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Spatial distribution and environmental geochemistry of zinc metal in water and surficial bottom sediments of Lagoon Burullus, Egypt

Abd El-Monsef Ahmed El-Badry[a,*], Ahmad Mohamed El-Kammar[b]

[a] National Institute of Oceanography and Fisheries, Aswan Research Station, Egypt
[b] Department of Geology, Faculty of Science, Cairo University, Egypt

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ABSTRACT

Lagoon Burullus is located in the North West quadrant of the Nile Delta. It receives drainage water through several drains around the lagoon. Understanding the mobility and bioavailability of zinc metal in bottom sediments of Lagoon Burullus is essential for the design of remediation processes and the institution of environmental recommendation for zinc pollution.

Single extractions used to fractionate zinc into five fractions. The chemical analyses preceded using atomic absorption spectrometry after using the digestion technique. Zinc concentrates in the residual fraction (167.5 μg/g) followed by the organic (14.6 μg/g), exchangeable (3.2 μg/g), carbonate (2.4 μg/g) and then the Fe-Mn hydroxides (1 μg/g) fractions. The average content of zinc (189 μg/g) is about three fold the average earth's crust.

Ecological pollution index show that the metal has a low-risk assessment to surrounding ecosystem. The anthropogenic activities considered as the main source of pollution.

1. Introduction

Zinc is an essential element, which is important for plants, animals, and humans for physiological and reproductive functions. The maximum allowable limit (MAL) of Zn for worldwide soils is 300 ppm (Kabata-Pendias, 1995). Applications of Zn fertilizers can temporarily help offset plant Zn deficiency symptoms. Hence, it is important to have a better understanding of the transformation of soil zinc fractions. This helps in understanding the zinc species and its availability to plants.

Zinc metal can be drained to an aquatic ecosystem by human activities. Several drains around the Lagoon Burullus throw agricultural and industrial wastewaters. Furthermore, Brimbal Canal, situated at the western side of the lagoon, throw fresh water into the lagoon. However, during the last few decades, the environment of the lagoon changed seriously due to the contribution of several new drains which dug to relocate agricultural and industrial wastes to the lagoon.

Many authors, e.g., Harter (1983), Calmano et al. (1993), Dho and Lee (2003), Chakraborty et al. (2014), Wojtkowska et al. (2016), and Lin et al. (2016), studied the role of pH, Eh, bioturbation or resuspension, grain size, organic matter content among other factors on the accumulation of heavy metals in bottom sediments. According to Bastami et al. (2017) monitoring of heavy metals deposition in sediments provides a continuous surveillance of pollution in the aquatic system and for advisable controlling on pollution.

Lagoon Burullus (UNESCO-protected area), like other Mediterranean lakes of Egypt, suffer from growing deterioration due to the unsupervised actions, especially during the last few decades. El-Asmar et al. (2013) reported that during the 1970s, the lagoon body was quite far from human intervention and the lake was one of the least polluted coastal lagoons in Egypt. The building of the high dam in the 1960s, affected the irrigation regime in the Nile Delta and necessitated large irrigation and drainage network. The expanded reclamation activities, especially in the southern and southwestern fringes and the landward movement of sand dunes, caused a drop in the open water surface area.

El-Sheikh et al. (2012) studied the crucial parameters controlling the plant resettlement on soil dredged from the outlet of Lagoon Burullus to the Mediterranean Sea and deposited nearby, forming by this way new land that underwent a primary plant succession. Hossen and Negm (2016) reported changes in the water body of Lagoon Burullus due to the severe anthropogenic activities. The agriculture area increased by 45.52% (10,529.02 ha), while the sand bar and urban area decreased mostly by the same amount during the period from 1984 to 2015. Khalil and El-Gharabawy (2016) added that lately, the lagoon becomes a sediment sink, which led to shrinking in its area and depth accompanying with increasing contaminant levels, especially by heavy

* Corresponding author.
E-mail address: amkammar@hotmail.com (A.E.-M.A. El-Badry).

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Table 1
Longitude and latitude of the sampling locations.

Station	Latitude	Longitude	Station	Latitude	Longitude
1	31°32′28.3″N	31°03′42.4″E	12	31°24′54.5″N	30°41′56.6″E
2	31°33′31.0″N	31°01′03.0″E	13	31°28′09.0″N	30°56′07.6″E
3	31°34′02.5″N	30°59′22.4″E	14	31°28′52.3″N	30°58′53.2″E
4	31°33′30.5″N	30°56′53.7″ E	15	31°24′52.9″N	30°36′28.5″E
5	31°32′47.2″N	30°54′41.1″E	16	31°24′02.3″N	30°36′50.7″E
6	31°31′46.8″N	30°51′47.5″E	17	31°24′57.4″N	30°39′32.0″E
7	31°30′21.5″N	30°48′54.5″E	18	31°26′13.1″N	30°46′58.8″E
8	31°29′08.8″N	30°46′11.3″E	19	31°26′33.4″N	30°49′24.7″E
9	31°28′00.3″N	30°42′58.5″E	20	31°29′14.3″N	30°52′42.7″E
10	31°27′37.4″N	30°42′56.6″E	21	31°26′34.2″N	30°53′39.3″E
11	31°26′59.5″N	30°43′33.6″E			

metals. Recently, El-Zeiny and El-Kafrawy (2017) applied remote sensing and GIS to assess water pollution in Lagoon Burullus. Total nitrogen (TN), total phosphorus (TP) and the biochemical oxygen demand (BOD) selected to evaluate water pollution and levels of water deterioration in the lagoon. They concluded that the eastern and southern parts of the lake are the most polluted due to the excessive human activities, particularly from agricultural and domestic sources.

