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Ecological risk assessment of coastal ecosystems: The case of mangrove forests in Hormozgan Province, Iran

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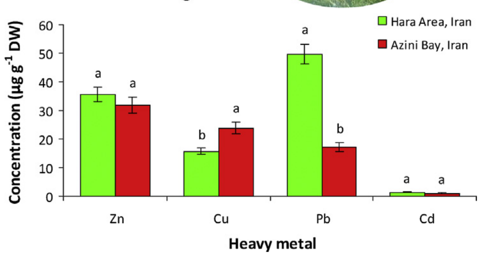
HIGHLIGHTS

- Sediment quality of mangrove forests in Hormozgan Province of Iran was assessed.
- Heavy metal concentrations in the Hara Area were in the order of Pb > Zn > Cu > Cd.
- Heavy metal concentrations in the Azini Bay were in the order of Zn > Cu > Pb > Cd.
- The degree of contamination (Cd) index was lower than 7 across all stations examined.
- Findings are of great importance for the design of long-term management policies.

GRAPHICAL ABSTRACT

$$CF = \frac{C_{metal}}{C_{background}}$$



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ABSTRACT

Sediment quality of mangrove forests in Hormozgan Province of Iran with a focus on two distinct habitats – the Hara Protected Area and the area of the Azini Bay – was studied. The accumulation of heavy metals in the sediments of the Hara Protected Area in terms of concentration was in the order of Pb > Zn > Cu > Cd and in those of the Azini Bay in the order of Zn > Cu > Pb > Cd. Based on Pearson's correlation coefficient, no significant correlations were found between concentrations of heavy metals in the sediments of the Hara Protected Area, while Zn and Pb concentrations were positively correlated in the sediments of the Azini Bay, implying a common pollution source. Common pollution indices, such as Contamination factor (Cf), degree of contamination (Cd), modified contamination degree (mCd), potential ecological risk index (RI) and metal pollution index (MPI), were used for assessing contamination status. The value of contamination (Cd) index was lower than 7 across all five stations of each studied region, implying a low degree of contamination. The modified contamination degree (mCd) index was lower than 1.5, showing that the sediment pollution was low in both regions. The potential ecological risk assessment index was 223.89 and 543.97 for the Hara Protected Area and the Azini Bay, respectively. Based on categorization of Hakanson's ecological risk, the Hara Protected Area region was in the range of 150 ≤ RI ≤ 300 (moderate ecological risk) and the Azini Bay region in the range of 300 ≤ RI ≤ 600

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(acceptable ecological risk). Findings raise awareness of the contamination status of mangrove forests in Hormozgan Province, provide a valuable benchmark for future comparisons in the area, and are important for the design of appropriate policies and long-term management of those ecosystems by local managers and the national authorities.

1. Introduction

Although the ever-increasing development of the industry has multiple advantages, unfortunately, it entails major challenges like the pollution of the environment (Kaewtubtim et al., 2016). Therefore, environmental pollution has emerged as a serious crisis threatening all human activities pertaining to nature (Rothlin and McCann, 2016). In the last two decades, this crisis was mostly related to the pollution of marine environment (Miola et al., 2016). The heavy metal contamination of aquatic ecosystems, as the final receiver of these metals (Peng et al., 2009), has been one of the main concerns and has been subjected to numerous studies throughout the world, including Iran (Garavand et al., 2012; Jorkesh et al., 2014; Bahador et al., 2015; Zhang et al., 2017). Research showed that in regions with high industrial and urban activities, high concentrations of these pollutants are always observed in the sediments and surface waters, posing a threat to the living organisms (Dias et al., 2009; Yan et al., 2015). Heavy metals flow into aquatic ecosystems directly by discharge or indirectly by rain run-off, and also by the atmosphere (De Mora et al., 2004). Industrial and urban effluents and sewages, agricultural run-off, and mining activities are among the main sources of direct inflow of heavy metals into the aquatic ecosystems (Cox and Preda, 2005; Gonzalez-Mendoza et al., 2007). Since pollutants reside in sediments for a long time (Casas et al., 2003), they can reflect the pollution history of an aquatic ecosystem (Singh et al., 2005).

