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Evaluation of mobile metals in sediments of Burullus Lagoon, Egypt

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ABSTRACT

The Burullus Lagoon north Nile Delta of Egypt is a UNESCO-protected area. Recently it has become a sediment sink which led to shrinking in its area and depth accompanying with increasing contaminant levels. In this study we attempt to explore the spatial distribution and their mobility of heavy metals (Zn, Cu, Ni, Cr and Pb) based on 21surface sediment samples recovered from Burullus lagoon basin and nine drains. The risk assessment code of the studied heavy metals can be arranged as Zn > Cu > Pb > Cr > Ni for all the samples collected from the lagoon basin and nine different drains. The heavy metals tend to accumulate in fine sediments and human activities promote the accumulation of contaminated sediments in water courses.

Lagoons of the Nile Delta are vital source of life for thousands of people in Egypt. In recent decades, as a result of rapid economic development, increasing population in the delta region and associated industrialization exerts high environmental pressures (Hamouda et al., 2014). Industrial wastes and municipal effluents have been largely pumped into the delta coastal lagoons wetlands, causing eco-environmental degradation with significant public health concerns (Soliman et al., 2006). Burullus Lagoon is one of the vulnerable Egyptian coastal lakes suffering from high density of aquatic plants, over fishing, expansion in fish farming and agricultural drainage discharges and increasing of human activities (Younis and Nafea, 2012).

Heavy metals of anthropogenic origin are toxic pollutants, which are able to transfer hierarchically into human society through the food chain (El-Gammal et al., 2013), and can be further transformed into more toxic compounds under certain circumstances (Chen et al., 2010). Analyses of spatial and temporal distribution of heavy metals in the delta coasts are useful to recognize the degradation processes of wetlands and trace sources of pollutants for better environmental assessment and management. Generally, free metal ions are the most mobile and the most bioavailable form (El-Gharabawy et al., 2011). Concentration of metals is not sufficient to assess their environmental impact. Thus, the total impact and the estimation of the bioavailable fraction become necessary. Bioavailable fraction is defined as the amount of metal that can be exchanged with biological organisms and be incorporated into their structure (Vangronsveld and Cunnihgham, 1998). The mobility and bioavailability of metals bound to sediments depend on the association of the elements with particles, the binding strength and the water properties such as pH, and the redox potential, salinity, dissolved metal species which are in touch with the solid phase (Filgueiras et al., 2004).

The main objectives of this study are (a) determination of heavy metals (Zn, Cu, Ni, Cr and Pb) concentrations in the surface sediments of Burullus lagoon; (b) Infer the bioavailability (and the mobility) of heavy metals in the sediments; and (c) discussing the potential sources of pollution, paying for an urgent attention on ecological safety. The obtained information may provide a better understanding of the environmental risks of heavy metals in sediment.

Burullus Lagoon has an elongated elliptical shape in the center of the Nile delta (Fig. 1). It located between the two Nile branches Rosetta to the west and Damietta to the east. It extends between longitudes 30°31′ and 31°05′ E and latitudes 31°25′ and 31°35′N. It occupies an area of 420 km^2 of which 370 km^2 are open water (Hereher et al., 2010). The rest of the area comprises a group of islands distributed within the water body. Burullus Lagoon is considered the second largest lake of the Nile delta. Its length is about 53 km, its width is about 13 km while its water depths ranging from 0.5 to 2.5 m (Frihy and Dewidar, 1993). It connects to the Mediterranean Sea through a narrow strait called Al-burg inlet or Boughaz El-Burullus at its northeast side (about 250 m wide and 5 m depth).

The lagoon is separated from the sea by a narrow coastal strip covered by sand sheets and sand dunes ranging from 0.4 to 5.5 km in width. They are generally <1.5 m above mean sea level, with beach face slopes ranging between 1:50 and 1:130. Low relief backshore and fore dunes characterize the western barrier. The eastern barrier is narrow and backed by coastal barchans dunes. These dunes encroach landward onto a cultivated coastal flat (El-Adawy et al., 2013).

The Burullus Lagoon receives drainage water at its southern boundary through seven drains. It also receives fresh water from Brimbal Canal located at its southwestern corner (Okbah and Hussein, 2006).

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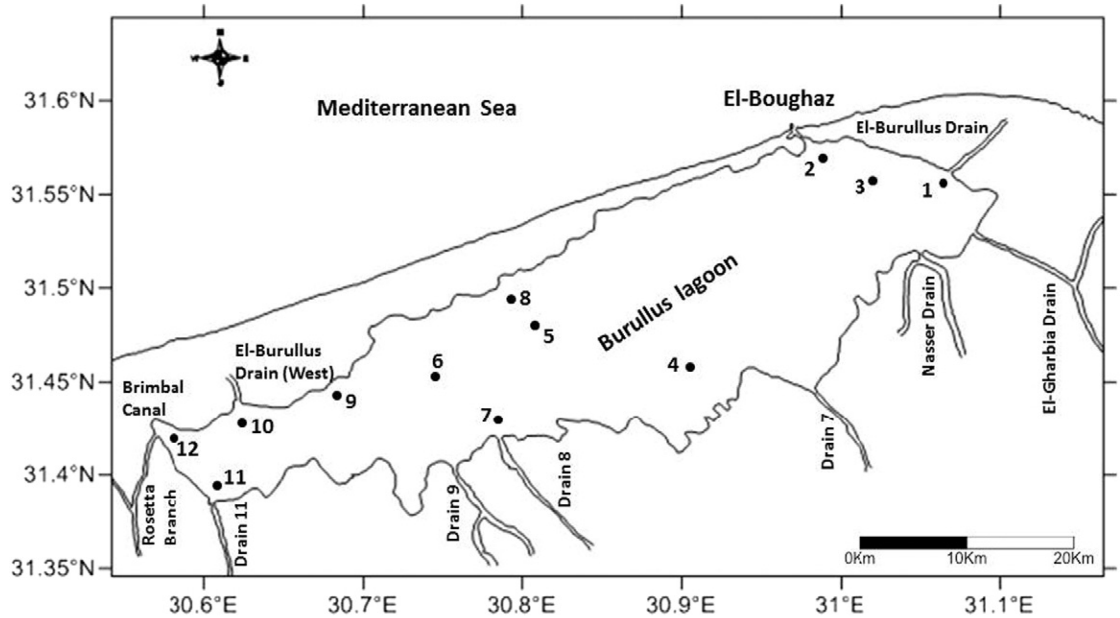

