

Geographical Information System Analysis for Sediments, Heavy Metals and Pesticides in Abu-Qir Bay, Egypt

S. Nasr†, M. El-Raey†, H. Ezzat‡, and A. Ibrahim‡

†Institute of Graduate
Studies and Research
Alexandria University
Alexandria, Egypt

‡National Institute of
Oceanography
Alexandria, Egypt

ABSTRACT

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A geographical information system (GIS) is used to relate sediment distributions to heavy metal concentrations and pesticides, to detect if they are related physically to sediments or they are affected mainly in their distributions by the discharge from land. Vector maps depicting distributions of bottom sediment, Copper, Iron, Cadmium and DDT, α -BHC and Lindane residues in water, are converted to raster format (5548 m² grid cells). The procedure employed can be applied to other environmental management tasks. Direct spatial correspondence between bottom muddy sediments and high concentrations of the three heavy metals studied, is detected. High concentrations of copper and iron indicate relationship to industrial sources in the western sector of the bay. No spatial correspondence is present between bottom sediments and pesticides.

ADDITIONAL INDEX WORDS: *remote sensing, marine pollution, environmental management.*



INTRODUCTION

Geographical information system (GIS) is a computer-based tool developed for handling spatially referenced data. Normally, it integrates database functions with analytical tools and techniques for geographic analysis and computerized cartography, (BARTLETT, 1993). BLOEMER *et al.* (1986), CARRARA (1989), LANGRAN (1989) and GUPTILL (1989) defined major requirements and functions of (GIS). They mentioned spatial data handling tool for solving complex geographical problems. ANGERMEIER and BAILEY (1991) used a GIS as a conservation tool for rivers.

The essential question addressed in this study is whether spreading of heavy metals and pesticides in Abu-Qir Bay are simply dependent on sediment size due to the physical adsorption on muddy sediment surfaces or are they mainly affected by the discharge from industrial outfalls. If the situation is the first, there is no problem since it is a natural phenomenon related to the discharge of the Rosetta Branch of the River Nile. But if the situation is the second, coastal management must be carried out.

STUDY AREA

Abu-Qir Bay is a semi-circular basin which lies at about 35 km northeast of Alexandria city, between longitude 30° 4' and 30° 20' East and latitude 31° 16' and 31° 28' North, (Figure 1). Its total area is about 500 km². The bay has a shoreline length of about 50 km. It is relatively shallow with a

depth ranging from less than one meter along the coast, increasing gradually away from the shore to reach a maximum depth of about 15 m. The slope of the beach is gentle, backed by a belt of sand dunes. The bay is bordered from the West by Abu-Qir Peninsula and from the East by Rosetta Peninsula where the Rosetta branch of the River Nile flows into the sea. Bottom sediment distribution of Abu-Qir Bay (Figure 2) is affected mainly by the discharge of Rosetta branch of the river. The bottom of the eastern half of the bay is of a muddy nature due to the large quantities of mud discharged annually through the Rosetta branch (2 to 5 × 10⁹ m³) (Academy of Scientific Research and Technology, ASRT, 1984). Abu-Qir Bay is exposed to industrial and agricultural waste, discharged through El-Tabia outfall, Maadia outlet and the Rosetta branch of the Nile River.

Several studies have dealt with heavy metal distribution in Abu-Qir Bay, (*e.g.*, ASRT, 1984; SAAD *et al.*, 1981; TOMA *et al.*, 1981; and EMARA, 1983). Distributions of DDT, Alpha Benzene Hexachloride (α -BHC), Lindane and bottom sediments are also studied (ASRT, 1984). Sources and types of pollution in Abu-Qir Bay are summarized in Table (1).

