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Benthic foraminiferal assemblages as bio-indicators of metals contamination in sediments, Qarun Lake as a case study, Egypt

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ABSTRACT

Qarun Lake, in the Fayoum Depression of the Western Desert of Egypt, lies within the deepest area in the River Nile flood plain. The drainage water in the Qarun Lake is derived from the discharge of the natural and artificial drainage systems in the Fayoum. Mixed domestic and agricultural pollutants, including heavy metals, nitrates, phosphates, sulfates and pesticides, are discharged into Qarun Lake. Forty-six samples, collected from the undisturbed layer of sediments were used for benthic foraminiferal analysis. Concentrations of some selected trace metal elements (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sr, V, and Zn) were also determined. Statistical analysis of the abiotic variables (Texture distribution of sediments, Physico-chemical parameters, and metals concentrations) and of the biotic variables (distribution of benthic foraminiferal species) were also performed. The Q-mode cluster analysis of benthic foraminiferal distribution has provided evidence that the Qarun Lake can be subdivided into two cluster groups (A and B), reflecting environmental changes in the lake ecosystem. Cluster B can also be subdivided into two sub-clusters (B1 and B2). The presence of only pollution tolerant taxa with higher faunal density and lower diversity and the absence of the other foraminiferal assemblages in cluster A were attributed to the high concentration of trace metal elements and the strong environmental stress at the eastern and central parts of the Qarun Lake.

1. Introduction

Sediments act as a major repository for pollutants in watershed systems and can preserve a record of the pollution sources and pathways (Degetto et al., 1997). Sediments can become toxic, under certain conditions, to the benthic organisms. Assessment of metal pollution in bottom sediment can provide an insight into the ecosystem conditions. Bio-indicators enable the detection of unforeseen impacts and are more directly related to the "ecological health" of an ecosystem than are chemical data (Frontalini and Coccioni, 2011).

Benthic foraminifera are abundant with small sizes in small size samples that can be used with a great accuracy in the statistical analysis (Armynot du Châtelet et al., 2004). They are neumerous in most marine and brackish water environments (Loeblich and Tappan, 1987; Lee and Anderson, 1991). Benthic foraminifera can be used as bioindicators according to their sensitivity to anthropogenic pollutants and physico-chemical parameters (Coccioni, 2000; Mendes et al., 2004; Armynot du Châtelet et al., 2004; Celia Magno et al., 2012). Recently, a large number of publications have shown the effect of trace element pollution on the distribution of benthic foraminifera (Alve, 1991; Coccioni, 2000; Le Cadre and Debenay, 2006; Frontalini et al., 2009; Cosentino et al., 2013; Ayadi et al., 2016).

Qarun Lake is considered as one of the biggest inland saline lakes in the North African Great Sahara (Abdel Wahed et al., 2015a). This inland saline lake is suitable habitat for shallow water marine organisms (e.g. foraminifera and molluscs), which may be transported to the lake by migratory birds (Plaziat, 1993; Wennrich et al., 2007; Abu-Zied et al., 2011). The sedimentology, benthic foraminifera, molluscs, and $\delta^{18}O$ and $\delta^{13}C$ of *Ammonia beccarii* tests in two late Holocene sediment cores from Lake Qarun (Egypt) was studied by Abu-Zied et al. (2011) to illustrate the relation between the change in salinity and the distribution of benthic foraminifera. The cores, QARU2 (upper section, 8.2 m) and QARU4 (1.4 m), span approximately the past 500 years of sedimentation (Abu-Zied et al.,

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2011). The sediments of this lake comprise large amounts of a relatively diverse benthic foraminiferal fauna, including brackish and shallow marine species such as *Ammonia tepida* and *Quinqueloculina seminula*, which represent the majority of the foraminiferal assemblage of the lake (Abu-Zied et al., 2007). The influence of textural characteristics of marine sediments on the distribution of benthic foraminifera is recorded by Celia Magno et al. (2012); Armynot du Châtelet et al. (2009).

Qarun Lake can be considered as the final destination of both natural (subsurface flow) and artificial (agricultural) drainage in the Fayoum Depression, because it is the deepest area in the River Nile flood plain (Madbouly, 2004). The drainage water in the Qarun Lake is derived from the discharge of the natural and artificial drainage systems in the Fayoum. This resulted in pouring in the lake more than 400 million m^3 of drainage water every year (Madbouly, 2004). Accordingly, many pollutants are recorded in this lake (such as heavy metals, nitrates, phosphates, sulfates and pesticides) (Mansour and Sidky, 2003; Barakat et al., 2013; Abdel Wahed et al., 2015b). The mixed domestic drainage water and agriculture drainage water discharge these pollutants into the Qarun Lake (Barakat et al., 2013). The Qarun Lake suffers from many contamination sources. For instance, these contaminants are introduced into the lake through the suspended load of sediment carried into the lake via the drains and this leads to the settling down and accumulation of suspended particle-associated contaminants in the water column. The assessment of contamination in bottom sediments of Qaroun Lake is studied by El-Sayed et al. (2015).

