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FULL LENGTH ARTICLE

The monitoring and risk assessment of aliphatic and aromatic hydrocarbons in sediments of the Red Sea, Egypt

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Abstract Polycyclic aromatic hydrocarbons (PAHs) and aliphatic hydrocarbon were analyzed in sediments collected from the Suez Gulf, Aqaba Gulf and the Red Sea proper stations Egypt. A geological study demonstrated that the sediments in the studied area have a nature from very fine sand to very coarse sand, mainly biogenic fragments, and carbonate aggregates. Total aliphatic hydrocarbon concentrations (C14–C32) ranged from 33.97 to 553.48 ng/g with a mean value of 174.8 ± 167.06. The highest and lowest alkane concentrations are recorded at El-Tour and Ras Mohamed, respectively. Accordingly, the variation in *n*-alkanes content may refer to the anthropogenic sources (sewage, industrial discharges, and shipping activities) and natural inputs (submerged/floating macrophytes and emergent terrestrial plants and microbial activity). Meanwhile, ΣPAH concentrations were in the range of 0.74–456.91 ng/g, with the mean value of 32.94 ng/g. The highest concentration of total PAHs is recorded in sediments collected from El-Quseir (456.91 ng/g), followed by that in Sharm El Mayaa (100.05 ng/g) and Suez 10 (97.19 ng/g); while lower concentrations are detected in Sheraton (0.74 ng/g), Ras Mohamed and Na'ama Bay (0.74, 6.86 and 11.1 ng/g, respectively). In this context, ratio of low molecular weight of PAHs (2- and 3-rings) to high (4- to 6-rings) has been used to differentiate between the pyrogenic and petrogenic sources of PAHs in the studied samples. In all studied stations, ΣLPAHs/ΣHPAHs ratios were < 1, revealing their pyrogenic sources. The concentration levels of PAHs in the current study were compared to the effect range low (ERL) and the effect range medium (ERM) values; the average concentration of level of PAHs for all investigated stations was below the ERL except El-Quseir station which recorded PAHs higher than the ERL but still lower than the ERM. This finding indicated that PAHs in surface sediments of the studied area have no adverse biological effects except at El-Quseir which may cause mild adverse biological effects but not acute effects. To assess the potential health risk of PAHs; the BaP equivalent (BaPE) is used. High levels of BaPE values were found

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at El-Quseir only, indicating that PAHs in this site showed relatively high toxicity among all sites. Toxic equivalency factors (TEFs) of seven carcinogenic PAHs (BaA, BbF, BkF, BaP, Chr, DBA and InP), were used to quantitatively assess the potential toxicological significance to human health. In this study, the toxic equivalent (TEQ_{carc}) values of sediment samples varied from not detected (ND) to 72.27 ng TEQ g^{-1}, with the mean value of 2.94 ng TEQ g^{-1}. The higher total TEQ_{carc} values were found at El-Quseir Station 72.27 ng TEQ g^{-1}.

Introduction

The polycyclic aromatic hydrocarbons (PAHs) have been listed as persistent organic pollutants (POPs) (Hu et al., 2007; Chung et al., 2007; Christensen and Arora, 2007; Tsang et al., 2011). PAHs can exert adverse effects on the environment and human health even far away from their origin (Petra et al., 2010). Many studies reported that PAHs were widespread and can be accumulated in various environmental systems (Liu et al., 2007). PAHs tend to be adsorbed tightly to sediments in aquatic system (Mouton et al., 2009; Li et al., 2009; Xu et al., 2014). Petroleum hydrocarbon pollution has been an increasing concern in the last 40 years due to its wide usage as an energy source in most industrial and developing countries. Petroleum hydrocarbons generated from human activities and industrial processes are widespread and cause serious environmental problems due to their persistence, toxic, mutagenic, bioaccumulation and carcinogenic properties (Sakari et al., 2008). Aliphatic and aromatic hydrocarbons inter to the environment through leaks, spills or accidents, industrial releases, or as by-products from commercial or domestic uses (Ou et al., 2004). Aliphatic hydrocarbons consist of straight and saturated carbon chain starting from C6–C40 containing odd and even carbon numbers indicating anthropogenic and natural hydrocarbon sources (El Sikaily et al., 2002, 2003; El Nemr and El-Said, 2012; El Nemr et al., 2004, 2007, 2012, 2013).

PAHs are compounds containing two or three aromatic rings with a linear, cluster and angular arrangement. These compounds are divided into two categories based on molecular weight; first, high-molecular weight (HMW) compounds containing 4–6 combined rings, like indeno (1, 2, 3-c, d) pyrene; second, low-molecular weight (LMW) compounds containing two or three combined benzene rings, like naphthalene, anthracene and fluorene (Tolosa et al., 2005; Abdollahi et al., 2013).

Aliphatic and aromatic hydrocarbons cause significant environmental problems due to their carcinogenicity and mutagenicity (Christensen and Bzdusek, 2005; Meyer et al., 2011). PAHs tend to be sorbed to sediments (Manariotis et al., 2011), which may release back into the water column by any chemical change in the aquatic system (Sofowote et al., 2008; Zhang et al., 2012).

The Northern Red Sea is an important sea area both for fishing and for its unique and often spectacular marine environment (Morgan, 2004).The sources and causes of water pollution in the Red Sea can be categorized into: sewage, persistent organic solids, heavy metals, oils (hydrocarbons), nutrients, sediment mobilization, and litter. The Gulf of Suez occupies the northwestern arm of the Red Sea between the Sinai Peninsula (east) and the Africa proper (west) of Egypt. The bay is subjected to different sources of pollution. The first and dangerous one is the oil effluents that discharge from the industrial complex south of Suez, which includes the oil refineries of El-Nasr and Suez Petroleum Companies (El Nemr, 2005, 2011, 2012). The second pollution source is the sewage of Suez City, which discharges into the bay (Nassar and Hamed, 2003). The Gulf of Aqaba is the second arm of the triple junction system (Limits of Oceans and Seas, 2010). The environmental problems in the region of the Gulf of Aqaba are primarily induced by associated activities of tourism and maritime traffic. Human impacts on the environment can be summarized into seven broad categories, as follows: wastewater management practices, solid waste management practices, ship-based activities, ferry traffic, tourism, cruise-boating, and marine aquaculture (REMIP, 2008). This study is a continuation of the previous work to further investigate the possible PAH sources and their trends in the Red Sea. The objectives of the current study were to: (1) measure the concentrations of PAHs in surface sediment of Suez Gulf, Aqaba Gulf and the Red Sea to investigate the sources of PAHs pollution, (2) evaluate the relationship between PAH compositions and particle size fractions, and (3) assess the potential human health risk.

Materials and methods

Sediment sampling

Surface sediment samples were collected from sixteen different locations along the Suez Gulf, Aqaba Gulf and the Egyptian Red Sea coast during 2011 (Fig. 1). Surface sediments were collected with Van Veen grab from the upper 5 cm. After collection, samples were putted in pre-cleaned wide-mouth glass bottles, stored at −20 °C until analysis. The samples were analyzed according UNEP techniques (UNEP/IOC/IAEA, 1991, 1992). The samples were air dried at room temperature, then kept in a clean stopped polyethylene bottle to be ready for grain size, total organic carbon (%TOC), and total organic matter. The water content for sample was estimated by drying exact weight of each sediment sample in the oven at 105 °C to a constant weight.

Grain size analysis

The grain size analysis was determined according to Folk (1974). The samples were air dried, then split to ensure that representative portions of the samples will be examined. About 50 g of each representative sample was washed thoroughly by