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ON THE PRESENT STATUS OF THE ENVIRONMENTAL AND FISHERY OFLAKE BOROLLUS

2. A. DISTRIBUTION AND CONCENTRATIONS OF TRACE ELEMENTS IN THE WATER, AND BOTTOM SEDIMENTS OF LAKE BOROLLUS.

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Key words: Lake Borollus – trace elements – water – Bottom sediments – pollution.

ABSTRACT

The concentrations of six trace elements Zn, Cu, Fe, Ni, Pb and Cd were determined in water and bottom sediments which were monthly collected from 15 sampling stations at Lake Borollus during the period 2000 to 2002.

The average concentrations (µg/L) of these elements in the water for the whole area of the lake were found to be for:

Zn = 11.07 µg/L	Cu = 8.48 µg/L	Fe = 10.31 µg/L
Ni = 3.73 µg/L	Pb = 5.00 µg/L	Cd = 4.99 µg/L

Comparing these concentrations with the internationally allowable ones in sea water, as indicated by Water Quality Criteria where the hazardous concentration are 50 µg/L for Cu, 100 µg/L for Zn, 300 µg/L for Fe, 100 µg/L for Ni and 50 µg/L for Pb., it appears that the water of Lake Borollus is still containing these elements with lower concentrations than the permissible ones.

On the other hand, the average concentrations (mg/kg) of these elements in the bottom sediments of the lake are:

Zn = 59.19 mg/kg.	Cu = 24.32 mg/kg.	Fe = 20121mg/kg.
Ni = 36.22 mg/kg.	Pb = 19.65 mg/kg.	Cd = 2.41 mg/kg.

Comparing these concentrations with the concentrations of some of these elements in the bottom sediments of other aquatic environments in Egypt, it was found that the bottom sediments of Lake Borollus contained lower concentrations.

The present investigation revealed that the concentrations of these trace elements in both the water and bottom sediments of Lake Borollus decreased away from the outlets of the drains discharging in the lake.

It was indicated also that the middle area of the lake is the least polluted area, while the Eastern area can be considered as the most polluted part.

INTRODUCTION

The northern delta lakes of Egypt are of particular importance in the fish economy of the country. These brackish water lakes contribute with a high percentage (about 50%) in the annual fish production of Egypt. The catchment area of Lake Borollus accommodates Governorates of Kafr El-Sheikh and El-Gharbia and parts of El-Monoufia and Dakahlia Governorates. More than 8 million people live and interact with the water resources within the catchment area.

Generally, Lake Borollus, the second largest one among these delta lakes has an area of about 50,000 hectar and an average depth of 115 (cm).

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Concerning the industrial activity, it covers less than 1% of the catchment area, while agricultural activities are widely spread and are the dominant polluting agent in this area. However industrial activities are situated near to big cities such as Al-Mahalla El-Kobra, Kafr El-Zayat, Tanta and Kafr El-Shiekh where the irrigation and drainage canals are often nearby. Textile, food, chemical and oil industries are the major industrial activities in the study area. Local scale industries are mainly found in urban area. Activities of petrol stations and car workshops are almost found within this area.

Accordingly This lake seems to be distinct in terms of waste material receives (Beltagy, 1985). Land run-off including solid materials from top soil erosion is carried out to the lake through the drainage system.

It is a matter of fact, that when chemical pollutants are dumped in the open water they enter a dynamic system. They are not only diluted and dispersed by storms, winds, tides, currents up-welling, etc. also becoming intimately involved in the complexities of the biological food web of the open water (Helstead, 1972). These toxic pollutants are not merely diluted but may be re-concentrated by the aquatic biota and sediments. Marine animals pick up pollutants and also help to distribute them in migratory activities. Animals feed on plants in the marine environment and concentrate these substances. Predatory animals concentrate the chemical constituents still further. If the final species is eaten by man, who receives the combined chemical concentrates at the end of the food chain.

Traces of heavy metals (Fe, Zn, Cu, Mn, Co) are absolutely necessary to living organisms, even these elements have deleterious effect above a certain tolerable concentration (Baccini and Roberts, 1976). As to the metals known to be harmful (Hg, Cd, Cr, Ni, Co), their toxicity rise with their concentration in an accessible form (Voutsinou-Teliadouri, 1982).

Therefore the analysis of metals in water, sediments and other organisms specially those eaten by man is of special importance. Such analysis will certainly help us to avoid the drastic toxic effects of heavy metals on human.

The present investigation deals with the rates of accumulation of some trace elements namely Cu, Fe, Cd, Pb, Zn and Ni in the water and sediments part (A), macrophytes and dominant fish species part (B) at Lake Borollus.

This investigation can be considered as a basis for any further plan for the management of the environmental conditions of the lake Borollus

Lake Borollus the second largest delta lake in Egypt it situated at the northern part of the Nile delta between the two branches. The eastern and southern borders of this lake are characterised by their irregularity and surrounded by agricultural land (Fig. 1).

Lake Borollus, receives its water from two main sources, the drains at the south and the lake sea connection at the north. Drain water is discharged through seven drains and a canal which connects the lake to Rosetta branch of the Nile. The second source of water to the lake is the lake sea connection where the sea water of the Mediterranean invades the lake during the stormy days of the year. Another less important sources of water are the rain fall which fluctuates around 200 mm per month, in addition to the seapage from the cultivated lands.

The concentrations of dissolved Cu, Fe, Cd, Zn and Pb in different drains discharging into Lake Borollus during 1997-1998 are given in Table (2) (After Radwan, 2000).

While the northern shore of the lake is sandy, the southern one is largely muddy with huge areas overgrown by reed.Lake Borollus is very shallow, almost everywhere the depth of water is less than one meter. The depth increases slightly westward.

The inflow of sea water through the lake sea connection and the discharge of drain water through seven drains play the important role in the hydrographic and chemical conditions of the lake.

Darag (1984) indicated the outflowing lake current and the inflowing sea water as shown in Fig. (2).Because of the continuos drain water input to the lake water level is always higher than that of the sea water except during surges and storms. The pilling up of sea water by the prevailing north-westerly winds causes sea water to penetrate into the lake during these periods and the extent of penetration depends on wind velocity and duration. On the other hand some areas are far from the drain water inflow and others are sheltered by islets therefore their water are partially stagnant.

Drains connected to Lake Borollus:

There are several drains connected to Lake Borollus. These drains discharge their water into the lake through pumping stations distributed along the lake.

The study area can be subdivided to three areas as follows:

1 -Eastern area; which receives the drainage water from El-Gharbia main drain, drain N° 7 and Borollus drain.
2 -Middle area; which receives the drainage water from drain N° 8 and drain N° 9.
3 -Western area; which receives the drainage water from drain N° 11.

It is attempted in the following part of these investigation, to indicate the sources and types of water discharged from the above mentioned drains.

a – El-Gharbia drain:

It is considered as one of the most important drains in the North Delta. It collects both the agricultural drainage water as well as the sewage and industrial waste water from El-Gharbia and El-Dakahlia Governorates. Although El-Gharbia main drain does not discharge its water directly in the lake, it has insidious harmful effects on the water quality of the lake through the lateral drains.

b – Drain No 7:

This drain collects the waste water of Kafr El-Sheikh and El-Gharbia provinces which are mixed from agricultural industrial and domestic wastes.

c – Borollus Drain:

This drain extends parallel to the sea, collecting drainage water from Baltim area. Sewage wastes are discharged in this drain near Kafr El-Sheikh village.

d – Brembal canal:

This canal was used to supply the lake with fresh water before the establishment of the High Dam. After the control of the Nile flood (1964-65) Brembal canal water became brackish. The sea water which penetrates into Rosetta branch up to Edfina barrage is mixed with some fresh water leaking from the barrage at intervals and from the surrounding cultivated lands.

MATERIAL AND METHODS

The work plan was designed for:

1. Collect monthly water samples from 15 sampling stations at Lake Borollus as shown in Fig. (1). The longitudes and latitudes of these stations are given in Table (1). Surface water samples were kept in well stoppered polyethylene bottles. Sampling were carried out during the period from July 2000 to June 2002.
2. Collect Sediment cores were taken every 6 months during the period of investigation from the water sampling stations. Iron corer coated at its end with plastic tube which digs gently into the upper most layer of sediment was used for sediment sampling. Wet samples were kept in clean plastic containers until being exposed for drying in the air. These samples were washed, dried again. Grinding was carried out in an agate mortar, sieved in 100 mesh sieve, dried at 105°C and kept for chemical analysis.

The Preparation of water, and sediments taken from the lake for trace elements determination was carried out according to the method described in FAO technical paper N^{o} 158 edited by Bernhard (1976).

Determination of the concentrations of Cu, Zn, Fe, Cd, Pb and Ni was carried out by the use of Atomic Absorption Spectrophotometry (AAS) Perkins Elmer model 2380, of the NIOF, Alexandria, Egypt.

Electric conductivity and chlorosity were measured in 1:5 soil water extract, pH in 1:2.5 soil water suspension according to Klute (1986).

Organic carbon was determined in sediments according to the method described by El-Wakeel and Riley (1957).An accurate weight of about 0.2 g of dried sediment was treated with 10 ml chromic acid into a tube which is transferred to boiling water for 15 min. Titration was undertaken after pouring into 200 ml. distilled water against 0.2 N ferrous ammonium sulphate using ferrous phenanthroline as an indicator.