MATERIALS AND DATA AVAILABILITY

The base map of Abu-Qir Bay was first digitised from the 1:100,000 bathymetric map. Vector maps of the selected parameters were obtained from the work carried out by the National Institute of Oceanography and Fisheries (ASRT, 1984). Maps of horizontal distributions of iron and copper are obtained from EMARA (1983), while those of Cadmium, DDT,

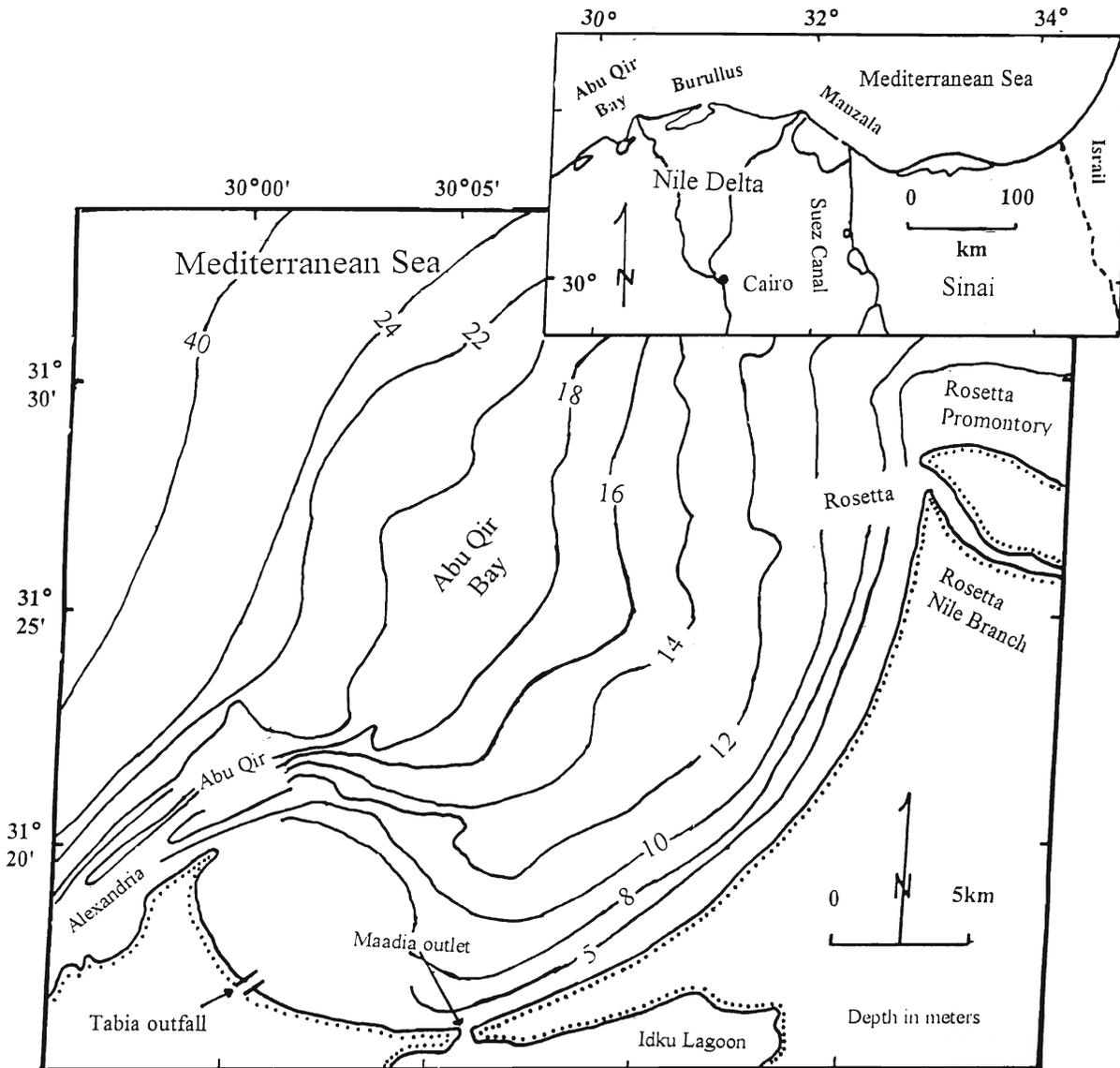


Figure 1. Location map for Abu-Qir Bay showing bathymetry.

α -BHC, Lindane and bottom sediment types are obtained from ASRT (1984). Processing and analysis were carried out using IDRISI software. The equipment and facilities are established at the Remote Sensing Laboratory of the Institute of Graduate Studies and Research at Alexandria University.

