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The distribution, contamination and risk assessment of heavy metals in sediment and shellfish from the Red Sea coast, Egypt

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HIGHLIGHTS

- Some metals exceed CCME level in the areas of Safaga city and Nuwebia port.
- Ubiquitous contaminants were Zn, Cu and Ni.
- Areas of expected potential ecotoxicological risk were identified.
- RQ calculation showed that Cu was the only heavy metal had an adverse effect on toddlers' health.

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ABSTRACT

Zn, Cu, Ni, V, Al, Pb, Cd, Hg, lipid and water contents were determined in the soft tissues of different shellfish species collected along the Red Sea shoreline. Metal contents showed a descending order of Zn > Cu > Ni > Al > V > Pb > Cd > Hg. The leachable concentrations found in the sediments gathered from the studied locations gave another descending order: Al > Zn > Ni > Pb > V > Cu > Cd. The determined leachable heavy metal contents in the sediment did not exceed the NOAA and CCME (Anonymous 1999) sediment quality guidelines. Accordingly, the sediments along the Egyptian Red Sea area did not pose any adverse impacts on the biological life. According to the hazard quotient (HQ) calculations for heavy metal contents in the soft tissue of shellfish, mercury did not pose any risk on human health; whereas, the other determined heavy metals gave HQ values of 1 < HQ < 10 and showed a possibility of risk on the long term. Cu is above the desirable levels in mussels. The RQ calculations of toddlers and adults reflected that Cu was the only heavy metal that had an adverse effect on toddlers' health. Based on the human organizations (EPA, BOE, MAFF, and NHMRC) that proposed safety concentrations of heavy metals, the studied shellfish were somewhat safe for human consumption.

1. Introduction

Metals are a group of the most important pollutants which cause considerable harm to the environment when they exceed certain concentrations (Pejman et al., 2016; Zhang et al., 2016; Otansev et al., 2016). Heavy metals are deemed serious pollutants due to their toxicity, persistence and non degradability in the environment. The importance of heavy metals in coastal environments is derived from both their potential toxic effects and excessive anthropogenic sources that can be equal to or exceed the natural input (Hyun et al., 2006; El Nemr, 2015) . From this point of view, studying the relationships between the concentrations of pollutants in the sediments and corresponding mussels can be a valuable tool to assess the contamination levels and risks to the population (María-Cervantes et al., 2009; Khaled et al., 2013a,b). Marine organisms, especially mussels, have the ability to accumulate metals from the environment. Mussels are considered reliable bioindicators that can identify biologically available metals (El Nemr and El-Said, 2014). Their usefulness as sentinel organisms in metal biomonitoring studies is widely recognized (Ünlü et al., 2008; Çulha et al., 2011). Also, heavy metal concentrations may affect the diversity and the abundance of mussel species along the polluted areas (Chen et al., 2010). Factors known to influence metal accumulation in these organisms include: metal bioavailability, season of sampling, hydrodynamics of the environment, size, sex, changes in tissue composition and reproductive cycle (Szefer et al.,

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2004). Seasonal variations related to a great extent to seasonal changes in flesh weight during the development of gonadic tissues (Szefer et al., 2004). Heavy metal concentration in sediment, which is essential to the functioning of aquatic ecosystems, is a lot greater than the same metals in the water column (Ünlü et al., 2008). The bioaccumulation of sediment-bound metals by benthic species is extremely important to the food webs and their eventual transfer back to man. Potential human risk exists universally because of the consumption of seafood contaminated by persistent pollutants. Some studies on persistent pollutant contamination in organism tissues associated with the human risk assessment have been carried out (El Sikaily et al., 2004; Binelli and Provini, 2004; Jiang et al., 2005; Yang et al., 2006; Li et al., 2008; Jia et al., 2010; El Nemr et al., 2012a,b, 2016).

Consequently, potential public health risks from dietary exposure to the heavy metals continue to be the subject of research and regulation. Several methods have been proposed for the assessment of the potential human health risks from their chemical exposures (El Nemr et al., 2013; Salem et al., 2014a,b; Pejman et al., 2016; Zhang et al., 2016). Current non-cancer risk assessment methods are typically based on the use of the hazard quotient (HQ); a ratio between the estimated dose of a contaminant and the reference dose below, which will not have any appreciable risk (Health Canada, 2007). If such ratio exceeds unity, there may be concerns of potential health effects. A different approach to estimating the exposure by the incremental lifetime cancer risks (ILCR), the carcinogenic risk based on the estimated daily intakes that was determined for adults, and the toxicological reference values for each contaminant, were reported (Health Canada, 2007; El Nemr, 2010; Giri et al., 2011; Wang et al., 2011; Nadal et al., 2011). Also, human health after seafood ingestion (RQ) is estimated by dividing the tolerable daily intakes by the consumption rates (PEMSEA, 2001). The distribution and environmental impacts of metals in marine sediments and mussels in the Egyptian Red Sea area have been reported (El Nemr et al., 2004, 2006, 2014, 2016; El-Moselhy et al., 2014; El-Sorogy and Attiah, 2015; El-Taher and Madkour, 2011; Mansour et al., 2013; Mustafa et al., 2016).