RESULTS AND DISCUSSION

I- Concentrations of trace elements in the water of Lake Borollus:

The water depth of Lake Borollus, due to its shallowness is subjected to comparatively large variations from day to another. The wind direction prevailing at the lake has a great effect on the movement of water in the lake. The wind direction plays therefore the most important role in the distribution of trace elements in the lake water. When it is easterly winds the drain’s fresh water covers most of the lake. The northerly winds drive sea water southerly. Fig. (3) shows the wind direction and duration over Lake Borollus as indicated by Darag (1984).

It appears therefore that the spatial distribution and seasonal variations in the concentrations of trace elements in the lake are strongly dependent on both the drainage water discharged from the various drains located at the south of the lake as well as the velocity and direction of winds.

A .Zinc concentrations in water:

Table (3) shows the seasonal concentrations of zinc in Lake Borollus water during the period from July 2000 to Dec. 2002.The spatial distributions of zinc in the lake water during 200, 2001 and 2002 are shown in Figs. 4, 5 and 6.

Zinc is a constituent of many metaloenzymes, proteins and structural cellular compounds in the marine life, but is listed also among the high potential pollutant elements. It is present in effluents associated with the manufacture of rubber and the process of zinc plating and galvanising (Jones, 1964). Portman (1968) indicated that concentrations up to 0.4 mg/L have been recorded in some estuarine waters and at these concentrations bivalve larvae were killed. The toxic levels for adult fish and shell fish are somewhat higher are of the order of 10 ppm. Affleck (1952) attributed the heavy mortality of the young stages of rainbow trout and brown trout in trout hatcheries to the toxicity of zinc. Galvanized pipes were used for the water supply. The water used at the hatchery was very soft containing only 1.7 ppm of calcium. So that it tended to pick up zinc from the supply pipes; from the galvanized iron containers and from the galvanized iron gauzes used to support the ova in the hatching troughs. Sawyer (1959), found that the fungicide zinc dimethyldithiochromate which was fetal to the sea lamprey in 6 hours at 0.5 ppm appeared to be very destructive to gill tissues.

It can be pointed out therefore that although zinc is considered as one of the essential elements for marine organisms at low concentrations; it becomes toxic for these organisms if present in sea water with high concentrations.

The average concentrations of zinc in water during the year 2000 were found as 8.81, 4.77 and 3.57 μg/L at the eastern, middle and western areas respectively. These concentrations increased up to 15.22, 8.28 and 6.82 μg/L during the year 2001 at the three areas in respective. These concentrations showed further increase during the year 2002 to be 15.36, 9.54 and 8.83 μg/L in the water of the above mentioned areas.

Abo-Wali (Unpublished data) in his study on the concentrations of trace elements in the drains discharging in Lake Borollus found that the concentrations of Zn in the water of these drains were as follows:

	Zn conc. In water (ppm) (mg/kg)
a. Eastern drains:	
Drain N$^{\underline{O}}$ 7	0.038
El-Gharbia	0.103
Borollus drain	0.081
b. Middle drains:	
Drain N$^{\underline{O}}$ 8	0.078
Drain N$^{\underline{O}}$ 9	0.046
c. Western drains:	
Drain N$^{\underline{O}}$ 11	0.174
Zaglul drain	0.149

This indicates that the drains located at the eastern part of the lake discharge its drainage water with higher concentrations of Zn in comparison with the water discharged in either the middle or western parts of the lake. This agrees with the data given by Radwan (2000) in Table (2).

It can be indicated also that the concentrations of Zn in the water of the three parts of the lake exhibited higher values from one year to the next during the three years 2000, 2001 and 2002.

On the other hand, the average concentrations of Zn in the whole water body of the lake were found as 6.42 μg/L, 11.23 μg/L and 16.54 μg/L during the years 2000, 2001 and 2002.

As for the spatial distribution of Zn concentrations in the lake water, it can be pointed out from Figs. (4), (5) and (6) that the area adjacent to the lake sea connection attained the highest concentrations of Zn. These concentrations showed gradual decrease northwards and westwards in all seasons.

The average concentrations of Zn in the various areas of the lake during the year 2000 were found to be 8.81, 4.77 and 3.57 μg/L in the eastern, middle and western areas respectively.

During the next year 2001 these concentrations were 15.22, 8.28 and 6.82 μg/L in these three areas.

Parallel to this trend, the eastern area exhibited the highest average concentration of Zn, reaching 19.58 μg/L in comparison with its concentrations at the middle and eastern areas where it reached 12.78 and 11.25 μg/L in the two areas respectively.

The present observation agrees to a large extent with the findings of El-Shinnawy (2003) who pointed out that the average concentrations of Zn in Lake Borollus were found as 12.32, 5.52 and 4.81 μg/L at the eastern, middle and western areas of the lake respectively.

B .Copper concentrations in water:

Copper forms stronger complexes in sea water than do most metals and it is both highly toxic to marine organisms although it is considered as an essential micro nutrient (Mackey and Szymczak, 1988). Copper is also known to be found in both the dissolved and particulate forms in natural waters. Riley (1969) separated the total copper into three fractions, soluble or ionic (Cu^{+2}), organic and sestonic.

This trace element is associated in natural waters with phospholipid, aminolipid or porphyrin fractions of the extractable organic material. Such compounds may be excretion products of marine organisms or may arise from the decomposition of dead organisms or by interaction between ionic copper and dissolved organic matter (Darag, 1984).

Open sea water has copper concentrations around 1 μg/L. In polluted areas values up to 11 μg/L have been reported (Bernhard and Zattera, 1975).

Harvey (1974) pointed out that, when metallic copper is placed in sea water cuprous compounds are rapidly oxidized to cupric and heavy supersaturation results which may persist long enough for a concentration of 2000 mg cupric copper per cubic metre to be temporarily attained.

The seasonal average concentrations of copper in the water of Lake Borollus are seasonally indicated in Table (4) during the years 2000, 2001 and 2002.

These concentrations ranged during the year 2000 between 2.83 to 6.06 with an average of 5.4 μg/L, from 2.16 to 3.37 with an average of 2.69 μg/L and from 3.60 to 7.16 with an average of 5.14 μg/L at the eastern, middle and western areas of the lake.

The concentrations of this trace element increased through the whole area of the lake during 2001 in comparison with its concentrations during the year 2000. The averages of these concentrations were found to be 9.75, 5.82 and 8.15 μg/L at the western, middle areas of the lake respectively.

Copper concentrations in the lake water exhibited further increase during the year 2002 where the averages of these concentrations were 14.44, 8.61 and 15.36 μg/L at the above mentioned areas.

The spatial distributions of copper concentrations in the lake water are shown during the years 2000, 2001 and 2002 by Figs. 7, 8 and 9 respectively.

It can observed from such data that the concentrations of copper in the water of the middle area of the lake were lower than the concentrations of this element in either the eastern or western areas.

On the other hand, it can be indicated that the water of the southern areas attained higher concentrations of copper in comparison with that of the northern areas.

However, it can be pointed out that the areas near to the outlets of the drains are characterised by higher concentrations. Away from these outlets, a gradual decrease in the concentrations of this element can be detected.

In this concern it was pointed out by Darag (1984) that a gradual decrease in the average copper concentrations in the base area (northern area) in comparison with its concentrations in the Potamogeton area (southern area) was existing during the period 1977-1978.

El-Shinnawy (2003) in his study on the environmental parameters at Lake Borollus during 2001-2002 indicated that the average concentrations of Cu in the water of the lake were 7.31, 3.85 and 6.15 μg/L at the eastern, middle and western sectors of this lake respectively. Such data do not differ greatly from the values given in the present investigation.

In fact the marine pollution does not only mean pollution of sea water, but also the possible contamination of its various components, both a biotic and biotic each of which plays a particular role in the system.

To indicate the effect of copper on the marine life, Fitzgerald (1966), treated various species of algae with different concentrations of potassium permanganate and copper sulphate in order to determine the concentrations required to kill cells after 12 and 72 hours treatment and to prevent growth of various species of cyanophytes, chlorophytes and diatoms. Toxicity of copper sulphate was highly variable, cyanophytes except *Oscillatoria* were killed at concentrating of 0.1 mg/L, others were killed after 4 hours at 0.4 mg/L. Growth of these species was inhibited by 0.1 to 0.2 mg/L of Cu.

Nitta (1972) found that higher water content of copper and zinc cause a dark green colouration in oysters. This occurs in case of waters having concentrations of copper or zinc 0.01 ppm and 0.1 ppm respectively. These elements are toxic for oysters above these concentrations.

Lewis *et al*. (1972) pointed out that copper concentrations above 5 μg/L reduced the survival of the early life stages of some marine organisms, although such concentrations could be tolerated if the metal is complexed or adsorbed. Therefore the naturally occurring organic matter in sea water and sediments could reduce the toxicity of some metals to the planktonic copepode *Euchaeta japonica*.

Ellis (1973), studied the effect of copper compounds on fish. She concluded that the toxic process of $CuSO_4$ was three fold in the attack on the respiratory system of fish. First the space between the gill filament become filled with precipitate so that the water flowing through the branchial chambers can not reach the gill filament cells. Secondly the space between the gill lamellae become filled so that the movement of the gill filaments become impossible, and this condition affects the circulation of blood in the gill capillaries. Thirdly this state is affecting the blood circulation in gills leads to heart block.