GIS MANIPULATIONS AND ANALYSIS

In the present work, the technique applied has three main phases: digitization, GIS manipulations and GIS analysis.

(a) Digitization

The ground-measured data, which exist in the form of contour maps, and bottom distribution of the sediments, were digitized manually. All features of each digitized line are

taken as x, y coordinates, the value of the contour line, z, is coded for each point. The majority of data selected are in the form of contour maps and were digitized and stored in vector files of line format. Only data representing bottom sediment types was then digitized and stored in vector file of polygon format. The seven vector files are then transformed into raster format.

Accuracy of digitization. To assess the accuracy of the manual digitization of the contour maps, comparison was made between manually digitized maps and the output of automatic encoding by a digitizer of the same map. The two vector files, resulting from the two methods of digitization, are then rasterized into two layers. A crosstabulation is then produced for data quality control. The overall accuracy was found to be 96.5%.

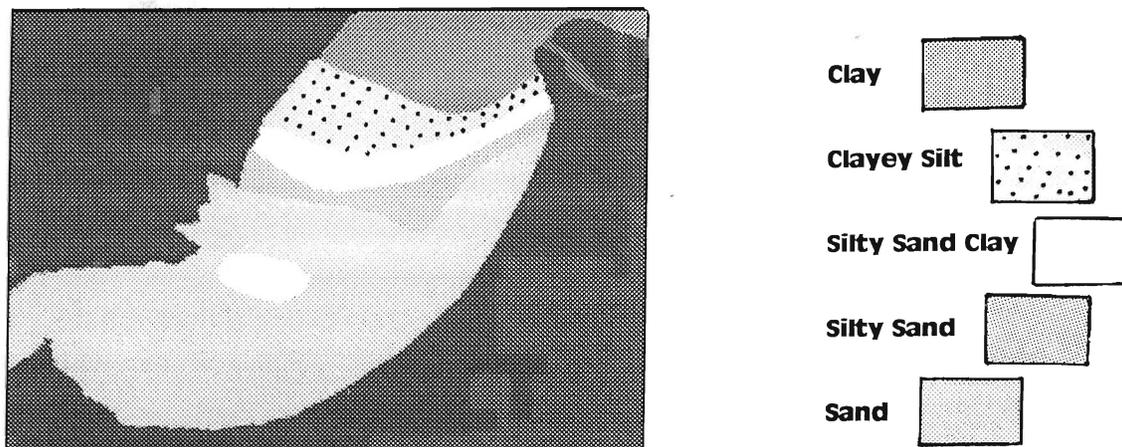


Figure 2. Distribution of bottom sediments for Abu-Qir Bay.

(b) GIS Manipulations

During this phase interpolation and retrieval operations are carried out according to methodologies of CARRARA (1989).

Interpolation. Interpolation of the 6 rasterized maps of Copper, Iron, Cadmium, DDT, α -BHC and Lindane concentrations, that are stored in vector files of point format is carried out. Full surface digital interpolated models (DIMs) are obtained from point data using moving averages.

Retrieval Operations. True geographic information systems provide a large set of tools aimed at retrieving information through (1) The geometric component of each geographical entity and/or (2) The attribute component of each geographical entity. In other words, the retrieval operation is a selection of specified data for direct application or subsequent manipulation.

These operations may involve entire scenes by windowing capabilities, depending on the geometric components, or specified entities by query windowing capabilities (calling up specific geographic entity) and Boolean capabilities (extracting specified data depending on their attribute component rather than their geometric one) (DANGERMOND, 1984 as cited in, BLOEMER *et al.*, 1986).

Table 1. Sources of various pollutants in Abu-Qir Bay.

Source	Types of Pollution, (ASRT, 1984 and SAID, 1989)	Rate of Discharge
El-Tabia Outfall	Food processing and canning, paper industry, fertilizers industry and textiles manufacturing	1.5–2 million m ³ /day, (ASRT, 1984)
Maadia outlet of Idku Lagoon	Drainage water from agriculture usually contains pesticides	1.5–2 million m ³ /day, (WAHBY and EL-DEEB, 1983)
Rosetta branch of the River Nile	Fresh water discharged carries agricultural waste from cultivated lands	2–5 × 10 ⁹ m ³ /year, (EL-HEHYAWI, 1984)

The following GIS layers have been identified: areas of clay to silty-sand muddy sediments, areas of high concentrations of Copper (above 1.0 μ g-atom/L), areas of high concentrations of Iron (above or equal to 0.6 μ g-atom/L), areas of high levels of DDT (above and equal to 75 ppt), areas of high levels of α -BHC (above and equal to 1.0 ppt), and areas of high levels of Lindane (above and equal to 10 ppt).