Fig. 1. The Burullus Lagoon study area map, showing sampling stations and drains locations.

Agricultural lands encompass the southern and eastern fringes of the lagoon. The environment of Burullus Lagoon has witnessed the significant change during the last three decades as many drains were constructed to convey agricultural wastes into the lagoon. In addition, substantial area has been dried up to agricultural land (Younis and Nafea, 2012).

Twenty one surface sediment samples were collected using Van Veen Grab sampler. Twelve samples were collected from the main lagoon basin and nine samples from the drains (Fig. 1). The top layer of the bottom sediments from the lagoon (10 cm thick) was collected, as this layer takes part in the processes of matter exchange.

To determine total heavy metal concentrations, the powder sediment samples are digested in closed Teflon vessels with mixture of concentrated HNO_3, HF and $HClO_4$ (3: 2: 1 v/v) according to Origioni and Aston (1984). The mobile fraction was extracted from 1 g of sediment sample by maintaining it in suspension during 6 h in 20 ml of 1M sodium acetate (NaOAC) at pH 5 (Tessier et al., 1979). Concentrations of metals in the extracts were measured using Flame-Atomic Absorption Spectrophotometer, Shimadzu model (6800) in the Central Lab of Nation Institute of Oceanography and Fisheries. The mobile fractions include exchangeable metals and metals bound to carbonates. This fraction provides an estimation of the labile metals in sediments, i.e. metals that can be potentially released from the sediments to become bioavailable and ultimately a threat to the environment.

The sediment grain size was analyzed according to (Folk, 1974) for both sieving and wet pipette analysis for fine fractions. The total organic carbon (TOC%) was determined according to (Loring and Rantala, 1992). Total carbonate in sediments was analyzed by titration according to (Black, 1965) technique.

The texture of the lagoon bottom sediments are a mixture of sand, silt and clay fractions. This combination is due to the enrichment of sediments from different sources. The sand sediments, (1% - 48%), enter the lagoon through the Mediterranean Sea connection of El-Boughaz, which derived mainly marine sediments, foraminifers, mollusks and shell fragments (Hamouda, 2014). Whereas, silty and clay rich sediments are distributed mainly in the eastern and southern parts of the lagoon, which transported by the drains and canals. There percentages are higher than sand and covers larger areas of the lagoon. The silt% ranges from (18% – 61%) while, the clay ranges from (19% – 62%).

TOC% is varied in the collected sediments samples from (1% to 3.6%). In general, the coarser sediments has low TOC% contents, while, the finer sediments of the lagoon and drains are significantly enriched with organic carbon. The higher values were recorded at the western part of the lagoon, that reflecting high rate of organic matter accumulation from the domestic drainage water and plants detritus from the nearby vegetation area.

The carbonate content in sediments of Burullus Lagoon is varied from 1% to 34%. The lower percentages were determined in the marine sediments where quartz sand is predominates. As well as, carbonate content in sediments from the drains showed values lower than those recorded inside the lagoon. It is thus evident that the shells of organisms are the principle contributors of carbonate in sediments.

Natural reservoirs such as lagoons and coastal lakes act as contamination basins for pollutants. Trace metal concentrations in the sediments tended generally to decrease from west to north-east. The spatial distribution of five heavy metals (Zn, Cu, Ni, Cr and Pb) was illustrated in Fig. 2 for total concentration and Fig. 3 for mobile percentages. Zn, Cu, Cr and Pb showed the highest percentages of mobile fraction in the basin of Burullus lagoon, and their ranges being between 16 and 93%, 24 and 93%, 5 and 85%, 23 and 93%, respectively. The mobile fraction was lower for Ni with range 4% to 13%. For drain sediments the mobile fraction range from 14% to 70%, 16% to 98%, 4% to 22%, 4% to 50%, and 15% to 83% for Zn, Cu, Ni, Cr and Pb, respectively.

The total concentration of Zn in lagoon basin (range 33.82 to 212.32 μg/g) is lower than its correspondence in the drains (range 46.41 to 197.86 μg/g). While, the mobile fraction was higher in drains sediments. This assumes that Zn was dissolute and diluted in the lagoon basin sediments with time. In aquatic environment Zn will predominantly bind to suspended materials before finally accumulating in the sediments. However, back resolubilization, makes it to be more bioavailable in aquatic environment (Bryan and Langston, 1992). The agriculture effluents of the drains enriching Zn concentrations in the lagoon which is considered as a common contaminant in agriculture and food wastes, moreover it is also used for manufacturing of pesticides (El-Gharabawy et al., 2011).

Important anthropogenic inputs of Cu in estuarine and coastal waters include sewage and agricultural discharges and antifouling paints (Kennish, 1996). The distribution of the total form of Cu in the lagoon is clearly affected by the drains discharge. The total Cu concentrations range between 23.67 μg/g and 57.67 μg/g that increasing near to Nasser, 7 and 8 drains. The mobile form percentage of Cu increases in the