C .Iron concentrations in water:

Iron is an essential constituent for living organisms. This element is found usually in the marine environment in the dissolved and particulate forms. The common compounds of Fe in the water are colloidal ferric hydroxide and ferric phosphate or as soluble complexes. No forms of trivalent iron in ionic solution is likely to be detectable in normal lake water (Darag, 1984).

It is a matter of fact that iron may be assimilated from both water and sediments by plants specially in the areas where plants grow intensively at the lakes.

The seasonal average concentrations of iron in Lake Borollus water during the period 2000 to 2002 are given in Table (5).
On the other hand, the spatial distributions of this element in the lake water are shown in Figs. 10, 11 and 12 for the years 2000, 2001 and 2002 respectively is found that:

(1) The concentrations of Fe were higher at the southern areas of the lake (Sations 6, 9 and 14) (Potamogeton area) in comparison with the northern areas (bare area) during the whole period of the present investigation (Table 5). These higher concentrations can be attributed to the decrease in the pH of the water at the southern areas due to the intensive growth of aquatic plants specially Potamogeton where CO_2 is liberated with high rates as a result of the respiration of the such plants. As mentioned before high concentration of iron are expected where pH of water is decreased.

Darag (1984) in his study on trace elements concentrations at Lake Borollus found that the concentrations of iron in the drains water were much higher than its concentrations in the lake water.

The higher concentrations of iron in the drains water are expected to increase the concentrations of this element in the areas of the lake near to the outlets of these drains.

This may help in explaining the higher values of iron concentrations at the southern areas at the lake in comparison with its concentrations at the northern or middle areas.

(2) The eastern part of the lake attained the highest concentrations of iron during the whole period of investigation in comparison

with either the middle or western parts of the lake.

The average concentrations of such element were 3.66 μg/L, 1.45 μg/L and 2.72 μg/L at the eastern, middle and western areas respectively during the year 2000.In 2001 these concentrations increased to 12.67, 6.42 and 9.98 μg/L in respective.

Further increase was existing during 2002 where these concentrations were found to be 21.71, 12.94 and 22.63 respectively.

El-Shennawy (2003), found that the average concentrations of iron in Lake Borollus water were 8.81 μg/L at the eastern part of the lake and 3.14 μg/L at the middle part while it was 5.63 μg/L at the western part. He pointed out that the water at the middle part of the lake attained the lowest concentrations of iron. This agrees well with data given in the present investigation.

D .Nickel concentrations in water:

Although Ni is considered as one of the essential elements for living organisms in the marine environment, high concentrations of this element in sea water adversely affects the life of marine organisms.

Pickering (1974) in his study on the chronic toxicity of Ni to the fat head minnow pointed out that nickel concentrations of 0.38 mg/L and lower do not adversely affect the survival, growth and reproduction of the fathead minnow. However a nickel concentration of 0.73 mg/L caused a significant reduction on both number of eggs per spawning and hatchability of these eggs. Among four heavy elements namely Cu, Zn, Cd and Ni, the same author indicated that Ni was the least adversely affecting the fish under the experimental investigation.

Rehwoldt *et al.* (1971) in his study on the effect of some common industrial outputs upon the life of Hudson River indicated that copper was the most toxic to all species and nickel was the least toxic for all species except the American eel zinc was toxic than nickel.

Shaw and Brown (1971) found that preliminary tests on the effects of copper and nickel on fertilization of rainbow trout eggs show that neither element is likely to be responsible for any impairment of fertilization among trout at existing natural levels. This does not imply that successful development would occur under conditions of continuous exposure to these poisons.

The concentrations of Ni at the various areas of Lake Borollus are given in Table (6). The average concentrations of this element did not exhibit significant difference from the year 2001 to 2002 at any of the eastern and middle areas. Significant increase in this concentration was found during the year 2002 at the western area where it increased from 2.3 μg/L during 2001 to 4.07 μg/L during 2002.

Concerning the spatial distribution of Ni at the lake, it can be observed that higher concentrations were existing at the east and western parts of the lake while lower concentrations were occurring at the middle areas (Figs. 13 and 14).

It is a matter of fact that the average concentrations of Ni at the various areas of Lake Borollus were in all cases below the concentrations that may adversely affect the growth or breeding of fish living at this lake according to the statements of Pickering (1974), Rehwoldt *et al.* (1971) and Shaw *et al.* (1957).

E . Lead concentrations in water:

Lead is considered as a one of the most abundant heavy elements and its use has been recorded from around 2500 BC onwards. Its extensive use in historic time made it as one of the earliest known metal pollutants.

Moriarty (1975) indicated that air contains from natural processes about 0.0005 μg of lead per m^3 of air which has been derived from air borne dust and by gaseous diffusion from the earth's crust. He showed also that air over the largest American cities contains 2000 times as much lead as much air over the Pacific. Most of this airborne lead must come from man's activities. The air content of Pb is a main source for water pollution with this element.

Marin and Knauer (1973) mentioned that the first tropic levels phytoplankton zooplankton and macrophytes can enrich lead to a considerable extent over the surrounding sea water.

As for the effect of lead pollution on the marine environment, Jones (1964) reported that all the affected rivers in Cardiganshire were quite devoid of fish and very lacking in flora and invertebrate fauna when these rivers were exposed to lead mining pollution.

Lead acts synergistically with combinations of copper and zinc and with copper, Zn and H^+ (Starodub *et al*., 1987).

The average concentrations of Pb in the water of Lake Borollus during the period of the present investigation are seasonally given in Table (7). The figures given in this table are used for graphical representation of spatial distribution of this element in the lake water as shown in Figs. 15, 16 and 17 during the years 200, 2001 and 2002 respectively.

It can be pointed out from the data given that the middle part of the lake which can be considered as the lake proper attained the lowest concentrations of Pb during the whole period of the present investigation in comparison with both the eastern or western areas. The average concentrations of Pb in such part of the lake were 1.26 μg/L, 3.99 μg/L and 5.96 μg/L during the years 2000, 2001, and 2002 respectively.

On the other hand, the eastern sector of the lake attained the highest concentrations of lead where the averages of these concentrations were 2.34 μg/L, 6.50 μg/L and 8.06 μg/L during 2000, 2001 and 2002 in respective. These high concentrations of Pb at the eastern area indicate that the drainage water of El-Gharbia, Borollus and Nasser drains are discharged with high levels of lead compounds. It is worth to mention that El-Gharbia drain transports the wastes of El-Dakahlia and El-Gharbia provinces to the lake where textile, food, chemical and oil industries are the major industrial activities.

This coincides with the data given by Radwan (2000), Table (2), where it indicates that Baltim and Nasser drains discharge high concentrations of Pb.

In agreement with that, El-Shennawy (2003) pointed out that the middle part of the lake attained the lowest concentrations of lead if compared with the other two parts namely eastern or western ones.

F .Cadmium concentrations in water:

Cadmium is one of the most toxic heavy metals, enters the environment from natural sources and as a result of mans activity e.g. from combustion of coal and oil, the zinc industry, the recycling of scrap metal, plastics, cadmium paints and electroplating works.

In the marine environment mainly coastal and estuarine areas are affected by cadmium pollution. It was first recognised as an environmental pollutant after the outbreak of (itai itai disease in Japan) (Kobayashi, 1971).

Positive correlation between cadmium concentration in sea water and its uptake by the whole soft body of *Mytilus edulis* was established by Scholz (1980), who pointed out that cadmium uptake increased significantly with increasing its concentration in the uptake medium. Until 100 μg Cd/ℓ neither limitation of uptake nor any saturation process can be observed.

The effect of calcium and cadmium uptake was studied by Stephenson and Mackie (1988) who observed strong negative effect in situ of calcium and cadmium levels in the amphipode *Hyalella aztecce* and suggested that Cd^{++} competes with Ca^{++} for uptake sites on the gill surface.

Yan *et al*. (1990) found negative effect of $[H^+]$ on cadmium accumulation in marine algae, insects and zooplankton. It is thought that $[H^+]$ compete with Cd^{++} for sites of ion uptake in the biota.

Considering the uptake of Cd in the presence of dissolved organic matter, Ramamorthy and Blumhagen (1984) reported that dissolved organic matter although decreased the uptake of Hg and Zn by fish, it increased the uptake of Cd.

The concentrations of Cd at the various sampling stations of Lake Borollus are shown in Table (8).

The averages of these concentrations were found to be 3.54, 1.54 and 2.03 μg/L at the eastern, middle and western areas of Lake Borollus during the year 2000.

These concentrations increased to 7.32, 3.28 and 3.66 μg/L in the three areas respectively during 2001.

Another increase in these concentrations was observed during 2002 where the concentrations of this element were found as 9.00, 4.36 and 7.06 μg/L at the eastern, middle and western areas of the lake in respective.

The spatial distribution of Cd at the lake is shown in Table (8) and illustrated as contour lines in Figs. (18, 19 and 20).

It can be demonstrated that the highest concentrations of Cd were found at the eastern area of the lake. On the other hand, the middle area exhibited the lowest concentrations throughout the whole period of study. The higher concentrations of Cd at the eastern area may be attributed to higher concentrations of this element in the water discharged in this area through the drains number 7, El-Borollus and El-Gharbia drain where all these drains discharge their water at the tmost eastern part of the lake. Data given in Table (2) (after Radwan, 2000) supports that the drains discharge high concentrations of Cd at the eastern part of the lake.

