Heavy Metal Pollution in Lagoon Mariut, on the Southern Coast of the Eastern Mediterranean Sea

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ABSTRACT. The distributions of Cu, Zn, Fe and Mn in water, suspended matter and sediments of lagoon Mariut proper have been studied. The results showed that the lagoon was polluted with these metals mainly due to the industrial effluents discharged at its far northeastern corner. The continuous current of water from the agricultural Qalaa Drain, the main source of water for the lagoon, flushes only the northwestern side of the lagoon as it flows towards the lower reach of another large agricultural (Umum) Drain. This has led to accumulation of pollutants at the northeastern side of the lagoon.

The contribution of metals from this lagoon to the Mediterranean Sea via the Umum drain has been estimated.

Introduction

Lagoon Mariut is one of four Egyptian delta lagoons on the Mediterranean coast, close to Alexandria and can be divided into four main basins. The eastern basin which represents the lagoon proper (Fig. 1), has an area of 25.2 m² and an average depth of 1.2 m. It receives discharges from various sources, industrial, urban (untreated sewage) from Alexandria City and agricultural effluent from two drains (Qalaa and Umum Drains).

The bottom of the lagoon is covered mainly with mud which ranges in colour from grey to black (with a smell of hydrogen sulphide) on going from west to east.

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The Qalaa Drain feeds the lagoon at its southeastern side with drainage water, contaminated with sewage effluents from the eastern district of Alexandria, at a rate of $\sim 465,000$ m$^3$/day. On the northern side of the lagoon, there are outfalls for the discharge of wastes. Two of them are for domestic sewage wastes and the northeasternmost is for industrial wastes. The total daily contribution from these three sources is $\sim 85,000$ m$^3$.

The surplus water from the lagoon ($\sim 540,000$ m$^3$/day) flows westwards (Saad et al. 1984) to the lower reach of another large agricultural drain, the Umum Drain, before its water is pumped into the Mediterranean Sea at El-Mex (Fig. 1). This drain borders the lagoon at its western side, its water frequently enters the lagoon through...
several breaks in the embankment separating the lagoon from the drain (Saad et al. 1984). The water discharges from the lower reach of the Umum Drain is at a rate of about six million m$^3$/day.

Previous studies of lagoon Mariut have concentrated mainly on the status of nutrients, the problems of eutrophication and the hydrography of this lagoon (Saad 1973, Saad et al. 1984, Wahby and Abdul-Moniem 1979, Wahby et al. 1978). The investigations of heavy metals in this lagoon especially in the abiotic environment are scanty (UNESCO 1986). The present work is an attempt to study levels and distributions of the metals copper, zinc, iron and manganese in the three main abiotic phases, water, suspended matter and sediments of the lagoon. To illustrate the effect of man's activities on the concentrations of these metals, a comparison has been made between their levels in the three phases in lagoon Mariut proper, and those present in the same phases of a neighbouring lagoon, the Nozha-Hydrodrome (Fig. 1). This lagoon was artificially separated from the mother lagoon Mariut in 1939 and is relatively free from anthropogenic input as it receives only Nile water.

**Material and Methods**

Surface water samples were collected from the lagoon at monthly intervals for fourteen months, from eight stations shown in Fig. 1. Five liters of the water samples were filtered through acid cleaned and preweighed 0.45 μm Millipore membrane filters. The filtrate was passed through a glass column containing Chelex-100 resin, in its ammonium form, to preconcentrate the metals, which were then eluted with 2 M nitric acid (Riley and Taylor 1968). The suspended matter content on the filter after drying at room temperature for several days, to constant weight, was obtained. The filter with its suspended matter was then subjected to acid extraction (2 M nitric acid), according to the method of Smith et al. (1981). Sediment samples were collected with an Ekman's grab. The metals in the sediments were extracted with 2 M nitric acid, according to the method of Smith et al. (1981). The metals in the acid extracts were then determined by atomic absorption spectrophotometry (AAS-IL-170). The precision of the analysis represented by the coefficient of variation was 8.5 and 1.9% for dissolved Cu and Zn, respectively. The coefficient of variation for the sediments (or suspended matter) was 1.0, 1.5, 1.0 and 3.0% for Cu, Zn, Fe and Mn respectively. Recovery from the water and sediments (or suspended matter) was better than 95% of the standard values of heavy metals.

