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Original article

Benthic foraminifera and trace metal distribution: a case study from the Burullus Lagoon, Egypt

Sherif M. El Baz *, Mohamed M. Khalil

Damietta University, Faculty of Science, Geology Department, 34517 New Damietta, Egypt

Abstract

Benthic foraminifera are widely used to detect the health of their habitat, where they are very sensitive to even slight variations in the ecosystem. Therefore, the main objectives of this study are to examine the benthic foraminiferal assemblages in the sediments of Burullus Lagoon, evaluate the pollution levels and deduce the impact of trace metals on foraminifera. The continuous discharge of trace metals from agricultural, industrial and domestic sources into the lagoon may lead to a severe environmental problem. The concentrations of Mn, Cu, Cd, Zn and Pb within the sediments were measured. Recently, the assessment of contamination is principally based on the contamination indices which provide fast and simple quantitative values on the degree of pollution in a given aquatic environment. Thus, some indices, including the contamination factor, the degree of contamination, pollution load index, geoaccumulation index, ecological risk factor and potential ecological risk index are applied in this investigation. Based on the contamination factors, the sediments are very highly contaminated with Cd, considerably to very highly contaminated with Cu and Zn, moderately contaminated with Mn, low to moderately contaminated with Pb. All sites display very high values for the degree of contamination. Moreover, the values of the pollution load index are higher than 1, indicating that the lagoon is polluted. Depending on the geoaccumulation index, the contaminants are arranged as follows Cd > Zn > Cu > Mn > Pb. It is clear that Cd is the main contributor to the ecological risk factor in Burullus Lagoon. Concerning the richness of the foraminiferal assemblages, it fluctuates between 1–5 species per sample. Because of its higher tolerance to extreme conditions (changes in salinity and pollution), *Ammonia tepida* is the most abundant species. The occurrence of rare living individuals (25) is restricted only to sites close to El-Boughaz Inlet where higher salinity and lower levels of pollution are recorded. The same trend of distribution is shown by *Cribroelphidium excavatum* and miliolids, where they occur at sites with higher salinities. The occurrence of test deformities in all the studied sites may be related to the response of benthic foraminifera to trace metal. The forms of deformation include spiroconvex, reduced chambers, twisted tests, twinning, additional chamber and complex forms. The deformation depends on the nature of pollutants. Twinning and reduced chambers are the most dominant forms in areas close to the agricultural drainage (southern drains), while complex forms are abundant in areas close to industrial drainage (El-Gharbia drain). Thus, salinity and pollution may be the most regulatory factors controlling the distribution of foraminifera. This investigation confirmed the role of benthic foraminifera as a good ecological indicator in Burullus Lagoon.

Keywords: Trace metals; Benthic foraminifera; Deformities; Burullus Lagoon; Egypt

1. Introduction

Recently, the levels of contamination around urban communities and coastal areas are rapidly increasing due to the anthropogenic activities. Trace metals are one of the principal constituents of these contaminants. Due to the persistence of trace metals, it is very hard to dispose of them from the environment (e.g., Diagomanolin et al., 2004; Soliman et al., 2015; El-Sorogy et al., 2016). The accumulation of trace metals is controlled by several parameters including the sediment grain size, temperature, salinity, pH, organic matters and hydrodynamic forcing (e.g., Wang et al., 2002; Mallick et al., 2016; Gurumoorthi and Venkatachalapathy, 2016). The study of El Nemr (2003) on the Burullus Lagoon suggested that the

* Corresponding author.
E-mail address: Sherif772003@du.edu.eg (S.M. El Baz).

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anthropogenic input is the chief source of trace metal contamination. Abd El-Hamid et al. (2016) indicated that the sediments from the Egyptian Mediterranean coast are mostly polluted with Zn and Pb. Moreover, the analysis of El-Sorogy et al. (2016) on the Abu Khashaba beach, Rosetta area, Egyptian Mediterranean coast showed that the sediments are strongly contaminated with Cd, As and Pb. These observations were also confirmed by several studies, such as Uluturhan, 2010; Diaz-de Alba et al., 2011; Ameen et al., 2013; Nasr et al., 2015; Soliman et al., 2015; Ayadi et al., 2016. The continuous discharge of trace metals, from agricultural, industrial and domestic sources, into the aquatic environments causes severe effects on the nature of water, sediments and biota. Some metals such as Cu, Fe and Zn are basic micronutrients for biota, however, they are risky at abnormal states, while Pb, Cr and Cd are among the carcinogenic elements (Forstner and Wittmann, 1983). Ameen et al. (2013) displayed the harmful effects of trace metals on the biodiversity in Burullus Lagoon.

