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Distribution and assessment of heavy metals in the aquatic environment of Lake Manzala, Egypt

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ABSTRACT

Analysis of trace metals from sediment and fish collected from eight locations in Lake Manzala, Egypt, during May, June and July of 2011, indicated anthropogenic impacts. The highest concentrations of metals, except Mn and Sr, were detected at Bahr Al-Baqar (S1) which drains from Cairo. At the other sampling locations, the concentrations of selected trace metals fall below the levels of concern while the geo-accumulation index (I_{geo}) suggests unpolluted conditions for the majority of the studied metals at most sites. However, near the Bahr Al-Baqar (S1) drain concentrations of Ag, Hg and Zn fall above the Long and Morgan's (1990) effects range low (ERL) while Pb was above their effects range median (ERM). I_{geo} values suggest unpolluted to moderately polluted condition for As and Sn, moderately polluted conditions for Zn, moderate to extremely polluted conditions for Ag, and severely to extremely polluted conditions for Pb at Bahr Al-Baqar. Two sites (Legan, S5, and Al-Ginka, S8) were indicated by I_{geo} as moderately polluted for Ag while two other sites (West of Bashar, S3, and Al Dehdy, S6) were indicated as unpolluted to moderately polluted for Ag. The Legan and Al-Ginka sites were also indicated as being moderately polluted for Zn. Similar to the sediments, the highest concentrations of metals in fish tissue were from Bahr Al-Baqar (S1). Al concentrations at all sites were comparable to concentrations known to cause lesions in fish. At all sites concentrations of selected trace metals in fish tissue were below the limits set by the FAO.

1. Introduction

Lake Manzala is the largest of the Nile Delta lakes. It is located on the northeastern edge of the Nile Delta, 170 km from Cairo and 15 km west of Port Said (Fig. 1). Several decades ago the surface area of Lake Manzala was 1698 km^2, however, by 1988 it was reduced to 770 km^2 (Saeed and Shaker, 2008) due to continuous land reclamation projects and it may be further reduced to 469 km^2 in the future. Lake Manzala is brackish, eutrophic, elongated, and shallow with an average depth of 1.2–1.5 m (El-Kholy et al., 2012). Freshwater inputs to the lake are not sufficient to provide adequate flushing to the sea, therefore trace metals entering the system are expected to accumulate over time.

Lake Manzala is an important fisheries resource in the Nile River Delta, accounting for over 30 percent of all commercial and recreational fish landed and consumed in Egypt. However, Lake Manzala has been classified as one of the most polluted Lakes in Egypt (Wahaab and Badawy, 2004). Accumulation of bioactive metals in fish is controlled by different metabolic pathways that control metal uptake and concentration in fish tissue. The concentrations of these metals in the fish reflect the environmental conditions where they are living. Environmental pollution in Lake Manzala and its main drainage channels have previously been documented by measuring the concentrations of selected trace metals in fish and sediment samples (Badawy and Wahaab, 1997; Bahnasawy et al., 2011). Soltan et al. (2005) studied heavy metal accumulation in two species of tilapia (*nilotica* and *galilea*) in Lake Nasser along with water, sediment and aquatic plants.

Authman (2008) proposed using *O. niloticus* as a biomonitor of heavy metal exposure in a study in the Sabal drainage canal where he found the concentrations of heavy metals exceeded the tolerance level for human consumption. Sources of contaminants to Lake Manzala include untreated sewage, atmospheric deposition, agricultural and industrial wastes which may impact human health when fish are consumed.

Heavy metals of environmental concern include arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), silver (Ag),

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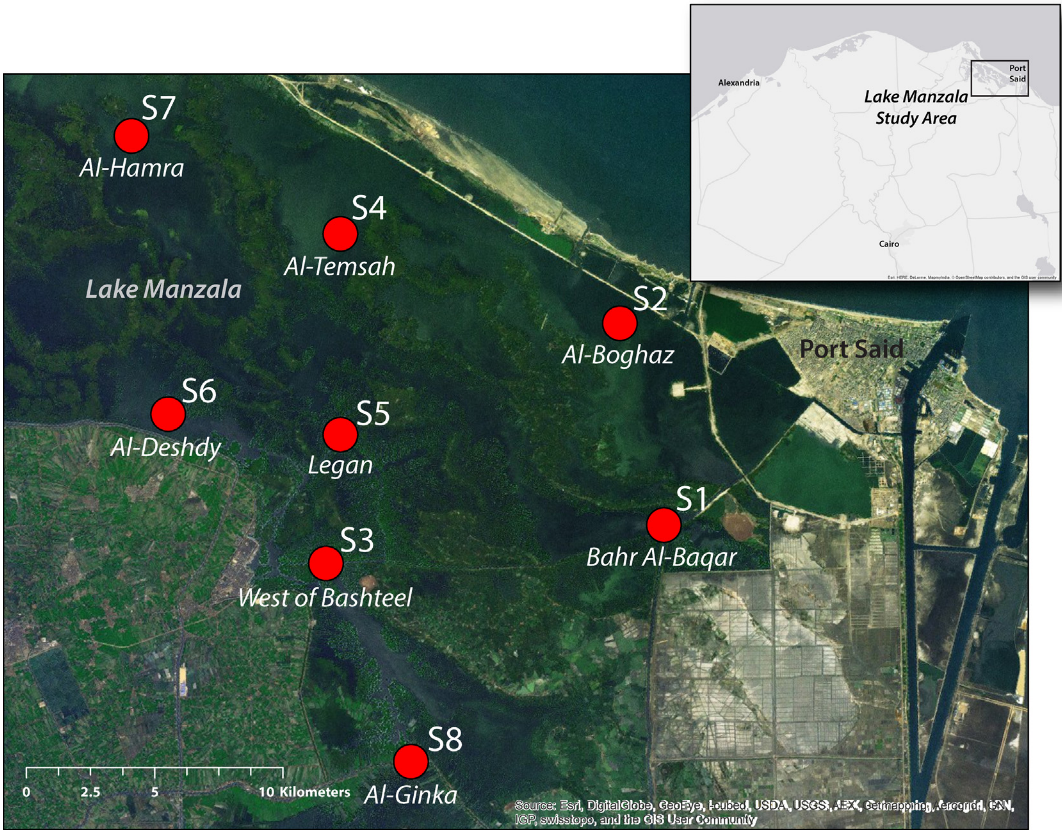