Overlay Analysis

Areas of high Copper concentrations are overlain on the bottom sediment types distribution. Areas of high levels of Iron, are overlain on sediment types distribution. To extract Iron values from the muddy sediment, the layer of the latter is overlain on DIM of iron. Areas of these Iron values are calculated in a number of pixels calculable area. The Iron level covering largest area is defined. The percent of its area in respect to the total separated areas of Iron levels, and those corresponding to muddy sediment, are calculated. The situation of Cadmium is different, since it is distributed in the eastern half of the bay only. The area of Cadmium distribution is overlain on the layer of sediment types to find which sediment type is related to Cadmium. Common areas among the three pesticides are produced by using the logic and operation. Finally, common areas among the three pesticides are overlain on the sediment type distributions.

RESULTS AND INTERPRETATION

From the data collected on the horizontal distribution of Fe, Cu and Cd in the surface water of Abu-Qir Bay (ASRT, 1984), and the levels values recorded in the bottom sediments in the bay, (SAAD *et al.*, 1981; TOMA *et al.*, 1981), we notice that: Heavy metal concentrations are high in front of the Rosetta branch, which is accepted logically. This is because of the fact that trace elements are associated more with finer muddy sized sediments, (clay and silt) (MOUSSA, 1983). High concentrations of heavy metals in sediment are found in front of the El-Tabia outfall and El-Maadia outlet. That is not re-

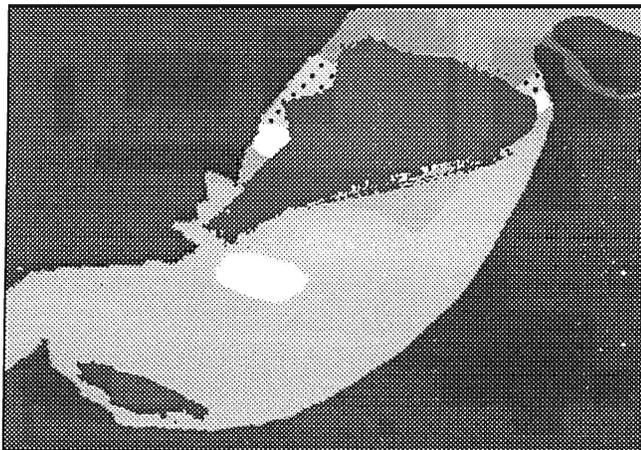


Figure 3. Copper overlaid bottom sediments.

lated to the nature of the sediment type in this area (sand), but to the effect of the discharges from these two sources.

Relationship Between Sediment Types and Copper

Figure (3) shows the distribution of high concentration of Copper overlain on bottom sediment types. From this figure it is noticed that: The areas of high levels of Copper are located mainly in the eastern sector of the bay, in front of Rosetta branch of the River Nile. In addition, a small area of high level Copper concentrations is present also in front of El-Tabia outfall. This is in agreement with results of MOUSSA (1983). It is normal for the high Copper concentrations to be associated with muddy sediment in the eastern sector of the bay. However, it is not normal to be present in areas of sandy sediments, like that of the western sector of the bay. It may be concluded that, the small area of high Copper concentra-

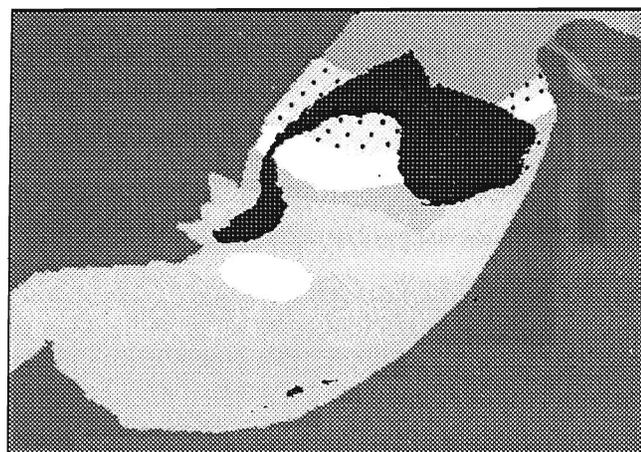


Figure 4. Iron (>0.6 µg-atom/L) overlaid bottom sediments.