The Persian Gulf has always been influenced by diverse pollution sources, especially heavy metals, due to its specific ecological features and its geographical constraints, as well as a wide range of human activities at the sea and the coastal areas (Agah et al., 2010). Pollution rooted in human activities in the neighboring countries directly flow into the Persian Gulf, severely impacting its marine environment (Bahador et al., 2015). Since heavy metals are stable and do not biologically decompose, they show a high tendency to accumulate in the body of marine organisms, so that they are often accumulated in the tissues of molluscs, bivalves, and fish (Ikem and Egiebor, 2005). These marine organisms are eaten by other organisms, resulting in the spread of pollution along the food chain upwardly towards humankind, posing health risks in certain cases (Mojtahid et al., 2008).

Although heavy metals are a constituent of the earth's crust and naturally occur in all ecosystems, their concentrations have considerably increased by human activities (Kumar et al., 2015). The harmful environmental impacts of heavy metals have turned them into a main subject of environmental research (Odum, 2016). Therefore, they have attracted the attention of many researchers who monitor heavy metal contamination in various ecosystems and search how to cope with it, especially in the recent decades (Rai, 2008; Gupta and Singh, 2011; Martin, 2012; Ali et al., 2013; Ahmed, 2015).

Mangroves are sensitive ecosystems with prominent ecological value that have lost much of their areas across the world, partly because of pollution (Davari et al., 2010). The mangrove forests of Hormozgan Province in the realm of the Persian Gulf and Oman Sea are among ecologically vulnerable regions that are threatened by physical risks, like the overexploitation of the wood and by chemical risks, like the inflow of industrial pollutants, effluents, and home sewage. There are also reports showing the penetration of petroleum and industrial pollutants induced by the surrounding activities (Sheibani Tazraji and Mahmoudabadi, 2014). A review of the literature shows that in addition to the commuting of local and commercial vessels, the fast development of the industries and the urbanization around these regions have brought about the inflow of pollutants, including heavy metals (Pb, Cu, Ni, Cd, Zn) (Bagheri et al., 2013; Bahador et al., 2015; Shirkhanlou et al., 2009). A previous study in the area identified three sources of pollution, i.e., industry, natural mineralogy of soils, and oil, with industrial activities being the most important source (Davari et al., 2010). In the same study, metal concentration in surface sediments ranged as follows: Cd 0.6–3.45, Cu 14.1–98.28, Pb 34.15–191.6, and Zn 44.91–306.15 $\mu g\ g^{-1}$ dry weight. This is an alarm for the need to develop organized plans at a national level to safeguard this invaluable environment. Therefore, it is imperative to know the degree and intensity of impacts of these pollutants, especially on biological communities and to regularly monitor them. The first step to estimate the possible pollution in the region is to make comparison with available standards. However, studies pertaining to the sediment quality of the mangrove forests of Hormozgan are limited.

Several calculation methods have been utilized for quantifying the extent of heavy metal occurrence in sediments, including proposed pollution impact scales (or ranges) to convert the calculated numerical results into broad descriptive bands of pollution (Wu et al., 2014). In the quality assessment of the sediments in the current study, we used contamination factor (Cf), degree of contamination (Cd), modified contamination degree (mCd), potential ecological risk index (RI), and metal pollution index (MPI), which are of the most commonly used quantitative methods for revealing the trend of pollution against the concentrations of the elements in the background samples. These indices consider the bioavailability of the different trace elements and the discrepancy of regional background levels (Li et al., 2013), show easiness in implementation, clarity for use by non-specialist stakeholders, as well as comparability and transparency (Wu et al., 2014). The major limitation is that crucial site-specific considerations cannot be included.

The objective of the present study, which is the first comprehensive investigation of heavy metal contamination in the sediments of mangrove forests of Hormozgan Province, was to document the spatial distribution of heavy metals and identify possible sources of sediment contamination by heavy metals. Sampling was done at full low tide on a daily basis from 10:00 to 15:00 in October to December of 2015. Sediment quality guidelines and standards were also used to compare the concentrations of the heavy metals in the sediments with sediment quality guidelines like National Oceanic and Atmospheric Administration (NOAA) standard, Canadian Interim Marine Sediment Quality (ISQGS) standard, and United States Environmental Protection Agency (USEPA) standard to determine the degree of pollution in the region.