Fig. 1. Study area and sampling locations in Lake Manzala, Egypt are shown with red label.

vanadium (V), zinc (Zn), lead (Pb) and mercury (Hg) (Babel and Kurniawan, 2003). Aquatic ecosystems act directly or indirectly as sinks for these trace metals. Trace metals enter aquatic ecosystems in the dissolved or particulate phase from domestic, industrial, and agricultural runoff, as well as from atmospheric deposition. Belabed et al. (2013) reported natural and/or anthropogenic input variations related to climatic conditions and human activities (agriculture, urban and industrial activities) such as occur on the Nile River Delta might affect the heavy metal deposition and thus the concentrations in sediments.

In populated areas, metals such as Cd, Cu, Cr, Ni, and Pb are released into the environment by industries including automotive, metal-producing, electroplating, battery and electric cable manufacturing, mining, tannery, steel, and textile (Demirezen et al., 2007). Pb is used in a number of industrial applications and has been used as an anti-knocking additive in gasoline and is deposited following combustion (Junior et al., 2002). Pb ranks as the metal of largest diffusion through the atmosphere (Abdallah, 2008). Industrial and domestic waste-waters containing Cd (and other metals such as Cu and Zn) were considered as major sources of these metals (Belabed et al., 2013). Cd enriched phosphate fertilizers enter the environment as agricultural run-off. In the Egyptian irrigation system, the main sources of Cu are wastes derived from fungicide application to citrus farms (Mason, 2002). Ho et al. (2010) reported that Co can be bound to the compounds of Fe and Mn (e.g. Fe and Mn hydrous oxides or possibly Fe and Mn sulfides) and deposited to the sediments. In the Nile Delta, Khairy et al. (2011) found road dust high in As, Ba, Cd, Cr, Cu, Se, and Sn due to industrial activities and in Pb, Ni, and V due to traffic emissions. Sources of Ba to the environment include manufacturing of a variety of products (e.g., cement, ceramics, fabrics, glass, plastics, oil additives, and pesticides), well-drilling mud, and atmospheric deposition (Abu Khatita, 2011).

The relatively high solubility of these metals in the aquatic environment results in the uptake of heavy metals by organisms (Mason et al., 1994; Fitzgerald et al., 1998; Hammerschmidt et al., 2004; Campbell et al., 2005). Trace metals such as Cr, Mn, Co, Cu and Zn are necessary in trace amounts for biochemical processes in fish and other organisms, but at high concentrations they can become toxic (Lasheen, 1987). Once they enter the food chain, ultimately humans may accumulate heavy metals from their diet (Barakat, 2011). Alquezar et al. (2006) documented the human health risks of metals associated with the consumption of contaminated fish. Lake sediments act as a sink for both natural and anthropogenic trace elements (Hamed et al., 2013). With time sediments may also act as a source of metals due to remobilization resulting in their gradual release to the aquatic phase or to benthic organisms (Emerson et al., 1984).

Sediment quality assessment guidelines (SQAGs) have been developed for assessing sediment quality in many countries (e.g., USA, Canada, Switzerland and EU). Threshold effect levels have been derived for substances or groups of substances including 9 of the 17 trace metals in this study. The guidelines reflect concentrations where adverse effects occur rarely and are often classified into the effects range low (ERL); where adverse effects occur occasionally, the effects range median (ERM) which falls above ERL and where adverse effects occur frequently when the ERM concentrations are exceeded (Long and Morgan, 1990; Long et al., 1995, 1997; Field et al., 1999; Wade et al., 2008a). Monitoring heavy metal contamination in the lacustrine sediments can provide an estimate of the quality of aquatic ecosystems by comparing measured concentrations to these SQAGs.

Normalization of trace metals in sediments with respect to reference elements such as Al, Li, and Fe is often used to reduce the natural effects of grain size and mineralogy on trace metal concentrations to provide a better estimate of the anthropogenic