**Results and Discussion**

Table 1 shows range, means and regional average concentrations of dissolved metals as well as the regional averages for the concentrations of dissolved oxygen and/or hydrogen sulphide, in addition to chlorosity in the surface water of lagoon Mariut and in the two drains. The distribution of these metals in the water, suspended matter and sediments are shown in Fig. 2, 3 and 4, respectively. The distributions of dissolved oxygen and (hydrogen sulphide) chlorosity in the lagoon surface water are also shown in Fig. 2.
Concentration ranges, means and regional average values of the dissolved metals as well as regional averages of dissolved oxygen and/or hydrogen sulphide and chlorosity in the waters of lagoon Mariut and of the two feeding drains.

<table>
<thead>
<tr>
<th>Station</th>
<th>Chlorosity* (g/l)</th>
<th>Cu μg/l</th>
<th>Zn μg/l</th>
<th>Fe μg/l</th>
<th>Mn μg/l</th>
<th>O₂/(H₂S)* ml/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagoon proper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1.10</td>
<td>4.3</td>
<td>12.7</td>
<td>22.4</td>
<td>55.7+</td>
<td>3.3/(2.7)</td>
</tr>
<tr>
<td>II</td>
<td>1.12</td>
<td>4.3</td>
<td>10.6</td>
<td>14.9</td>
<td>39.4</td>
<td>5.1/(0.8)</td>
</tr>
<tr>
<td>V</td>
<td>1.10</td>
<td>5.8+</td>
<td>12.6</td>
<td>17.7</td>
<td>41.2</td>
<td>4.4/(1.1)</td>
</tr>
<tr>
<td>VI</td>
<td>0.98</td>
<td>4.7</td>
<td>14.1+</td>
<td>31.3+</td>
<td>24.2</td>
<td>1.8/(7.6)</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>4.78</td>
<td>12.50</td>
<td>21.58</td>
<td>40.13</td>
<td>3.65/(3.05)</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>0.8-15.5</td>
<td>2.5-28.7</td>
<td>4.6-48.1</td>
<td>0.8-156.4</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>1.68</td>
<td>3.0-</td>
<td>9.7</td>
<td>10.5</td>
<td>11.8</td>
<td>10.4/(ND)</td>
</tr>
<tr>
<td>IV</td>
<td>1.68</td>
<td>3.2-</td>
<td>8.8-</td>
<td>8.6-</td>
<td>4.1-</td>
<td>5.4/(ND)</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>3.10</td>
<td>9.25</td>
<td>9.55</td>
<td>7.95</td>
<td>7.9/(ND)</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>0.8-8.4</td>
<td>3.2-27.0</td>
<td>1.5-25.2</td>
<td>0.7-100.8</td>
<td></td>
</tr>
<tr>
<td>Drains</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qalaa VIII</td>
<td>1.06</td>
<td>4.4+</td>
<td>10.8+</td>
<td>37.9+</td>
<td>26.1+</td>
<td>1.4/(9.8)</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>1.9-11.5</td>
<td>3.6-16.5</td>
<td>0.8-89.3</td>
<td>0.9-99.1</td>
<td></td>
</tr>
<tr>
<td>Umum VII</td>
<td>1.64</td>
<td>4.1-</td>
<td>8.8-</td>
<td>10.4-</td>
<td>4.3-</td>
<td>6.5/(ND)</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>2.1-9.3</td>
<td>2.4-18.1</td>
<td>3.1-24.0</td>
<td>1.2-22.3</td>
<td></td>
</tr>
<tr>
<td>Lagoon mean</td>
<td></td>
<td>4.2</td>
<td>11.4</td>
<td>17.6</td>
<td>29.4</td>
<td></td>
</tr>
<tr>
<td>Lagoon range</td>
<td></td>
<td>0.8-15.5</td>
<td>2.5-28.7</td>
<td>1.5-48.1</td>
<td>0.7-156.4</td>
<td></td>
</tr>
</tbody>
</table>

Regional average values calculated from the concentrations of 14 cruises (112 sample).
The minimum averages are designated by (−) and the maximum by (+).
ND = Not detected.
*Data from Saad et al. (1984).

