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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

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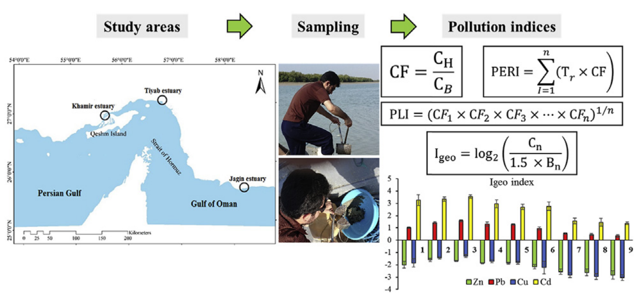
HIGHLIGHTS

- We examined distribution of trace metals in surface sediments along the coastal waters of the Persian Gulf and Oman Sea.
- Metal pollution indices and sediment characteristics were assessed.
- Anthropogenic activities and fine grained sediments might explain for high enrichment.
- Sediment particle size and shrimp farms effluents effects the concentration of trace metals.

GRAPHICAL ABSTRACT



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ABSTRACT

This study aimed to investigate the ecological risk assessment of Khamir, Tiyab, and Jagin estuaries and the impact of anthropogenic activities on these ecosystems during a one-year study period (April 2015 to March 2016) using trace metals as pollution indices. The sediment samples were collected from nine sampling stations, following a gradient of contamination from the industrial wastewater and shrimp farming effluents to the less impacted stations. Pollution indices (i.e. PERI and PLI) were applied to ascertain the sediment quality. Based on pollution indices, the overall pattern of environmental quality status demonstrated that industrial sewage and shrimp farming effluents are major sources of pollution in the Khamir and Tiyab estuaries, respectively. The sediments in the most stations in studied coastal ecosystems of Iran posed moderate or considerable ecological risk. Results from this study showed that Zn, Pb, Cu, and Cd were mostly derived from anthropogenic activities such as domestic sewage and industrial effluents. Also, the findings of this study revealed that the pollution indices are suitable for evaluating the environmental situation of coastal ecosystems and the separation of areas with less impacted by human activities from areas affected by these activities and could be used as a robust management tool for monitoring programs in coastal areas. Altogether, these findings could be useful in

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providing more effective and targeted strategies of development better management practices for coastal areas.

1. Introduction

Estuaries and coastal areas are amongst the most threatened by anthropogenic activities (Mucha et al., 2005) and considered to be naturally stressed ecosystems with changeable physicochemical parameters of water and sediments (Elliott and Quintino, 2007). Trace metals distribution and concentration of these metals closely correspond to different anthropogenic sources such as the petrochemical industry, mining, municipal waste, agriculture, smelting, aquaculture, printing, and the electronic industry (Wang et al., 2013; Sharifinia et al., 2016). The trace metals derived from these sources eventually discharged into the coastal waters where they can be bio-accumulated by various plants, animals, and other living organisms in marine environment and even biomagnified through the food chain (Cardoso et al., 2014).

The ecological risk assessment of the levels of trace metals in coastal ecosystems has attracted a lot of attention from both researchers and policy-makers owing to their potential toxicity, persistence, tendency to bio-accumulate, and public concern for seafood safety (Ye et al., 2012; Adel et al., 2016). For that reason, better understanding and awareness of the trace metals pollution status in coastal environments is important for the public health concerns, seafood industry, and the sustainable development of coastal areas. The fluctuations of trace metals concentration in sediments are usually lower than that in the water columns. Given that sediments act as both trace metal carriers and sink for pollutants, therefore, they reflect the amount of contamination from catchment inputs into the coastal waters. Therefore, there is an urgent need to investigate the metals concentration in the sediment phase (Akcil et al., 2015).

Copper (Cu) and zinc (Zn) are biologically required, but the identification of these metals pollution sources and their behavior in the coastal ecosystems are also important, since they have the potential to be toxic to aquatic organisms above certain threshold concentrations (Vallee and Auld, 1990; Liang et al., 2016). Lead (Pb) is categorized as a priority pollutant because it is not necessary for metabolic activities and can be toxic and harmful even at low concentrations (Telišman et al., 2007; Liang et al., 2016).

