration, spatial distribution, and ecological risk of heavy metals in coastal sediments of northern part along the Persian Gulf. Science of the Total Environment. 2019;653:783-91.

28 Mirzaei M, Hatamimanesh M, Haghshenas A, Moghaddam SM, Ozunu A, Azadi H. Spatial-seasonal variations and ecological risk of heavy metals in Persian gulf coastal region: case study of Iran. Journal of Environmental Health Science and Engineering. 2020:1-15.

29 Roberts D, Johnston E, Knott N. Impacts of desalination plant discharges on the marine environment: a critical review of published studies. Water Res 2010;44(18):5117-28.

30 Sola I, Yolanda F-T, Aitor F, Carlos V, Yoana dP-R, M. G-CJe, et al. Sustainable desalination: Long-term monitoring of brine discharge in the marine environment. Marine Pollution Bulletin. 2020;161

31 Obiri-Nyarko F, Duah AA, Karikari AY, Agyekum WA, Manu E, Tagoe R. Assessment of heavy metal contamination in soils at the Kpone landfill site, Ghana: Implication for ecological and health risk assessment. Chemosphere. 2021:131007.

32 Barbieri M. The importance of enrichment factor (EF) and geoaccumulation index (Igeo) to evaluate the soil contamination. J Geol Geophys. 2016;5(1):1-4.

33 Müller G. Die Schwermetallbelastung der sedimente des Neckars und seiner Nebenflusse: eine Bestandsaufnahme. . Chem Ztg. 1981;105:157-64.

34 Rabee AM, Al-Fatlawy YF, Nameer M. Using Pollution Load Index (PLI) and geoaccumulation index (I-Geo) for the assessment of heavy metals pollution in Tigris river sediment in Baghdad Region. Al-Nahrain Journal of Science. 2011;14(4):108-14.

35 Waheshi YAA, El-Gammal MI, Ibrahim MS, Okbah M. Distribution and assessment of heavy metal levels using geoaccumulation index and pollution load index in Lake Edku sediments, Egypt. Egypt IJEMA. 2017;5:1-8.

36 Singh A, Sharma RK, Agrawal M, Marshall FM. Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. Food and chemical toxicology. 2010;48(2):611-9.

37 Shirani M, Afzali KN, Jahan S, Strezov V, Soleimani-Sardo M. Pollution and contamination assessment of heavy metals in the sediments of Jazmurian playa in southeast Iran. Scientific reports. 2020;10(1):1-11.

38 Ammour F, Chekroud R, Houli S, Kettab A. Performance Evaluation of SWRO Desalination Plant at Skikda (Algeria). Exergy for A Better Environment and Improved Sustainability 2: Springer; 2018. p. 1131-8.

39 Aziz M, Kasongo G. Scaling prevention of thin film composite polyamide Reverse Osmosis membranes by Zn ions. Desalination. 2019;464:76-83.

40 Ghasemzade F, Moussavi Harami R, Pourkerman M, Amjadi S, Alizade Ketek Lahijani H. The Study of Pollution and Environmental Impact of Heavy Metals, and Chemical and Physical Variables Associated with the Distribution of These Elements in Continental Shelf Sedimentsof the Gulf of Oman, Chabahar Area. Journal of Oceanography. 2012;3(10):27-35.