In agreement with that El-Shinnawy (2003) found that the concentrations of Cd were 5.54, 2.16 and 2.63 μg/L at the eastern, middle and western parts of the lake.

On the other hand, Abo-Waly *et al.* (Unpublished data) showed that the water discharged to Lake Borollus from drain N^{o} 7 and Borollus drains which are situated to the east of the lake contained higher concentrations of Cd in comparison with the other drains of the lake. The concentration of this element in Borollus drain water was found to range from 20 to 24 μg/L. These concentrations ranged from 3 to 18 μg/L in the water of drain N^{o} 7. The water discharged from the drains situated to either the middle or the west of the lake contained Cd with concentrations ranging from 3 to 10 μg/L.

Concentrations of trace elements of the lake water in comparison with the allowable concentrations:

The allowable concentrations of trace elements in water according to the report of the committee of Water Quality Criteria (1972) were given as follows:

Element	Minimal risk Concentration (μg/L)	Hazardus Concentrations (μg/L)	Average 2000	Concentration 2001	In lake 2002	Water Average
Zn	20	100	6.42	11.23	15.55	11.07
Cu	10	50	4.45	8.12	12.88	8.48
Fe	50	300	2.73	10.05	18.14	10.31
Ni	2	100	-	3.36	4.10	3.73
Pb	10	50	2.23	5.50	7.27	5.00

If the concentrations of these elements in the water of Lake Borollus are compared with these allowable concentrations it could be indicated that:

1. For Zn the concentrations in the lake water are still below the minimal risk concentrations.
2. For Cu the concentrations in the lake water exceeded the minimal risk concentration during the year 2002 only, but still far below the hazardous concentrations.
3. For Fe the concentrations in the lake are still below those allowable ones.
4. For Ni the concentrations in lake water are slightly more than the minimal risk concentration but far from the hazardous concentration.
5. For Pb the concentrations of such black listed element in the water of the whole area of the lake are below the minimal risk concentrations.

It appears therefore that the water of Lake Borollus can be considered to be far from the state of pollution with trace elements in spite of the discharge of drainage water through several drains located at the south and east edges of the lake.

In agreement with the above indication Moussa (1984) in his study on metal pollutant levels at Lake Borollus evidenced that this lake is neither polluted by trace metals nor has a polluting effect on the nearly Mediterranean waters.

II -Concentrations of trace elements in the sediments:

Natural reservoirs such as lagoons and coastal lakes act as containment basins for pollutants. During containment, metal pollutants may to different degrees become important in the basin sediments. Anthropogenic contamination can thus be traced from the level of excess metal concentration in sediments whose initial natural composition is known (Moussa, 1984).

However it is attempted in the present investigation to follow the changes in trace elements concentrations transplanted from the surface area of the Nile delta to the marine environment through Lake Borollus.

As for the nature of bottom sediments at Lake Borollus, it was indicated by Zazou, 1974 that the bottom of the lake extending along the northern shore from the lake-sea connection westwards is mainly clayed sand with some patches formed of molluscan shells. The eastern and western regions of the lake are silty clay while the southern areas are formed mainly from clay and silt with small areas covered with mulluscan shells.

A .Zinc concentrations in sediments:

Although zinc is one of the most abundant toxic heavy metals, the oral toxicity in humans to most zinc compounds is relatively low (Helsted, 1972).

High concentrations of this metal in the marine environment may exist from the discharge of industrial wastes specially electroplating and synthetic fiber production.

It is a matter of fact that El-Gharbia drain which discharges its waste water directly at Lake Borollus plays a role in transplanting the wastes of many Textile companies located at El-Mehalla El-Kobra. These wastes are believed to contain high concentrations of Zn compounds.

The concentrations of Zn in the sediments of Lake Borollus during the years 2000 and 2001 are indicated in Tables (9) and (10) respectively.

It is obvious from the data given in these tables that the concentrations of Zn in the sediments at the eastern and middle areas did not differ significantly. The average concentrations were found to be 52.33 and 51.78 mg/kg at the eastern and middle areas respectively during the year 2000. These concentrations were found as 53.94 and 55.09 mg/kg at the two areas in respective during 2001.

On the other hand, higher concentrations were found in the sediments at the western area of the lake, where these concentrations had an average of 94.40 mg/kg during the year 2000 and 94.53 mg/kg during the year 2001.

These high concentrations can be attributed to the high concentrations of Zn in the fresh water discharged at the west of the lake from Birembal canal. This as well the water discharged from the drains laying to the west of the lake.

B .Copper concentrations in sediments:

It is a matter of fact that drainage water is the main source of copper for Lake Borollus.The average concentrations of copper in the bottom sediments of Lake Borollus during 2000 and 2001 are given in Tables (9) and (10). The spatial distribution of these concentrations are represented in Fig. (22).

It can be indicated from the data given that the average concentrations of this element were low in the eastern area of the lake in comparison with either its middle or western areas.

These concentrations were 21.87 and 23.78 mg/kg at the eastern area during the years 2000 and 2001 respectively. On the other hand such concentrations were 21.32 and 21.10 mg/kg at the middle area of the lake and increased to 35.47 and 30.42 mg/kg at the western sector of this lake during 2000 and 2001 respectively.

It can be pointed out therefore that the average concentrations of copper in the sediments of Lake Borollus did not differ significantly during the two years 2000 and 2001.

It can be demonstrated also that the concentrations of copper in the bottom sediments of the lake decreased northwards away from the outlets of the drains. The higher concentrations found at the southern areas may be due to the release of adsorbed copper from particles in the lake water.

Darag (1984) in his study on trace metals concentrations in the bottom sidements of Lake Borollus, pointed out that the concentrations of this element tended generally to decrease from west to north-east. This agrees to great extent with the data given in the present study.

On the other hand, it was indicated by Goldberg and Arrhenius (1958) that copper was found with concentrations up to $2x10^6$ μg/kg dry weight in the sediments of the Pacific Ocean. This means that our fishing grounds are far away from the hazardous concentrations which occur in some areas of the world.

C .Iron concentrations in sediments:

It is a matter of fact that the drain water transplants respectful concentrations of iron to Lake Borollus.

Precipitation of iron may be undertaken by bacteria in two ways. In the first way only the organic matter associated with iron is metabolised, ferric hydroxide being left over is precipitated. Secondly iron is actually involved in the metabolism of bacteria which can derive energy for the synthesis of organic compounds from the oxidation of ferrous salts such as $FeCO_3$ or $Fe(HCO_3)_2$ (Hutchinson, 1957).

The sediment content of iron is mostly controlled by two factors, namely the distance from the outfall and the nature of sediment. In this concern Rohatgi and Chen (1975) pointed out that trace metal concentrations in sediment were found to decrease with respect to the distance away from outfall, indicating a lower rate of deposition of suspended particulates away from the discharge area. The sandy nature of the bottom sediment may also be related to their relatively lower iron content.

The average concentrations of iron in the sediments of Lake Borollus during the years 2000 and 2001 are indicated in Tables 9 and 10. The spatial distribution of these averages are shown in Fig. (23).

It can be observed from the data given that the average concentrations of iron in the sediments of the lake increased from the year 2000 to 2001. These concentrations were found as 12.11, 13.35 and 33.03 mg/kg dry weight at the eastern, middle and western areas of the lake during 2000. The average increased to 24.15, 12.84 and 40.83 mg/kg at the same areas respectively during 2001.

It can be observed also from the horizontal distribution of iron in the sediments of the lake that the concentrations of this element were higher in the sediments of the western area in comparison with its concentrations in either the middle or eastern areas.

On the other hand, these concentrations decreased northwards away from the outfalls of the drains to the lake. The sandy bottom at the north of the lake plays important role in decreasing the iron content in the bottom sediments.

Nickel concentrations in sediments:

The concentrations of Ni in the sediments of Lake Borollus during the years 2000 and 2001 are shown in Tables (9) and (10) and graphically represented in Fig. (24) for the spatial distribution of this element in the sediments of the lake.

The data given in these tables indicate that the average concentrations of Ni in the sediments decreased from the year 2000 to 2001 where these concentrations were 19.56, 45.24 and 71.87 mg/kg in the eastern, middle and western areas in respective during the year 2000. These concentrations decreased to 15.87, 43.17 and 60.33 mg/kg during the year 2001.

It is obvious also from the data given that the sediment content of Ni attained its minimum values at the eastern stations of the lake. Increased values were observed at the stations laying in the middle areas while the highest concentrations were found at the western areas of the lake.

In agreement with these data Abo-Wali (Personal Communication) found that the average concentrations of Ni in the sediments of Lake Borollus were 40.4, 62.2 and 110.2 mg/kg dry weight at the eastern, middle and western areas respectively. He pointed out that the most polluted area of Lake Borollus is the eastern area where high concentrations of pollutants were detected in both the macrophytes and sediments located at the eastern area of the lake.

Lead concentrations in sediments:

Lead is one of the most abundant heavy elements and its use has been recorded from around 2500 BC onwards (Coleman *et al.*, 1980).

The extensive use of lead in historic time made it as one of the earliest known metal pollutants. In the present century it has increasing usage as an additive to petrol fuel for use in internal combustion engines and in making batteries. This rapid rise in the use of lead by man has resulted in large increase in the levels of lead prevailing in the environment.

IPCS/WHO (1987) reported that lead in the environment is strongly absorbed into sediment and soil particles reducing its availability to organisms. Uptake of lead from marine environment was found to exceed that of copper and cadmium. Many plants concentrate the uptake of lead in roots.