During the past twenty-five years, aquaculture activities have expanded in the coastal zone, becoming a potential polluter of marine ecosystems and a concern for the impact on critical environmental parameters (Findlay et al., 1995; Wu, 1995). The most obvious effect of aquaculture activities on coastal environments is the accumulation of organic matter in benthic sediments, owing to its waste of unused food and fecal pellets (Wu, 1995; Neofitou et al., 2010; Tomassetti et al., 2016). The settlement of uneaten food and fish feces from fish farms results in accumulation of organic matter on the sea bottom, and such organic enrichment generally has a strong impact on local environment changes (Hargrave, 2010; Neofitou et al., 2010; Tomassetti et al., 2016). Furthermore, aquaculture activities may also impose adverse effects by discharging considerable amounts of various trace metals to the ambient coastal environment (Tal et al., 2009; Liang et al., 2016). Therefore, monitoring risk assessment of trace metals using pollution indices (Yap et al., 2002; Bastami et al., 2015) would provide a certain theory support for risk management and ecological assessment programs in coastal systems.

The Persian Gulf is a semi-enclosed marine system surrounded by eight countries, many of which are experiencing a rapid and very extensive coastal development. In terms of pollution, estuaries in southern Iran are increasingly influenced by various anthropogenic pressures, with several of these systems being extensively impacted by human activities (Taherizadeh and Sharifinia, 2015; Kamrani et al., 2016). Furthermore, the Persian Gulf has been subjected to several additional anthropogenic stresses such as fisheries, oil pollution, wastewater effluents, dredging and reclamation, the passage of oil tankers, and hypersaline water discharges from desalination plants. Some of the less-polluted areas have been developed recently for shrimp farming. Thus, there is a pressing need to ecological risk assessment of pollution for the Persian Gulf and Gulf of Oman coastal waters, and knowing this information would be instructive for understanding and communicating ecological risk assessment phenomena in estuaries elsewhere.

In the present study, three subtropical estuaries along the Persian Gulf and Gulf of Oman (Khamir, Tiyab, and Jagin estuaries) spanning a range of anthropogenic impacts were sampled for sediment variables. Sampling locations differ in terms of their proximity to human and industrial activities in one estuary (Khamir), a shrimp farm in a second estuary (Tiyab), and a third estuary (Jagin) with less human impact. Therefore, this study aimed to: (a) evaluate the concentration of trace metals in surface sediments impacted by anthropogenic activities, (b) evaluate the spatial distribution patterns of trace metals and the degree of contamination using pollution indices and (c) determine ecological risk assessment of Zn, Pb, Cu, and Cd in surface sediments of the Persian Gulf and Gulf of Oman.

2. Material and methods

2.1. Study areas and site descriptions

The Persian Gulf is a semi-enclosed, marginal sea that is subject to arid and subtropical climate with minimum water exchange (3–5 years' water residence time) and average depth of 35–40 m. It is located between latitudes 24°–30° N, and is surrounded by most of the Earth's deserts (Kämpf and Sadrinasab, 2006). The study was carried out along the Iranian coasts of the Persian Gulf and Gulf of Oman. Three subtropical estuarine systems were sampled: Khamir, Tiyab (both located on the coast of Persian Gulf), and Jagin (located on the coast of Gulf of Oman; Fig. 1). The study areas have shallow depth and high temperature and salinity, and negligible precipitation, therefore, the impacts of pollution on the marine environment can be significant. The sediment of these areas where mangrove forests are located is muddy with high salinity water (Ebrahimi-Sirizi and Riyahi-Bakhtiyari, 2013). Annually, many oil tankers and ships transport high volumes of petroleum products through the Persian Gulf. Hence, the Khamir and Tiyab estuaries which are located in the north and northeast of Persian Gulf are continuously exposed to petroleum pollution.

Khamir estuary: this estuary is located in the northern part of the Persian Gulf, suffering from municipal and industrial wastewater load on regular daily basis over the past three decades. The estuary is favorable and common habitat for different fish and