Analysis of the data and the distributions shows that the high metal concentrations in the three abiotic phases are restricted to the eastern side of the lagoon, stations I, II, V and VI, covering most of the lagoon area (with the exception of the western part containing stations III and IV). This area also contained the lowest regional average values of dissolved oxygen and hydrogen sulphide frequently was present in this water, especially close to the outflow from the Qalaa Drain (Fig. 2). The water of the western side was always oxygenated. The general distribution pattern for the dissolved elements, however, was a decrease in the concentration westwards. The distribution pattern of the chlorosity (Fig. 2) showed an increase in the chlorosity westwards from values less than 1.06 mg/l near to the outlet of the Qalaa Drain, to values of 1.68 mg/l in the western water lining the course of the Umum Drain, with a transition or mixing zone between these two water types. This pattern of distribution is, however, similar to that for dissolved oxygen, i.e. the low chlorosity water contained the least dissolved oxygen and vice versa.
The water on the western side is well oxygenated (super saturated). It seems likely that the conditions there are favourable for the fresh water plants. Figure 2, showed that the Qalaa Drain water was responsible for the low values of dissolved oxygen. Actually for most of the time, the Qalaa Drain water was blackish in colour and had a smell of hydrogen sulphide.
From above, it is evident that most of the lagoon is filled mainly with water from the Qalaa Drain. However, the water in the western side is mixed with water from the upper reach of the Umum Drain.

Distribution of the metals in the surface suspended matter (mg/g) is shown in Fig. 3. The suspended matter in the water adjacent to the far northeastern corner of the lagoon, near to the industrial discharge outlet, was most heavily contaminated with trace metals. The figure also shows that the isolines of the metal concentrations in the suspended matter were closely backed near to the industrial discharge site and became further apart towards south and southwest as a result of progressive dilution with suspended matter carried by the water from the Umum Drain. The effect of the discharge of industrial waste on the suspended metal concentrations is shown in Fig. 5. This distribution pattern shows similarity with those for Fe and Mn, and to certain extent for Cu, in the bottom sediments of the lagoon (Fig. 3). Again, the highest concentrations are in the sediments on the northeastern area of the lagoon, and the concentration decreases towards the southwest. In the case of Cu and Zn, the maximum value is in the sediments at station VI, in front of the outlet of (the euxinic) Qalaa Drain. This zone is probably an accumulation site for precipitated colloidal Cu and Zn sulphides from the bottom water there. However, this phenomenon needs further investigation. The surface water at this site had lower chlorosity and dissolved oxygen values and high concentrations of dissolved Cu, Zn and Fe (Fig. 2).

Fig. 3. Distribution of the metals in the suspended matter from the surface water of lagoon Mariut.
FIG. 4. Distribution of metals in the bottom sediments of lagoon Mariut.

FIG. 5. Relationships between total suspended matter (TSM) and suspended metals in lagoon Mariut.
To illustrate the influence of metal pollution on lagoon Mariut, the mean levels of the investigated metals in the water, suspended matter and sediments of its eastern and western sides were compared with the corresponding means in the neighbouring lagoon, Nozha-Hydrodrome (Table 2). In lagoon Mariut, the levels of metals in the water, suspended matter and sediments of the eastern side, that receives the polluted effluents, were, in general, considerably higher than the corresponding levels in the western side of the lagoon and in the Hydrodrome.