The average concentrations of Pb in the sediments of Lake Borollus during the years 2000 and 2001 are given in Tables (9 and 10). The spatial distribution of these concentrations in the sediments of the lake is represented in Fig. (25).

The data given in Tables 9 and 10 indicate that the sediments at the middle area of the lake attained the lowest concentrations of Pb. On the other hand, the eastern area contained the highest concentrations of Pb. The average concentrations of this element were found to be 23.96, 13.60 and 19.80 mg/kg at the eastern, middle and western areas respectively during the year 2000. These concentrations were 22.98, 14.17 and 20.88 mg/kg at the three areas respectively during 2001.

This means that the middle area of Lake Borollus is the least polluted area of the lake with Pb which is considered as one of the black listed pollutants.

The spatial distribution of the average concentrations of Pb in the lake shows that its concentrations are high near the outlets of the drains. These concentrations decrease gradually far from these outlets. In most cases the narrowness of the contour lines expressing the distribution of such concentrations can be taken as an evidence for the sharp decrease of Pb concentrations away from the outlets.

Cadmium concentrations in sediments:

It is a matter of fact that Cd is one of the black listed elements and can be considered as one of the most dangerous elements on marine life and humans.

The concentrations of this element in the sediments of Lake Borollus are given in Tables 9 and 10 during the years 2000 and 2001.

It can be pointed out that the most polluted sediments with this element located at the western area of the lake.

The average concentrations of Cd were found to be 1.94, 1.74 and 2.60 mg/kg dry weight at the eastern, middle and western area respectively during the year 2000. These concentrations were found to be 2.70, 2.60 and 3.36 mg/kg at the eastern, middle and western areas in respective during the year 2001.

Comparison between present concentrations of Zn and Cu in sediments with other areas in Egypt:

In the following it is attempted to compare between the concentrations of Zn and Cu in the sediments of Lake Borollus with the concentrations of these elements in the sediments of various areas in Egypt (Averagers of concentrations given in brockets).

Element	Area	Concentration (ppm)	References
	Lake Mariut	70-2960	Wahby (1979)
	Nile delta shelf	2-119(89.4)	Mousa (1982)
	Nile River	62-216(108)	Emelyanov *et al.* (1978)
	Easter Harbour	8-174(53)	Elsayed *et al.* (1980)
Zn	Abo Qir Bay	9-758(102)	Saad *et al*. (1980)
	East Medit.	Tr-200	Mousa (1977)
	Lake Borollus (1984)	21-55(40)	Mousa (1984)
	Lake Borollus	19-121(58)	(2000) (present study)
	(present study)	27-122(62)	(2001) (present study)
	Lake Mariut	16-500	Wahby (1979)
	Nile delta shelf	6-77(33.4)	Mousa (1982)
	Nile River	31-70(52)	Emelyanov *et al.* (1972)
	Eastern Harb.	5-104(27)	Elsayed *et al.* (1980)
Cu	Abu Qir Bay	Tr-91(12)	Saad *et al*. (1980)
	East Medit	5-50	Mousa (1977)
	Lake Borollus (1984)	10-29(18)	Mousa (1984)
	Lake Borollus	10-46(24)	(2000) (present study)
	(Present study)	9-51(24)	(2001) (present study)

Comparing the concentrations of Zn and Cu in the sediments of Borollus Lake with those in the sediments of other areas in Egypt it appears that this lake is still considered to be cleaner in comparison with those other areas, but it tended to increase than that previous record.

However a high concentration of trace elements in sediments can be considered as an indicator for the industrial activity around the aquatic environment where industrial wastes are discharged.

Correlation between the concentrations of trace elements in water and sediments:

The calculated values of the coefficient of correlation between the concentrations of trace elements in the water of Lake Borollus during the year 2000, 2001 and 2002 are given in Tables (11, 12 and 13) respectively.

It appears from the data given that there is high correlation between the concentrations of Cu and Fe in the water where a positive relationship between these two elements is existing. Another positive correlations are found between Cu and Cd, from one side, from the other side stronger positively correlation exists between Cd and Fe.

However the calculated values of correlation coefficient exhibit positive correlation between the concentrations of the six trace elements in the water of the lake. This may be due to the continuous discharge of drainage water from various industrial, agricultural and domestic activities carried out at the wide lands surrounding the lake. Such drainage water transplants different trace elements from different sources to the lake. Among the regularly transplanted elements are Zn, Cu, Fe, Ni, Pb and Cd. compounds.

Electric conductivity, Chlorosity, pH and organic matter The main physical and chemical factors which govern the distribution and behaviour of trace elements (Riley and Skirrow, 1965) were therefore determined in the sediments of Lake Borollus during the years 2000 and 2001 as indicated in Tables (14) and (15).

On the other hand, it is attempted to correlate between the concentrations of various elements in the water and those in the sediments of the lake. The calculated values for correlation coefficient during the years 2000 and 2001 are given in Tables (16 and 17) respectively.

It can be observed that the correlation is positive in cases of Cu, Fe and Pb while it is negative in the cases of Cd, Zn and Ni.

It is obvious from the data given in these tables that both the electric conductivity and chlorosity of sediments are higher at the eastern area of the lake in comparison with either the middle or western areas. This is expected because of the existence of the lake sea connection at the northern periphery of the eastern part of the lake which gives a chance for sea water invasion to this part of the lake.

It is obvious also that the organic matter content of sediments was higher at the middle and western areas of the lake specially at the southern parts where the lake connects with the drains. In this concern Darag (1984) found that in contradition to the overlying water, the sediment in the western basin was relatively richer with organic matter if compared with other areas.

The correlation coefficients between concentrations of trace elements and different parameters contents in sediments of the lake are given in Tables 18 and 19 for the years 2000 and 2001 respectively.

It can be indicated from the data given in these tables that:

(1) Concentrations of all trace elements investigated attained positive correlation with each others mostly. This means that these concentrations increase simultaneously in the sediments of the lake.

(2) Trace elements concentrations did not exhibit regular tendency through their correlation with electric conductivity

chlorosity, pH or organic matter in the sediments of the lake.

SUMMARY AND CONCLUSIONS

It has been concepted for a long time that the north delta lakes can receive any discharged pollutants without resulting any burden on their environment. Nowadays it has been ascertained that such conception is not the case. Our most valuable marine food resources are taken from the north delta lakes. These lakes contribute with more than 50% of the annual fish yield.

It is attempted in the present paper to study the effect of drainage water discharged to Lake Borollus, the second largest one among the north delta lakes, on the level of pollution of its water and bottom sediments with six trace elements namely Zn, Cu, Fe, Ni, Pb and Cd during the period 2000-2003.
The following points can be concluded from the present investigation.

(1) The water and sediments laying to the south parts of the lake are subjected to higher rates of pollution with trace elements due to its closeness to the outfalls of the drains which discharges high loads of agricultural, industrial and domestic wastes into the lake.

(2) The area of the lake can be classified to three parts according to the level of pollution with trace element. The presence and distribution of more than 30 small islands in the lake plays an important role in classifying the lake into eastern, middle and western parts. The water and sediments of the eastern part is the most polluted area of the lake with trace elements.

(3) Comparing the concentrations of trace elements in the water of Lake Borollus with the allowable levels it can be indicated that these concentrations in the water of this lake can be considered as below the permissible concentrations according to the recommendations of the international organizations.

(4) Comparing the concentrations of Zn and Cu in the bottom sediments of Lake Borollus with those in other aquatic Egyptian environments it can be pointed out that this lake is still considered to be cleaner in comparison with such environments.

(5) Concentrations of trace metals in the water of Lake Borollus were found to be in the following order: Zn > Fe > Cu > Pb > Cd > Ni. The corresponding order of the concentrations of these elements in the bottom sediments of the lake was found to be as follows: Fe > Zn > Ni > Cu > Pb > Cd.

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Table (1) : Latitudes and Longitudes of the Sampling stations at Lake Borullus .

St. No.	Station Name	Latitude N			Longitude E		
1	Outlet	31˚	34'	27.6"	30˚	59'	28.4"
2	Drainage mouth (El-Borullus)	31˚	33'	29.9"	31˚	04'	25.3"
3	Drainage mouth (El-Gharbyiah)	31˚	31'	42.4"	31˚	04'	56.0"
4	Drainage mouth (Nasser)	31˚	31'	06.5"	31˚	03'	55.4"
5	Mishkhillah	31˚	30'	58.7"	30˚	57'	03.8"
6	Drainage mouth (No. 7)	31˚	27'	56.1"	30˚	56'	17.5"
7	Middle of eastern sector	31˚	32'	59.0"	30˚	58'	23.5"
8	El-Zankah	31˚	27'	53.3"	30˚	47'	10.0"
9	Drainage mouth (No. 8)	31˚	24'	46.9"	30˚	45'	54.9"
10	El-Tawillah	31˚	26'	21.2"	30˚	44'	54.9"
11	Abou-Amer	31˚	25'	41.0"	30˚	40'	40.2"
12	El-Maksabah	31˚	29'	09.0"	30˚	45'	24.4"
13	Brimbal	31˚	24'	06.2"	30˚	35'	00.4"
14	El-Hoksa (Drainage mouth 11)	31˚	23'	15.5"	30˚	36'	15.3"
15	Middle of western sector	31˚	24'	17.5"	30˚	37'	01.9"

