Humic Substances in the Sediments of Lake Edku, Egypt:  
I – Occurrence and Distribution

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ABSTRACT. Humic substance (HS) as humic and fulvic acids were determined in the surface sediments of Lake Edku (Egypt). Their sources, distribution and behavior were assessed. The lake is geographically subdivided into eastern, central and western sub-basins; subdivision is based on the presence of natural barriers and proximity to the drains or to the sea-lake connection. The central basin showed the highest concentrations of HS, which is attributed to intensive development of macrophytes and to enhanced phytoplankton primary production. In the eastern basin, high turbidity and water turbulence downstream from the drains limit primary production. In the western basin, however, water turbulence, sandy bottom, elevated salinity and decrease in nutrients due to mixing with seawater limit the growth of macrophytes as well as the phytoplankton productivity.

Introduction

Humic substances (HS) are the largest reservoir of organic carbon in the aquatic and terrestrial environments (Gjessing 1976; Mantoura et al., 1978). The bulk of the organic matter in most soils, waters and sediments consists of humic substances (Schnitzer and Khan 1972), which may constitute as high as 70% of the organic matter in the lake sediments (Kemp 1971). This fairly stable and extremely complex copolymers have received a great deal of interest due to their active participation in the biogeochemical processes in the aquatic environment (Duursma 1963; Nissenbaum & Kaplan 1972; Prakash et al., 1973; Stumm & Brauner 1975; Frimmel & Christman 1988).

The origin of the HS is of great importance since it will determine their chemical composition and structural characteristics and both will define their fate and reactiv-
Humic Substances in the Sediments (Part I).

Fig. 1. Lake Edku and position of sampling stations.
Humic Substances in the Sediments (Part I).

TABLE 1. Percentage of total organic matter (TOM) and mud in sediment samples.

<table>
<thead>
<tr>
<th>Stations</th>
<th>% TOM</th>
<th>% Mud</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.2</td>
<td>9.8</td>
</tr>
<tr>
<td>II</td>
<td>4.4</td>
<td>32.8</td>
</tr>
<tr>
<td>III</td>
<td>8.8</td>
<td>79.4</td>
</tr>
<tr>
<td>IV</td>
<td>2.5</td>
<td>50.9</td>
</tr>
<tr>
<td>V</td>
<td>2.7</td>
<td>49.2</td>
</tr>
<tr>
<td>mean</td>
<td>4.1</td>
<td>44.4</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.5</td>
<td>22.9</td>
</tr>
</tbody>
</table>

waters and mainly due to the proliferation of the macrophytes which reduce the water velocity and favors deposition of the fine sediments.

In the eastern sub-basin (stations IV, V), mud gave a large proportion of the sediments (about 50%). Evidently, most of the coarse fraction carried by the drain, sediments in this basin which is still under the influence of the water current generated by the inflowing water. Calcareous shell fragments contributed also to the coarse fraction.

TOM varied approximately in the same way, peaking in the central basin (8.8% at Station III) and decreasing in both the eastern and western basins. Evidently, organic carbon co-varied with the mud content, decrease in the mean particle diameter, due to the increase of the mud content, results in the increase of the exposed surface, which favors surface reactions like sorption (Bordovskii 1965).

However, plot of TOM against the mud content (Fig. 2) reveals that the eastern basin was relatively deficient in TOM. It is worthy noting that TOM in the sediments from the eastern basin (2.5%) lies in the range found for most of the coastal lagoons, which eliminates the possibility of a rapid mineralization of the land derived organic matter. Evidently, the in situ primary productivity, particularly macrophytes, contributed largely to the TOM in the central basin, the western basin was consequently affected.

Distribution of total humic substance

Concentrations of total humic substances (THS), as well as THS/TOM FA/THS ratios in the different sediment samples are given in Table 2. The average of THS concentration in the lake sediments was $25.27 \pm 31.14$ mg g$^{-1}$, ranging between 4.37 and 85.54 mg g$^{-1}$. Obviously, a considerable variation existed between the sampling sites.

The highest THS concentration was associated with the sediments having maximum mud and TOM content. Fig. 2 and Tables 1 and 2 show that THS is well correlated with TOM and mud content which agrees with the observations of Bojanowski & Pempkowiak (1980). It seems that the macrophytes represent an im-
TABLE 2. Total humic substances (THS), humid acid (HA), fulvic acid (FA), THS/TOM and FA/THS in sediment samples.

<table>
<thead>
<tr>
<th>Stations</th>
<th>THS*</th>
<th>HA*</th>
<th>FA*</th>
<th>THS/TOM</th>
<th>FA/THS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>6.4</td>
<td>1.0</td>
<td>5.5</td>
<td>0.3</td>
<td>85.3</td>
</tr>
<tr>
<td>II</td>
<td>26.8</td>
<td>14.9</td>
<td>11.9</td>
<td>0.6</td>
<td>44.4</td>
</tr>
<tr>
<td>III</td>
<td>85.5</td>
<td>38.4</td>
<td>47.2</td>
<td>1.0</td>
<td>55.2</td>
</tr>
<tr>
<td>IV</td>
<td>4.7</td>
<td>1.0</td>
<td>3.8</td>
<td>0.2</td>
<td>78.9</td>
</tr>
<tr>
<td>V</td>
<td>4.4</td>
<td>1.1</td>
<td>3.3</td>
<td>0.2</td>
<td>75.5</td>
</tr>
<tr>
<td>Mean</td>
<td>25.6</td>
<td>11.2</td>
<td>14.3</td>
<td>0.5</td>
<td>68.1</td>
</tr>
<tr>
<td>S.D.</td>
<td>31.1</td>
<td>14.6</td>
<td>16.7</td>
<td>0.3</td>
<td>15.6</td>
</tr>
</tbody>
</table>

*THS, HA and FA in mg g⁻¹ sediment

Important source for sedimentary humic substances. Mayer (1985) stated that macrophyte debris may serve as an important site of alteration/humification process. Humification is also enhanced in muddy sediments (Cauwet 1985).

It is surprising that the sediments at station I contained almost the same content of THS as those at stations IV and V, despite the fact that the mud content of the later stations was about 5 times higher than that in the sediments at station I. This might result from the flocculation/precipitation of dissolved humic substances due to the increase in salinity in the area of fresh water/seawater mixing (Sholkovitz 1976). It has also been demonstrated that increased salinity enhanced adsorption of humic substances on clay minerals (Rashid et al., 1972).

Whatever is the total organic carbon in the sediments, the extractable organic matter is an important parameter; it may reflect the degree of association between the organic matter and mineral support, as well as the nature of the organic matter (Cauwet 1985). THS/TOM ratio increased regularly from 0.3 at station I to almost 1.0 at station III, then decreased to almost a constant level of 0.17 and 0.19 in the most eastern part of the lake (Table 2).

The plot of THS/TOM ratio against the mud content reveals the distinct character of the eastern basin and the rest of the lake (Fig. 3). The central and western basins showed an increasing extractability with the increase in the fine fraction. Despite the high mud ratio in the eastern basin, the degree of extractability was very low (6-7.5%). It has been stated (Cauwet 1985) that, the nature of the humic substances particularly the degree of polymerization may be one of the factors controlling the binding of the humic substances to clay particles (Cauwet 1985).

**Humic substances and relative abundance of humic and fulvic acids**

The concentrations of humic and fulvic acids, as well as FA/THS ratio in the humic extracts are given in Table 2. Humic substances in Lake Edku sediments were characterized by dominance of the fulvic acid fraction whatever the sampling site and consequently the origin of the organic matter. This seems to be a general feature of
Humic Substances in the Sediments (Part I).


