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Review

Assessment and management of heavy metal pollution in the marine environment of the Arabian Gulf: A review

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ABSTRACT

The Arabian Gulf is considered among the highest anthropogenically impacted regions in the world. Heavy metals contamination in coastal and marine environments is becoming an increasingly serious threat to both the naturally stressed marine ecosystems and humans that rely on marine resources for food, industry and recreation. Heavy metals are introduced to coastal and marine environments through a variety of sources and activities including sewage and industrial effluents, brine discharges, coastal modifications and oil pollution. The present paper reviews heavy metal contamination in a variety of marine organisms, and sediments, and suggests measures for environmental management of heavy metal pollution in the Arabian Gulf. Most of the reviewed literature confirmed that heavy metal concentrations in marine organisms were generally within allowable concentrations and pose no threat to public health. Likewise, studies suggested that levels of heavy metals in marine sediments are similar or lower compared to other regions. However, localized hotspots of chronic metal pollution in areas influenced by industrial facilities, desalination plants, and oil refineries have been reported. Holistic spatial and temporal monitoring and comprehensive national and regional strategies are critical to combat and manage heavy metal pollution in the Arabian Gulf.

Contents

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1. Introduction

Heavy metals are considered a major anthropogenic contaminant in coastal and marine environments worldwide (Ruilian et al., 2008). They pose a serious threat to human health, living organisms and natural ecosystems because of their toxicity, persistence and bioaccumulation characteristics (DeForest et al., 2007). Many heavy metal ions are known to be toxic or carcinogenic to humans (Fu and Wang, 2011). Heavy metals can contribute to degradation of marine ecosystems by reducing species diversity and abundance and through accumulation of metals in living organisms and food chains (Hosono et al., 2011). Anthropogenically, heavy metals can be introduced to coastal and marine environments through a variety of sources, including industries, wastewaters and domestic effluents (Fu and Wang, 2011).

Heavy metals contamination in coastal and marine environments of the Arabian Gulf is becoming an increasingly serious threat to both the naturally stressed marine ecosystems and humans that rely on marine resources for food, industry and recreation. The Arabian Gulf is a semi-enclosed sea situated in the subtropical zone and characterized by marked fluctuations in sea temperatures and high salinities. It is relatively a shallow basin with an average depth of 35 m (Sheppard et al., 2010). Flora and fauna species in the Arabian Gulf inhabit one of the harshest marine environments due to natural stressors represented by higher levels of salinity and temperature, and reduced levels of pH (Uddin et al., 2012). Native marine organisms of the Arabian Gulf are living close to the limits of their environmental tolerance (Price et al., 1993). Despite these harsh environmental conditions, the Arabian Gulf supports a range of coastal and marine habitats such as mangrove swamps, seagrass beds, coral reefs, and mud and sand flats (Naser, 2011a). These habitats provide feeding and nursery grounds for a variety of marine organisms, including a number of valuable commercial species (Carpenter et al., 1997).

In the past few decades, Arabian Gulf countries have witnessed major economic, social and industrial developments. The coastlines of the Arabian Gulf have been extensively developed and modified. Dredging and reclamation, industrial and sewage effluents, hypersaline water discharges from desalination plants, and oil pollution are examples of anthropogenic stresses that contribute to environmental degradation in the Arabian Gulf (Sheppard et al., 2010), which is classified among the highest anthropogenically impacted regions in the world (Halpern et al., 2008). These anthropogenic activities are mobilizing and discharging elevated levels of heavy metals into the marine environment of the Arabian Gulf (Naser, 2012a). Metal pollution in the Arabian Gulf could be intensified due to the relatively long time of seawater flushing, which is estimated to be in the range of 3–5 years (Sheppard et al., 1992). Therefore, pollutants such as heavy metals are likely to reside in the Arabian Gulf for considerable time.

People of the Arabian Gulf are related economically and socially to the sea. Waters of the Arabian Gulf have been rich in varieties of fish, which are a major source of food for local people. Marine environments of the Arabian Gulf are contributing substantially to the sectors of industry, trade, shipping, tourism, electricity production, and water desalination. Indeed, most of the fresh water needs in the Arabian Gulf countries are being obtained from seawater through the various processes of desalination (Hashim and Hajjaj, 2005). Consequently, additional anthropogenic inputs of heavy metals in the Arabian Gulf might be critical not only to vulnerable and fragile ecosystems, but also to humans' health and well-being.

The objectives of this paper are to identify major anthropogenic impacts contributing to heavy metal loads in coastal and marine environments of the Arabian Gulf, review literature dealing with heavy metal contamination in a variety of living organisms and sediments, and suggest measures contributing to environmental management of heavy metal pollution in the Arabian Gulf.

2. Major anthropogenic sources of heavy metals

2.1. Reclamation and dredging

The coasts of the Arabian Gulf are undergoing rapid construction activities that are often associated with intensive dredging and reclamation (Naser, 2011b). Coastal and marine environments in the Arabian Gulf are the prime target for most of the major housing, recreational, and economic developments (Naser et al., 2008). It is currently estimated that more than 40% of the coasts of the Arabian Gulf have been developed (Hamza and Munawar, 2009). Dredging and reclamation processes are typically associated with short and long term biological, physical and chemical impacts. These activities may result in physically smothering the coastal and subtidal habitats and deoxygenating the underlining sediments (Newell et al., 1998; Allan et al., 2008). Physical and chemical alternations due to dredging and reclamation may reduce biodiversity, richness, abundance and biomass of marine organisms (Smith and Rule, 2001). Additionally, elevated levels of heavy metals are mobilized during dredging and reclamation activities (Guerra et al., 2009; Hedge et al., 2009). These contaminants may enter important food web components including fish and shellfish, and ultimately pose threats to human health.

2.2. Sewage discharges

Sewage discharges are major sources of coastal pollution in the Arabian Gulf countries. Despite high standards of sewage treatment throughout the Arabian Gulf countries (Sheppard et al., 2010), large quantities of domestic effluents are discharged to coastal and marine environments. These effluents are characterized by high-suspended solid and high load of nutrients such as ammonia, nitrate and phosphate (Naser, 2011a). Sewage effluents are generally accompanied by biological and chemical pollutants, including heavy metals (Al-Muzaini et al., 1999; Shatti and Abdullah, 1999) that may cause degradation in the receiving coastal and marine environments, and subsequently affect the quality of human food and health (Singh et al., 2004)

2.3. Industrial effluents

The Arabian Gulf countries have witnessed a rapid industrial growth, mainly in the sectors of oil refining, petrochemical industries. These major industries are discharging wastewater containing a variety of chemicals, including heavy metals, hydrocarbon compounds, and nutrients (Sale et al., 2010). Petroleum refinery wastewaters are composed of different chemicals, which include oil and greases, phenols, sulphides, ammonia, suspended solids, and heavy metals like chromium, iron, nickel, copper, molybdenum, selenium, vanadium and zinc (Wake, 2005). Coastal and marine environments receiving intensive industrial effluents along the coastline of the Arabian Gulf are recognized as hotspots for high concentrations of heavy metals (De Mora et al., 2004, 2010; Naser, 2012a).

2.4. Desalination plants

The Arabian Gulf countries are witnessing rapid industrial development and population growth, which increase the need for fresh water (Smith et al., 2007). Due to the low precipitation and high aridity in the Arabian Gulf countries, most of the fresh water

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