St. = Station

Table (2) : Seasonal Variations of dissolved Cu, Fe, Cd, Zn and Pb in different drains discharging into Lake Borullus during 1997-1998. (After Radwan 2000)

		Baltim Drain	Nasser Drain	Drain 7	Drain 8	Drain 9	Drain 11
Winter March 1997	Cu	6.53	8.63	6.65	2.98	1.68	2.05
	Fe	4.75	6.31	2.88	1.59	1.66	1.03
	Cd	3.86	4.53	3.15	2.45	3.76	2.25
	Zn	5.73	9.51	2.23	3.86	7.65	4.26
	Pb	1.56	2.43	0.86	1.03	1.76	0.45
Spring April	Cu	4.21	6.35	2.25	1.87	0.79	1.35
	Fe	2.86	4.58	1.59	1.13	0.45	0.88
	Cd	2.91	2.79	1.87	1.36	1.76	1.65
	Zn	3.95	5.81	2.61	2.00	3.89	2.16
	Pb	1.56	1.46	1.31	0.89	1.05	0.79
Summer July	Cu	7.63	9.45	5.53	6.23	2.87	4.55
	Fe	5.21	6.85	3.45	2.61	2.04	1.98
	Cd	2.21	3.52	1.03	0.86	1.62	1.05
	Zn	17.51	19.35	11.45	8.33	9.15	8.83
	Pb	11.76	13.36	12.63	9.85	8.76	1.53
Autumn October	Cu	5.81	7.39	6.71	3.71	3.51	5.31
	Fe	3.46	4.91	4.31	2.43	1.86	2.51
	Cd	2.79	3.31	2.51	1.59	0.79	1.86
	Zn	10.25	11.73	7.89	6.45	5.81	6.51
	Pb	7.33	9.88	9.71	5.66	6.79	0.69
Winter February 1998	Cu	6.21	9.61	9.85	10.53	11.23	4.86
	Fe	4.86	3.79	5.23	7.83	6.88	3.32
	Cd	2.56	4.86	3.59	2.56	1.39	0.89
	Zn	21.15	23.76	18.91	9.88	7.85	5.63
	Pb	2.88	3.15	1.89	1.03	0.79	0.65

Table (3) : Concentrations of Zinc (ug / L) in the water of Lake Borullus during 2000 to 2002.

Area / Season	Eastern areas									Middle areas							Western areas					Total Av.
	1	2	3	4	5	6	7	Av.	S.D.	8	9	10	11	12	Av.	S.D.	13	14	15	Av.	S.D.	
Summer 2000	10.30	5.36	5.63	7.30	4.25	3.64	7.74	6.32	2.30	3.76	3.36	2.20	4.29	3.90	3.50	0.80	3.44	1.49	1.49	2.14	1.13	4.54
Autumn 2000	18.67	12.51	8.57	10.05	5.89	10.99	12.40	11.30	3.99	5.93	7.11	3.83	9.10	4.25	6.04	2.16	4.97	6.32	3.73	5.01	1.30	8.29
Average 2000	14.49	8.94	7.10	8.68	5.07	7.32	10.07	8.81		4.85	5.24	3.02	6.70	4.08	4.77		4.21	3.91	2.61	3.57		6.42
Winter 2001	21.26	14.96	12.24	14.27	12.00	18.18	16.82	15.68	3.33	8.34	9.39	4.54	7.96	3.08	6.66	2.71	7.76	11.55	3.92	7.74	3.82	11.08
Spring 2001	20.63	15.10	14.31	13.94	13.66	18.67	15.56	15.98	2.65	7.98	10.48	4.38	5.41	3.78	6.41	2.79	3.62	6.16	2.74	4.17	1.78	10.43
Summer 2001	19.81	14.87	11.51	12.50	9.76	10.29	17.15	13.70	3.74	11.23	9.66	6.56	8.57	6.81	8.57	1.96	8.79	6.53	5.57	6.96	1.65	10.64
Autumn 2001	21.49	14.02	13.18	14.53	13.39	15.71	16.33	15.52	2.87	10.47	11.21	10.20	13.20	12.42	11.50	1.28	9.99	8.53	6.66	8.39	1.67	12.76
Average 2001	20.80	14.74	12.81	13.81	12.20	15.71	16.47	15.22		9.51	10.19	6.42	8.79	6.52	8.28		7.54	8.19	4.72	6.82		11.23
Winter 2002	32.86	19.52	24.19	16.83	24.06	28.12	28.62	24.89	5.52	16.65	23.19	13.63	21.11	18.89	18.69	3.74	23.77	13.59	11.01	16.12	6.75	21.07
Spring 2002	22.63	15.52	15.40	16.21	22.72	20.21	16.75	18.49	3.28	10.91	15.95	18.21	7.18	4.14	11.28	5.87	6.74	9.24	8.38	8.12	1.27	14.01
Summer 2002	26.49	18.47	17.93	18.33	15.83	16.73	23.30	19.58	3.86	15.68	14.07	12.37	9.07	6.87	11.61	3.61	9.93	15.83	10.10	11.95	3.36	15.40
Autumn 2002	21.48	10.62	12.13	15.94	12.29	17.56	17.50	15.36	3.86	8.45	11.58	7.53	12.35	7.81	9.54	2.25	9.35	10.07	7.08	8.83	1.56	12.12
Average 2002	25.87	16.03	17.41	16.83	18.73	20.66	21.54	19.58		12.92	16.20	12.94	12.43	9.43	12.78		12.45	12.18	9.14	11.26		15.65

Table (4) : Concentrations of Copper (ug / L) in the water of Lake Borullus during 2000 to 2002.

Area	Eastern areas									Middle areas							Western areas					total Av.
Season	1	2	3	4	5	6	7	Av.	S.D.	8	9	10	11	12	Av.	S.D.	13	14	15	Av.	S.D.	
Summer 2000	2.70	4.17	5.78	6.64	2.07	3.51	3.43	4.04	1.64	1.79	2.28	3.33	2.70	3.44	2.71	0.70	4.61	7.14	3.85	5.20	1.72	3.83
Autumn 2000	6.85	7.94	4.94	9.46	3.59	9.05	5.47	6.76	2.20	2.73	4.46	2.48	1.61	2.12	2.68	1.08	4.70	7.17	3.35	5.07	1.94	5.06
Average 2000	4.78	6.06	5.36	8.05	2.83	6.28	4.45	5.40		2.26	3.37	2.91	2.16	2.78	2.69		4.66	7.16	3.60	5.14		4.45
Winter 2001	9.73	10.59	12.32	9.89	4.13	8.54	8.62	9.12	2.54	2.59	8.46	2.25	4.89	2.14	4.07	2.70	3.26	6.08	3.80	4.38	1.50	6.49
Spring 2001	9.74	10.04	12.04	7.68	3.17	14.68	7.89	9.32	3.64	5.06	11.86	4.05	4.80	2.64	5.68	3.58	9.08	12.89	8.34	10.10	2.44	8.26
Summer 2001	9.91	9.89	13.33	10.83	6.65	7.76	12.25	10.09	2.35	7.46	7.46	5.27	3.86	3.92	5.59	1.79	7.44	7.85	4.34	6.54	1.92	7.88
Autumn 2001	10.54	8.89	8.69	11.18	7.75	16.69	9.46	10.46	2.98	6.56	13.30	9.33	4.24	6.19	7.92	3.51	12.52	13.68	8.50	11.57	2.72	9.83
Average 2001	9.98	9.85	11.60	9.90	5.43	11.92	9.56	9.75		5.42	10.27	5.23	4.45	3.72	5.82		8.08	10.13	6.25	8.15		8.12
Winter 2002	20.46	15.58	7.18	9.88	21.98	26.16	17.47	16.96	6.71	11.30	17.51	6.34	10.37	5.49	10.20	4.79	20.37	17.53	9.69	15.86	5.53	14.49
Spring 2002	11.62	14.56	12.25	13.66	15.18	17.85	9.10	13.46	2.81	4.65	9.85	10.05	5.78	2.70	6.61	3.25	12.23	17.54	8.39	12.72	4.59	11.03
Summer 2002	10.12	13.97	15.93	14.87	8.70	8.03	11.37	11.86	3.11	11.47	15.17	8.77	6.60	3.63	9.13	4.44	19.43	14.13	19.20	17.59	3.00	12.09
Autumn 2002	13.52	12.43	8.18	19.47	21.17	21.68	11.99	15.49	5.25	6.83	12.74	10.62	6.01	6.39	8.52	3.00	15.80	20.17	9.87	15.28	5.17	13.12
Average 2002	13.93	14.14	10.89	14.47	16.76	18.43	12.48	14.44		8.56	13.82	8.95	7.19	4.55	8.61		16.96	17.34	11.79	15.36		12.68

Table (5) : Concentrations of Iron (ug / L) in the water of Lake Borullus during 2000 to 2002.