Table 2. Iron concentrations and their areas in pixels and km²

Fe level (µg-atom/L)	Area (No. of pixels)	Area km ²
0.0	170,973	949
0.2	2,068	11
0.3	5,379	30
0.4	5,551	31
0.5	5,176	29
0.6	4,373	24
0.7	9,232	51

tions in front of El-Tabia outfall is caused by industrial waste discharged into the sea from industrial activities there.

Relationship Between Sediment Types and Iron

Levels of Iron in the area of muddy sediments are shown in Figure (4). Table (2) represents levels of Iron and its area in number of pixels, and in square kilometers. It is found that, the largest area (51 km²), corresponded to the highest level of (Fe = 0.7 µg-atom/L). This level is located mainly in the area of muddy sediments. This result supports the assumption that Iron is associated with this category of sediment type (MOUSSA, 1983).

Relationship Between Sediment Type and Cadmium

Figure (5) shows the aerial distribution of Cadmium overlain on bottom sediments types. It was found that, Cadmium is located only in the eastern part of the bay. This implies absence of industrial sources of Cadmium in the western sector of the bay, at least during the period of sampling.

Relationship Between Sediment Types and Pesticides

Figure (6) shows common areas between DDT, α-BHC and Lindane all overlain on the distribution of the bottom sediment types. As shown in this figure, the common areas of the pesticides are located near the shore in front of El-Maadia

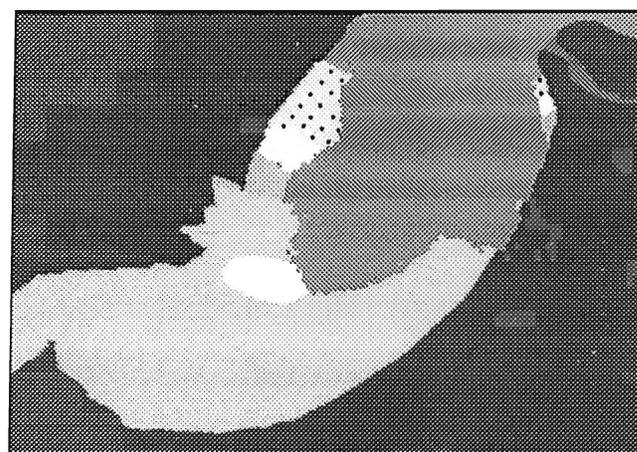


Figure 5. Cadmium overlaid bottom sediments.



Figure 6. Pesticides (DDT, α -BHC and Landine) overlaid bottom sediments.

and beside Rosetta branch. These are the main sources of agricultural waste into the bay. The high levels of pesticides are not located just in front of Rosetta branch because of the clockwise circulation pattern in the eastern side of the bay as shown by results of SAID, (1989) and EL-GINDY *et al.* (1991). This means that the distribution of pesticides in the bay is not related to muddy sediments, but to a great extent, it is affected by point sources of agricultural discharge into the bay.

CONCLUSIONS

High concentrations of Copper and Iron are found in front of El-Tabia outfall and El-Maadia outlet, although the bottom sediments in this area are of sand nature. This indicates the effectiveness of industrial sources for these two heavy metals in the El-Tabia area. A direct spatial correspondence between high concentrations of the three studied heavy metals (Copper, Iron and Cadmium) and bottom muddy sediments in front of Rosetta branch is proved. The expected spatial correspondence between the three pesticides (DDT, α -BHC, Lindane) and bottom muddy sediments is absent. High concentrations of the three pesticides are concentrated in front of El-Maadia outlet and near Rosetta branch of the River Nile. This indicates that the spatial distributions of pesticides studied are dependent mainly on the human impact and not on the sediment type.

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