Accordingly, with the consequent risk of contamination by mussel ingestion for the local population and for tourists from other regions, the aim of this work is to study the heavy metal concentrations, distribution and sources in sediments, as well as bioaccumulation of some heavy metals in different mussels from the Egyptian Red Sea coast. Also, it is important to estimate the human health risk due to mussel ingestion since it is a marine organism that is supposed to be a source of seafood for human consumption.

2. Materials and methods

2.1. Sampling

The samples (sediments and shellfish) were collected from fourteen locations (Taba, Nuweiba, Dahab, Na'ama Bay, Ras Mohamed, El Tour, Suez, Ras Gharib, Hurghada-NIOF, Hurghada-Sheraton, Safaga, Quseir, Marsa Alam and Shalatin) distributed along the Egyptian Red Sea coast during July–August 2009, Fig. 1. However, these locations are known for their human activities including; oil pollution, industrial, agriculture, sewage and domestic wastes (Khaled et al., 2003, 2006; El Sikaily et al., 2004, 2005; El Nemr et al., 2006; Youssef and El-Said, 2011). Taba, Nuweiba and Dahab are located on the Egyptian coast of Aqaba Gulf. El Tour, Ras Suder, Suez, Ain Sukhna and Ras Gharib sites are on the Egyptian coast of Suez Gulf. Na'ama Bay and Ras Mohamed are found in-between Aqaba and Suez Gulfs. Hurghada-NIOF, Hurghada-Sheraton, Safaga, Quseir, Marsa Alam and Shalatin sites

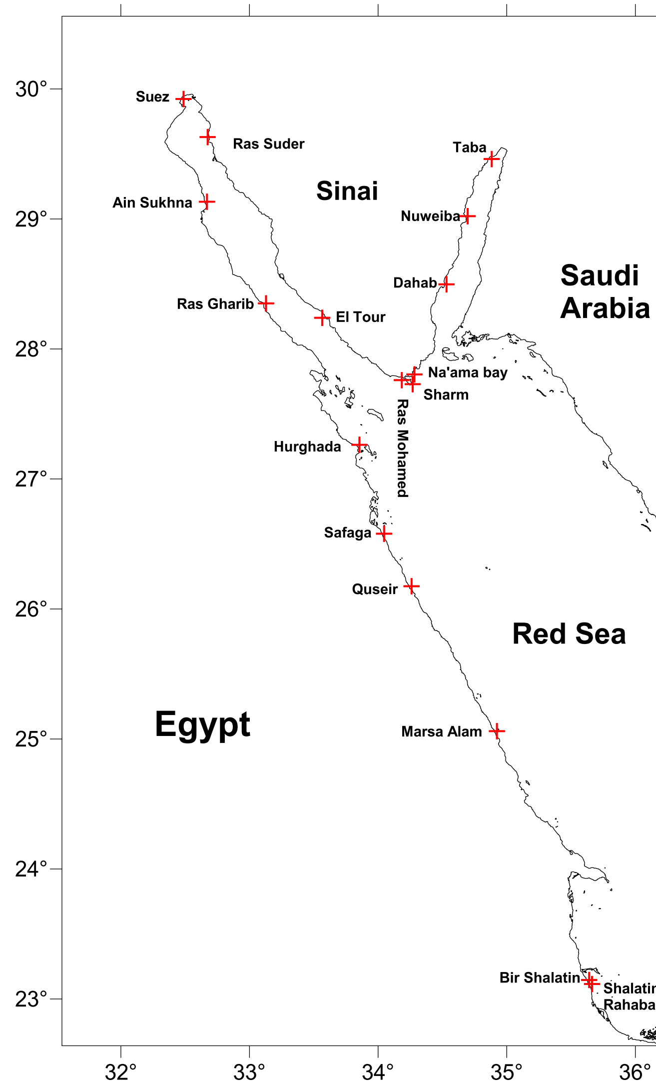

Fig. 1. Sampling locations along the Egyptian Red Sea coast.

are along the west side of the Red Sea proper coast.

The sediment samples were collected from a depth ranging between 3 and 5 m with a 0.025 m^2 Van Veen grab sampler. Only grabs that had achieved adequate penetration (2/3 of total volume) to collect the first 5 cm of the sediment and that showed no evidence of leakage or surface disturbance were retained and transferred to a cooler. When sufficient sediment was collected from a particular station, the contents of the cooler were homogenized with a Teflon spoon until no color or textural differences could be detected. The coolers were then chilled (−4 °C) and transported to the laboratory. From each sampling location, three replicates were taken. Samples were received at the laboratory 8–10 h after collection. Samples were transferred to the lab into labeled polyethylene bags and stored at −20 °C until analysis. In the laboratory, sediment samples were defrosted at room temperature and air-dried in a controlled clean environment. Then, the samples were transferred to an oven and dried at 105 °C up to a constant weight. Each sample was homogenized, sieved using a 0.75 mm plastic sieve and finely powdered in an agate mortar. For Aqaba Gulf sediments, the texture varied from medium to coarse sand type; however, almost all Aqaba Gulf sediments were coarse sand (Draz et al., 2009). Suez Gulf sediments were of a sand character and