Abdel-Satar and Goher, 2015 mention that Qarun Lake showed high mobility factor for all studied metals than Wadi El-Rayan lakes based on the comprehensive assessment of the potential pollution risks of the metals by using the mobility factor and risk assessment code. Consequently, all the humans, plants, animals and the general biota within the vicinity of this aquatic system are quite vulnerable to the trace metal exposure. The aim of the present work is to evaluate the effect of trace element contamination on distribution of the benthic foraminiferal assemblages in the sediments of the Qarun Lake.

2. Materials and methods

2.1. The study area

Qarun Lake, a natural reserve in Egypt's Fayoum province, the oldest in the world, is distinguished by its matchless environmental and natural assets. It occupies the lowest pit of the Fayoum depression (latitude 29° 25′-29° 30′ N, longitude 30° 25′-30° 50′ E) which is considered to be an extensive oasis situated in the Western Desert (Fig. 1). The lake has an area of more than 200 km^2. It has a roughly elongate shape with its long axis lying east-west; the length of the lake is about 45 km and its width is about 11 km. The average depth of the lake is about 5.6 m and its maximum depth is 9 m. The lake seems nearly to be divided into two basins by a middle constriction. In the middle of the lake, there is a sandy island (El Qarn), which has an area of 2.25 km^2. The Qarun Lake is bounded to the north by bioclastic sandstone cliffs (70 m) of the Birket Qarun Formation (Eocene) and sand dunes, while this lake is bounded by agricultural lands from south and southeastern sides. This agricultural lands slope toward the lake and allow farm drainage and municipal waters to flow into it. 70,000 tons of salt per year have been extracted by AMESAL Company from the Qarun Lake since 1990 (Abu-Zied et al., 2011). The lake is located in arid region (air temperature ranges 15.7–39.3 C°, the average rainfall is about 10.8 mm/year). According to Keatings et al. (2007), evaporation in the Qarun Lake exceeds total inflow at all times of the year except during the months of November, December and March. There is no thermal stratification in Qarun Lake and it is considered being homothermic in nature.

2.2. Sampling

A total of 46 sediments samples were collected from 0 to 15 cm depth using a Van Veen grab sampler (Fig. 1). The accurate locations of sampling sites were determined by using GPS (Garmin GPSMAP 62 with precision to within 3 m). Samples were stored in sealed polythene bags and immediately transported to the laboratory in

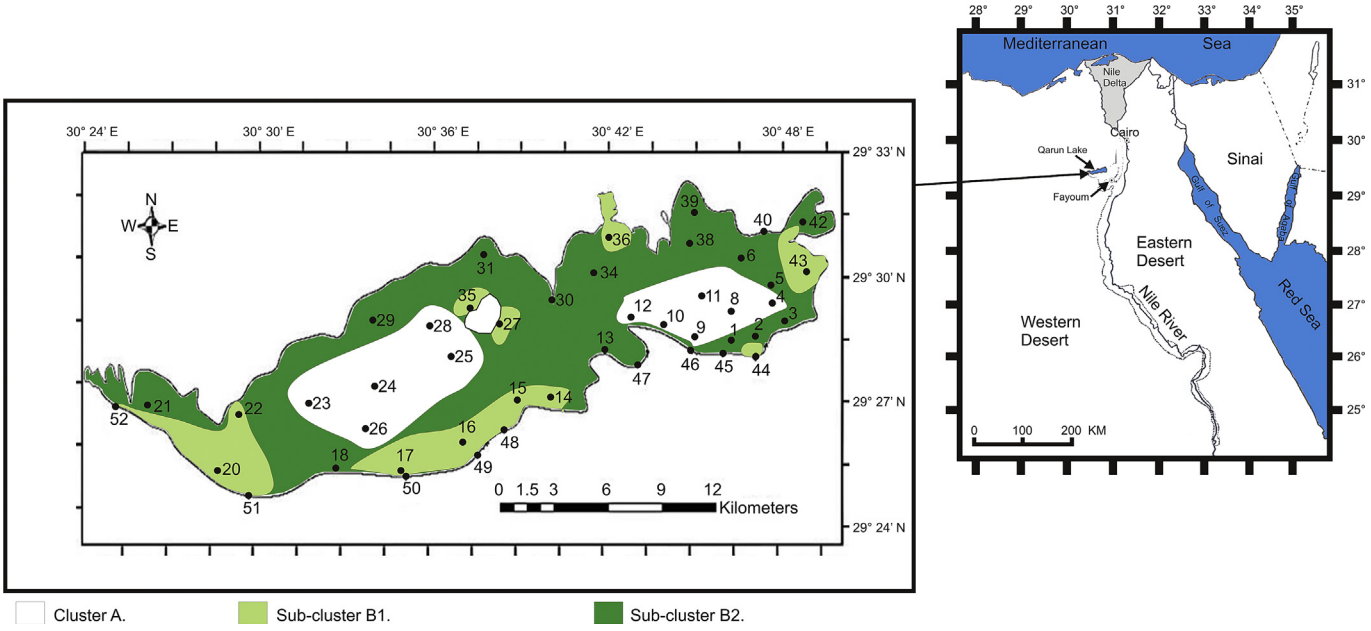

Fig. 1. Location map of surface and bottom sediment sampling sites in the Qarun Lake. the q-mode cluster analysis divided this lake into two clusters (A and B). cluster b is subdivided into two sub-clusters (B1 and B2).