Area	Eastern areas									Middle areas							Western areas					total Av.
Season	1	2	3	4	5	6	7	Av.	S.D.	8	9	10	11	12	Av.	S.D.	13	14	15	Av.	S.D.	
Summer 2000	0.70	0.55	1.29	0.80	0.28	0.56	0.53	0.67	0.32	0.52	0.33	0.84	0.53	0.72	0.59	0.20	1.50	1.35	0.89	1.25	0.32	0.76
Autumn 2000	7.11	4.68	8.96	10.01	4.16	7.86	3.72	6.64	2.48	2.12	3.64	1.46	1.19	3.17	2.32	1.06	4.49	5.80	2.26	4.18	1.79	4.71
Average 2000	3.91	2.62	5.13	5.41	2.22	4.21	2.13	3.66		1.32	1.99	1.15	0.86	1.95	1.45		3.00	3.58	1.58	2.72		2.73
Winter 2001	12.26	7.91	15.34	21.50	8.38	13.01	11.06	12.78	4.64	4.58	9.81	4.44	3.94	5.42	5.64	2.39	5.83	10.53	5.71	7.36	2.75	9.31
Spring 2001	18.56	13.23	17.58	22.57	6.70	15.85	11.50	15.14	5.19	4.24	7.76	3.13	1.93	1.33	3.68	2.54	9.35	13.31	6.57	9.74	3.39	10.24
Summer 2001	15.89	12.66	12.23	13.36	7.69	9.16	13.06	12.01	2.75	8.65	9.90	4.43	4.07	5.49	6.51	2.62	9.97	8.67	6.24	8.29	1.89	9.43
Autumn 2001	12.57	9.28	8.14	10.57	9.38	16.37	8.89	10.74	2.86	5.98	18.76	9.73	7.34	7.53	9.87	5.15	14.58	18.71	10.26	14.52	4.23	11.21
Average 2001	14.82	10.77	13.32	17.00	8.04	13.60	11.13	12.67		5.86	11.56	5.43	4.32	4.94	6.42		9.93	12.81	7.20	9.98		10.05
Winter 2002	28.97	20.89	14.57	22.26	25.38	42.91	25.78	25.82	8.81	15.43	32.47	13.20	17.22	8.72	17.41	9.00	33.42	29.83	16.22	26.49	9.07	23.15
Spring 2002	21.67	21.30	20.76	27.77	19.84	27.35	23.62	23.19	3.20	8.02	14.64	19.36	7.38	5.35	10.95	5.85	23.88	30.13	10.32	21.44	10.13	18.76
Summer 2002	24.40	19.57	22.80	20.23	14.00	13.73	22.03	19.54	4.19	17.37	18.77	11.97	9.23	6.40	12.75	5.27	29.17	17.57	26.90	24.55	6.15	18.28
Autumn 2002	18.19	18.50	12.77	25.69	14.44	24.42	13.97	18.28	5.10	10.03	14.63	11.37	7.81	9.48	10.66	2.56	20.64	28.52	14.97	21.38	6.80	16.36
Average 2002	23.31	20.07	17.73	23.99	18.42	27.10	21.35	21.71		12.71	20.13	13.98	10.41	7.49	12.94		26.78	26.51	17.10	23.46		19.14

Table (6) : Concentrations of Nickel (ug / L) in the water of Lake Borullus during 2001 to 2002.

Area	Eastern areas									Middle areas							Western areas					Total Av.
Season	1	2	3	4	5	6	7	Av.	S.D.	8	9	10	11	12	Av.	S.D.	13	14	15	Av.	S.D.	
Summer 2001	5.08	3.96	2.61	3.52	2.47	2.79	4.90	3.62	1.07	2.41	2.58	1.49	1.77	1.27	1.90	0.57	2.02	2.12	1.10	1.75	0.56	2.67
Autumn 2001	4.90	2.92	4.37	3.65	4.46	5.90	4.60	4.40	0.94	4.08	5.84	3.29	4.90	3.36	4.29	1.08	3.23	3.59	1.74	2.85	0.98	4.06
Average 2001	4.99	3.44	3.49	3.59	3.47	4.35	4.75	4.01		3.25	4.21	2.39	3.34	2.32	3.10		2.63	2.86	1.42	2.30		3.36
Winter 2002	8.99	7.05	7.72	8.19	8.98	8.71	8.61	8.32	0.72	3.66	10.44	4.72	4.15	4.93	5.58	2.76	11.11	5.97	2.96	6.68	4.12	7.08
Spring 2002	2.59	3.11	3.57	3.09	3.15	3.67	6.23	3.63	1.20	2.36	2.52	3.94	2.39	0.76	2.39	1.13	3.43	5.17	1.54	3.38	1.82	3.17
Summer 2002	4.87	3.65	3.33	3.42	3.86	6.13	4.37	4.23	1.00	1.95	4.06	2.10	1.40	2.52	2.41	1.01	3.67	4.00	1.62	3.10	1.29	3.40
Autumn 2002	2.82	2.84	2.46	2.77	2.52	3.17	3.52	2.87	0.37	1.89	3.33	2.29	2.55	1.55	2.32	0.68	3.25	4.41	1.67	3.11	1.38	2.74
Average 2002	4.82	4.16	4.27	4.37	4.63	5.42	5.68	4.76		2.47	5.09	3.26	2.62	2.44	3.18		5.37	4.89	1.95	4.07		4.10

Table (7) : Concentrations of Lead (ug / L) in the water of Lake Borullus during 2000 to 2002.

Area	Eastern areas									Middle areas							Western areas					Total Av.
Season	1	2	3	4	5	6	7	Av.	S.D.	8	9	10	11	12	Av.	S.D.	13	14	15	Av.	S.D.	
Summer 2000	0.48	2.76	3.68	0.82	0.64	0.48	0.43	1.33	1.33	0.76	0.63	0.63	0.56	0.80	0.68	0.10	1.27	2.74	1.75	1.92	0.75	1.23
Autumn 2000	1.79	5.13	5.04	4.83	2.10	2.60	1.99	3.35	1.56	1.27	4.43	1.33	1.22	0.98	1.85	1.45	4.28	7.07	4.51	5.29	1.55	3.24
Average 2000	1.14	3.95	4.36	2.83	1.37	1.54	1.21	2.34		1.02	2.53	0.98	0.89	0.89	1.26		2.78	4.91	3.13	3.60		2.23
Winter 2001	4.54	7.55	5.52	11.15	2.43	6.65	3.25	5.87	2.94	1.31	4.14	1.52	0.84	0.85	1.73	1.38	4.61	9.27	4.44	6.11	2.74	4.54
Spring 2001	7.59	4.16	6.94	7.91	2.86	9.84	8.34	6.81	2.45	2.72	8.77	3.41	1.61	2.08	3.72	2.90	3.25	6.04	2.79	4.03	1.76	5.22
Summer 2001	6.62	7.08	7.54	8.27	4.22	5.27	5.37	6.34	1.44	4.63	5.87	1.26	2.49	2.77	3.40	1.83	5.42	5.70	3.22	4.78	1.36	5.05
Autumn 2001	5.44	8.64	7.90	8.92	7.52	6.28	4.35	7.01	1.70	4.42	9.73	5.14	7.10	9.23	7.12	2.37	7.25	8.68	7.01	7.65	0.90	7.17
Average 2001	6.05	6.86	6.98	9.06	4.26	7.01	5.33	6.51		3.27	7.13	2.83	3.01	3.73	3.99		5.13	7.42	4.37	5.64		5.50
Winter 2002	12.75	9.79	10.39	11.54	13.51	10.77	9.02	11.11	1.60	4.78	18.93	9.51	13.82	9.57	11.32	5.32	13.77	10.75	6.03	10.18	3.90	11.00
Spring 2002	6.85	10.48	10.48	8.62	5.95	11.32	6.19	8.56	2.25	4.55	10.80	6.01	2.37	1.33	5.01	3.72	6.97	5.75	8.15	6.96	1.20	7.05
Summer 2002	8.06	6.87	5.87	7.83	5.10	3.70	7.23	6.38	1.58	5.21	2.76	2.44	2.34	1.59	2.87	1.38	5.39	6.93	4.70	5.67	1.14	5.07
Autumn 2002	5.32	6.38	6.22	7.23	4.89	7.62	5.52	6.17	1.00	4.76	5.54	3.28	5.50	4.07	4.63	0.97	7.54	9.52	6.26	7.77	1.64	5.98
Average 2002	8.25	8.38	8.24	8.81	7.36	8.35	6.99	8.05		4.83	9.51	5.31	6.01	4.14	5.96		8.42	8.24	6.29	7.65		7.27

Table (8) : Concentrations of Cadmium (ug / L) in the water of Lake Borullus during 2000 to 2002.