Because of the accumulation of these metals in the sediments, they are broadly utilized to evaluate the status of the environment (e.g., Hakanson, 1980; Tomlinson et al., 1980; Selvaraj et al., 2004; Chen et al., 2010; Zahran et al., 2015). Hakanson (1980) introduced a risk index which provides a fast and simple quantitative value on the potential ecological risk of a contaminated aquatic environment. In order to assess the human impacts on coastal aquatic environments using sediments, Birch (2003) proposed the enrichment factor. Based on the contamination indices, Masoud et al. (2011) evaluated the degree of pollution in the sediments of Burullus Lagoon. They assumed that, the lagoon is considered as of very high degree of contamination. Okbah et al., 2014) indicated that the Egyptian Mediterranean coast is not contaminated with Cu, Cr, Mn, Ni, Zn and Pb, based on the results of the geo-accumulation index. Depending on the geo-accumulation index, Shalaby et al. (2017) established that the sediments of Burullus Lagoon are unpolluted with Mn and Pb, unpolluted to moderately polluted with Zn and strongly polluted with Cd. They also concluded that, Cd exhibits very high ecological risk factor in Burullus and Manzala lagoons.

The transitional environments are characterized by the existence of abundant numbers of benthic foraminifera (Sen Gupta, 1999). Their distribution patterns are mainly based on some parameters including salinity, dissolved oxygen, food, temperature, substratum type, water depth and levels of pollution (e.g., Samir, 2000; Murray, 2006; Armynot du Châtelet and Debenay, 2010; Alve et al., 2016). Schönfeld et al. (2012) and Barras et al. (2014) concluded that the living individuals reflect the foraminiferal response to prevailing environmental conditions. Concerning test deformities, Alve (1991) illustrated that the normal rate of deformed tests in a non-stressed population is about 1%. According to Boltovskoy et al. (1991) and Alve (1995), test deformities may be a result of several effects and would be very difficult to separate any single specific reason. Samir (2000) concluded that benthic foraminifera are more sensitive to industrial wastes having trace metals. Samir and El-Din (2001) detected a strong relationship between deformed tests and trace metals concentration in El-Mex Bay (Egypt). Moreover, Geslin et al. (2002) examined the morphological abnormalities of recent benthic foraminiferal tests in paralic environments of Brazil. They concluded that, it is difficult to differentiate between the effect of natural stress and anthropogenic influence. Burone et al. (2006) established that the differences among foraminiferal associations along the Uruguayan coast appeared to be related to the combination of several types of pollutants and the natural abiotic variables, such as the rapid salinity changes that occurred in this area. The study of Coccioni et al. (2009), in the Adriatic Sea, revealed a negative relationship between trace element concentrations, species richness and the relative abundance of *Ammonia parkinsoniana*. Similarly, Sundara Raja Reddy et al. (2012) proved that concentrations of contaminant in sediments tended to be negatively correlated with foraminiferal abundance and diversity, and positively correlated with the commonness of deformed tests. Consequently, benthic foraminifera are widely used to detect the health of their marine environments, where they are very sensitive to even slight variations in the ecosystem.

The main objectives of this study are to examine the benthic foraminiferal assemblages in the sediments of Burullus Lagoon, assess the degree of contamination and deduce the response of foraminiferal species to pollution.

2. Study area

The Burullus lagoon represents one of the most important coastal lagoons in northern Egypt. In terms of fish production, it accounts for 42% of the production of the northern lagoons. The area covered by the lagoon is estimated by 420 km^2. Unfortunately, it is subjected to continuous reduction, resulting from reclamation projects on the eastern and southern shores. It is separated from the Mediterranean Sea by a narrow sandy bar covered by sand dunes, sabkhas and sand flats, but it connects with the sea through the El Boughaz inlet in the northeastern part (Fig. 1). Moreover, it incorporates some islets, those close to the El Boughaz inlet are comprised of sand, while the others are comprised of clay. The amount of drainage water that is entered annually into the lagoon is fluctuating from one year to the other, with an average amount of about 2.5 billion m^3/year (El-Adawy et al., 2013). The lagoon receives agricultural drainage water along with waste from fish farms (Tira drains, drain 7, drain 8 and drain 11), waste water effluents (Tira drains, drain 7 and El-Gharbia drain) as well as the industrial drainage water discharged from the El-Gharbia drain (Fig. 1).

The lagoon is categorized into three divisions: eastern, middle and western, each one has its own characters. The eastern sector covers an area of about 117.6 km^2, with a maximum width of 14 km. It represents the shallowest part with a mean of 0.8 m (Masoud et al., 2011). The highest values of salinity are recorded in this sector due to the connection with the sea through the El Boughaz inlet. The eastern drains include El Gharbia, Baltim, Tirah and Nasser. The central part occupies an area of about 189 km^2. The depths fluctuate between 40–130 cm. The southern drains include drains 7, 8 and 9. Intermediate values of salinity are recorded in this sector. The width of the western part is about 4 km. The depth decreases westwards. It displays the lowest values of salinity due to the discharge of Drain 11 and Brimbal canal. The study area suffers from pollution resulting from the continuous discharge of the drains into the lagoon. Ameen

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