Shokr et al. (2016) confirm that the sediment adjacent to lagoon represent a hazard to human life in the area, where inc content greatly exceeded permissible limits (377.6 mg/kg). This could be caused by infiltration of irrigation water through the studied area. Zn contents are higher than the 52 mg/kg average of the upper lithosphere (Wedepohl, 1995) and lower than the maximum permissible value of 200 mg/kg (CSQG, 2007).

El-Amier et al. (2017) stated that the lagoon sediments work as important sources of different toxic pollutants such as heavy metals, which in turn accumulate in aquatic organisms through food chains. The main aim and objectives of this manuscript is to map water and bottom sediment pollution for zinc metal and its fractionation in the lagoon using original chemical analysis data.

2. Materials and methods

Fourteen sites, covering the Lagoon Burullus body, considered for sampling during summer 2014. Table 1 shows the details of longitude and latitude of the sampling locations, each site represents bottom sediment and surface water samples. In addition, seven bottom sediment samples collected near from the agricultural drains (Fig. 1). The bottom sediments were collected from the lagoon using a grab sampler (Ekman type), which was immersed to a depth ranging between 60 cm and 450 cm. The preparation of sediment for total zinc content analysis was done where the surface bottom sediment samples were air-dried, grind and preserved for chemical analyses.

Table 2
Summary of the sequential extraction steps of Zn fractionation.

Step	Fraction	Reagent	Experiment conditions
F1	Exchangeable	8 ml of 1 M 2MgCl	Shake for 1 h at neutral pH
F2	Carbonate-bound	8 ml of 1 M sodium acetate	Shake for 5 h at pH 5.0
F3	Fe-Mn	0.04 M $NH_2OH·HCl$, CH_3COOH	Shake for 6 h at pH 2 (96 °C)
F4	Organic-bound	3 ml of H_2O_2 in 0.02 M HNO_3	Shake for 2 h at pH 2 (85 °C)
F5	Residual	Mixture of 3 HF-HCI/ HNO_3	16 h at 80 °C in a digestion bomb

The chemical analyses for the zinc performed for whole sediment and the five sequential extraction fractions by atomic absorption spectrometry (Perkin-Elmer 3110, USA) with graphite atomizer HGA-600, after using the digestion technique according to the standard APHA (1998).

2.1. Sequential fractionation methods

The sequential extraction procedure described by Tessier et al. (1979) and modified by Rao et al. (2008) adopted in the present study (Table 2).

The exchangeable extracted with 8 ml of 1 M $2MgCl_2$ at neutral pH for 1 h. The carbonate-bound fraction (F2) extracted with 8 ml of 1 M sodium acetate adjusted to pH 5.0 with acetic acid (for 5 h). The Fe-Mn oxyhydroxides bound fraction (F3) extracted with 0.04 M hydroxylamine hydrochloride in 25% Acetic acid (v/v) at 96 °C with occasional stirring for 6 h. The organic-bound fraction (F4) extracted with 3 ml of 30% hydrogen peroxide in 0.02 M nitric acid (adjusted to pH 2 with HNO_3). The mixture then heated to 85 °C for 2 h with occasional stirring. The crystalline residual/lithogenic fraction (F5) obtained by complete digestion of the residue with aqua-regia in a digestion bomb.

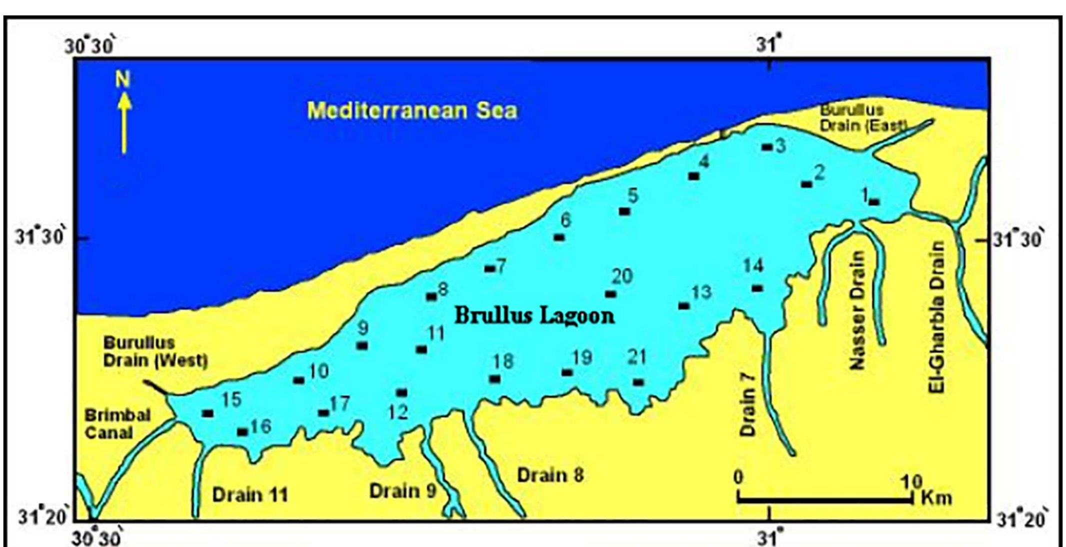

Fig. 1. Location map of the sampling sites.