**TABLE 2.** A comparison between the mean levels of heavy metals in water, suspended matter and sediments of the two zones of lagoon Mariut with those in the corresponding three phases of a neighbouring pond.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Lagoon Mariut</th>
<th>Nozha Hydrodrome</th>
<th>Lagoon Mariut 1969</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eastern zone</td>
<td>Western zone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Cu</td>
<td>4.8</td>
<td>1.27</td>
<td>0.17</td>
</tr>
<tr>
<td>Zn</td>
<td>12.5</td>
<td>1.78</td>
<td>0.48</td>
</tr>
<tr>
<td>Fe</td>
<td>21.6</td>
<td>7.76</td>
<td>5.18</td>
</tr>
<tr>
<td>Mn</td>
<td>40.1</td>
<td>4.10</td>
<td>0.85</td>
</tr>
</tbody>
</table>

A = Dissolved metals (μg/l), B = Metals in suspended matter (mg/g) and C = Metals in sediments (mg/g)

Based on annual discharge of 197 million m³ from the lagoon to the Mediterranean, we estimate that the metal flux via this route to be 3.2, 7.6, 62.6 and 17.5 tonnes/year of Cu, Zn, Fe and Mn, respectively.

The comparison of the annual metal fluxes from lagoon Mariut with that from the other land-based sources on the southeast Mediterranean is shown in Table 3.

**TABLE 3.** Comparison of the annual metal flux from lagoon Mariut with that from other sources on the southeast Mediterranean.

<table>
<thead>
<tr>
<th>Source</th>
<th>Water discharge rate (billion m³/year)</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
<th>Mn</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagoon Mariut</td>
<td>0.2</td>
<td>3.2</td>
<td>7.6</td>
<td>62.6</td>
<td>17.5</td>
<td>Present Work</td>
</tr>
<tr>
<td>Lagoon Manzalah</td>
<td>5.3</td>
<td>26.0</td>
<td>78.0</td>
<td>5035.9</td>
<td>111.3</td>
<td>Dowidar et al., 1984</td>
</tr>
<tr>
<td>River Nile (through Rosetta Mouth)</td>
<td>3.5</td>
<td>4.6</td>
<td>28.7</td>
<td>2.3</td>
<td>1.8</td>
<td>El-Rayis and Saad, 1984</td>
</tr>
</tbody>
</table>

**Conclusion**

The distribution of the heavy metals studied in the three abiotic components of the lagoon Mariut ecosystem showed that the lagoon was under stress. This was mainly due to the inflow of euxinic water from the Qalaa Drain, the main feeding source for the lagoon with water, and to the sewage and industrial discharges at its northeastern
Heavy Metal Pollution in Lagoon Mariut.

The last of these is responsible for contamination of the suspended matter with Cu, Zn, Fe and Mn. The flowing water from Qalaa Drain was not efficient in flushing the recipient water from the northeastern side of the lagoon, and this has led to the accumulation of the pollutants there. Before the deterioration becomes chronic, all the effluents including that from industrial sources must be well treated and aerated prior to the discharge.

Acknowledgement

The authors are grateful to Mrs. H.H. Ahdy for her valuable assistance during the field work and for analyses. We wish to express our thanks to Prof. J.P. Riley (Head of the Oceanography Department, Liverpool University, England) for critical reading of the manuscript.

References


التلوث بالفلزات الثقيلة في بحيرة مريوط، على الساحل الجنوبي
لشرق البحر الأبيض المتوسط

عباس عبد المطلب الريس و مصطفى عبد الرحمن عبد
قسم علوم البحار - كلية العلوم - جامعة الإسكندرية
الإسكندرية - مصر

الخلاصة

تم بحث بحيرة مريوط لمعرفة مستوى الفلزات الثقيلة، النحاس والزنك
والحاديد والمجنيز، وتوزيعها في محويتها غذاء الحياة، وهي المياه والمواد العالقة
والرواسب. اتضح من النتائج أن البحيرة كانت ملوثة بهذه الفلزات الثقيلة بسبب
إفراط النفايات السائلة الصناعية عند الركن الشمالي الشرقي للبحيرة والتدفق المستمر
من مصرف القلعة الزراعي، وهو المصدر الرئيسي لتلوث البحيرة بالمياه، دورها في
عملية نقل مياه الجانب الشمالي الغربي للبحيرة، وذلك أثناء اندماجها في هذا
الإثراء نحو مصب مصرف العموم الضخم. وقد أدى هذا إلى تراكم الملوثات عند
الجانب الشمالي الشرقي للبحيرة.

وقد تم حساب مقدار مساهمة البحيرة في إضافة الفلزات الثقيلة للبحر الأبيض
المتوسط

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