Area / Season	Eastern areas									Middle areas							Western areas					Total Av.
	1	2	3	4	5	6	7	Av.	S.D.	8	9	10	11	12	Av.	S.D.	13	14	15	Av.	S.D.	
Summer 2000	4.27	2.13	2.33	2.32	0.91	3.40	3.50	2.69	1.11	1.57	1.34	0.81	1.27	0.76	1.15	0.35	0.97	0.47	0.42	0.62	0.30	1.76
Autumn 2000	8.80	4.03	1.98	5.12	1.79	3.49	5.47	4.38	2.40	2.12	3.53	1.00	1.63	1.33	1.92	0.99	3.38	4.49	2.44	3.44	1.03	3.37
Average 2000	6.54	3.08	2.16	3.72	1.35	3.45	4.49	3.54		1.85	2.44	0.91	1.45	1.05	1.54		2.18	2.48	1.43	2.03		2.57
Winter 2001	13.60	7.68	4.34	11.24	9.25	10.06	9.87	9.43	2.89	2.49	5.59	2.25	2.17	1.02	2.70	1.71	3.96	4.66	2.25	3.62	1.24	6.03
Spring 2001	7.24	3.78	4.83	4.58	2.12	6.26	7.93	5.25	2.03	1.79	4.75	2.19	2.33	3.88	2.99	1.27	1.68	3.37	1.20	2.08	1.14	3.86
Summer 2001	9.21	6.62	6.06	8.14	4.37	5.63	7.48	6.79	1.63	4.47	5.52	3.09	2.30	2.59	3.59	1.36	2.95	3.78	1.67	2.80	1.06	4.93
Autumn 2001	10.19	7.89	5.67	7.80	5.45	9.38	8.25	7.80	1.75	3.07	5.25	2.84	2.92	5.07	3.83	1.22	6.35	7.66	4.40	6.14	1.64	6.15
Average 2001	10.06	6.49	5.23	7.94	5.30	7.83	8.38	7.32		2.96	5.28	2.59	2.43	3.14	3.28		3.74	4.87	2.38	3.66		5.24
Winter 2002	13.69	10.06	6.18	13.05	8.86	13.85	10.57	10.89	2.84	1.67	6.28	1.88	13.00	7.94	6.15	4.70	8.90	5.97	1.76	5.54	3.59	8.24
Spring 2002	9.61	5.56	6.80	5.64	4.60	8.50	8.32	7.00	1.85	2.82	5.43	3.73	1.63	0.49	2.82	1.90	5.27	8.34	3.81	5.81	2.31	5.37
Summer 2002	11.14	7.66	9.80	8.43	8.20	8.73	11.03	9.28	1.39	5.70	5.37	3.17	2.39	1.71	3.67	1.78	5.86	8.36	4.73	6.32	1.86	6.82
Autumn 2002	8.97	7.81	4.69	11.66	7.19	10.90	10.38	8.80	2.44	5.63	4.74	5.01	3.19	5.32	4.78	0.95	10.90	13.33	7.46	10.56	2.95	7.81
Average 2002	10.85	7.77	6.87	9.70	7.21	10.50	10.08	9.00		3.96	5.46	3.45	5.05	3.87	4.36		7.73	9.00	4.44	7.06		7.06

Table (9) : Concentrations of trace metals (mg / kg) in the sediment of different stations of Lake Borullus during the year 2000.

stations	Eastern area								Middle area						Western area			
metals	1	2	3	4	5	6	7	Average	8	9	10	11	12	Average	13	14	15	Average
Fe	5700	10200	19500	16300	6200	18400	8500	12114	2500	28300	17100	11500	7360	13352	30500	41200	27400	33033
Cu	10.30	9.80	15.90	45.80	20.40	32.21	18.70	21.87	13.70	35.90	18.90	22.80	15.30	21.32	29.90	36.80	39.70	35.47
Zn	22.80	43.00	48.00	120.70	21.80	66.40	43.60	52.33	18.90	86.40	63.80	51.90	37.90	51.78	91.40	105.30	86.50	94.40
Pb	9.70	12.10	16.40	63.50	17.30	33.90	14.80	23.96	10.30	11.80	9.70	16.50	19.70	13.60	14.30	32.80	12.30	19.80
Cd	1.02	1.08	5.19	0.86	1.23	3.25	0.97	1.94	1.08	4.08	1.87	1.01	0.64	1.74	3.43	2.36	2.00	2.60
Ni	5.10	8.30	11.50	37.40	29.10	35.80	9.70	19.56	14.80	46.90	66.40	58.40	39.70	45.24	88.90	73.60	53.10	71.87

Table (10) : Concentrations of trace metals (mg / kg) in the sediment of different stations of Lake Borullus during the year 2001.

stations	Eastern area								Middle area						Western area			
metals	1	2	3	4	5	6	7	Average	8	9	10	11	12	Average	13	14	15	Average
Fe	67410	15860	20905	17975	8440	25950	12495	24148	4210	29950	15410	11485	3119	12835	39320	49215	33945	40827
Cu	14.50	9.20	18.55	50.55	20.05	33.05	20.55	23.78	13.55	40.80	17.40	20.60	13.15	21.10	29.65	30.50	31.10	30.42
Zn	26.60	40.55	52.50	122.40	30.45	66.60	38.45	53.94	25.70	95.05	74.85	47.60	32.25	55.09	91.05	99.95	92.60	94.53
Pb	11.00	12.70	16.90	51.85	18.10	32.60	17.70	22.98	12.40	15.60	10.05	15.40	17.40	14.17	19.90	30.70	12.05	20.88
Cd	1.31	1.58	7.32	2.08	2.44	3.15	1.01	2.70	1.42	6.19	2.76	1.63	1.02	2.60	5.14	1.98	2.97	3.36
Ni	3.10	5.90	9.85	29.95	21.70	32.30	8.30	15.87	14.75	39.00	64.80	55.30	42.00	43.17	71.60	66.55	42.85	60.33

Table (11) : Correlation coefficient between the concentrations of trace metals in the water of Lake Borullus during the year 2000.

Metals	Cu	Fe	Cd	Pb	Zn
Cu	1.00				
Fe	0.84	1.00			
Cd	0.51	0.52	1.00		
Pb	0.65	0.50	-0.01	1.00	
Zn	0.35	0.45	0.91	-0.13	1.00

Table (12) : Correlation coefficient between the concentrations of trace metals in the water of Lake Borullus during the year 2001.

Metals	Cu	Fe	Cd	Pb	Zn	Ni
Cu	1.00					
Fe	0.90	1.00				
Cd	0.72	0.83	1.00			
Pb	0.88	0.93	0.67	1.00		
Zn	0.63	0.68	0.94	0.49	1.00	
Ni	0.59	0.58	0.83	0.42	0.90	1.00

Table (13) : Correlation coefficient between the concentrations of trace metals in the water of Lake Borullus during the year 2002.

Metals	Cu	Fe	Cd	Pb	Zn	Ni
Cu	1.00					
Fe	0.93	1.00				
Cd	0.73	0.82	1.00			
Pb	0.80	0.83	0.69	1.00		
Zn	0.45	0.49	0.76	0.51	1.00	
Ni	0.78	0.82	0.80	0.78	0.68	1.00

Table (14) : Various parameters of the sediment of different stations of Lake Borullus during the year 2000.

stations / parameters	Eastern area								Middle area						Western area			
	1	2	3	4	5	6	7	Average	8	9	10	11	12	Average	13	14	15	Average
E.C.	9.06	6.21	3.32	1.91	2.03	1.74	5.46	4.25	3.57	1.31	1.01	1.06	0.98	1.59	0.87	0.81	0.61	0.76
Cl.	3.02	2.07	1.11	0.64	0.67	0.58	1.82	1.42	1.19	0.44	0.34	0.35	0.33	0.53	0.29	0.27	0.20	0.25
pH	8.00	7.36	7.63	8.10	7.90	7.88	7.70	7.80	8.30	7.38	7.56	8.20	7.59	7.81	8.40	7.86	7.70	7.99
O.M.	0.77	1.88	2.06	2.73	3.01	4.13	0.85	2.20	2.08	4.37	1.57	3.89	1.05	2.59	2.66	5.23	3.79	3.89

E.C. : electric conductivity (mmohs) Cl. : chlorosity (gm / kg)
pH : hydrogen ion concentration O.M. : organic matter (mg O / L)

Table (15) : Various parameters of the sediment of different stations of Lake Borullus during the year 2001.

stations / parameters	Eastern area								Middle area						Western area			
	1	2	3	4	5	6	7	Average	8	9	10	11	12	Average	13	14	15	Average
E.C	6.64	3.98	2.52	1.64	1.76	1.57	4.17	3.18	1.59	1.08	1.17	0.94	1.12	1.18	1.48	0.47	0.70	0.88
Cl.	2.00	0.88	0.84	1.04	0.97	1.10	1.30	1.16	0.38	0.29	0.34	0.33	0.52	0.37	0.66	0.24	0.27	0.39
pH	7.97	7.56	7.48	7.85	8.00	7.92	7.72	7.78	7.76	8.03	7.69	7.90	7.78	7.83	7.97	7.52	8.21	7.90
O.M.	0.89	2.70	2.11	0.98	1.44	3.37	1.05	1.79	3.11	2.68	3.34	4.51	3.73	3.47	3.27	5.67	3.06	4.00

E.C. : electric conductivity (mmohs) Cl. : chlorosity (gm / kg)
pH : hydrogen ion concentration O.M. : organic matter (mg O / L)

Table (16) : Correlation coefficient between trace metal concentrations in the water and sediment of Lake Borrulus during the year 2000.

water Cu	0.42
sediment Cu	
water Fe	0.21
sediment Fe	
water Cd	-0.13
sediment Cd	
water Pb	0.24
sediment Pb	
water Zn	-0.31
sediment Zn	

Table (17) : Correlation coefficient between trace metal concentrations in the water and sediment of Lake Borrulus during the year 2001.

water Cu	0.38
sediment Cu	
water Fe	0.54
sediment Fe	
water Cd	-0.13
sediment Cd	
water Pb	0.68
sediment Pb	
water Zn	-0.35
sediment Zn	
water Ni	-0.60
sediment Ni	

Table (18) : Correlation coefficient between the concentrations of trace metals and various parameters of the sediment of Lake Borullus during the year 2000.

metal / parameter	Fe	Cu	Zn	Pb	Cd	Ni	E.C	Cl.	pH	O.M
Fe	1.00									
Cu	0.70	1.00								
Zn	0.81	0.90	1.00							
Pb	0.20	0.64	0.61	1.00						
Cd	0.60	0.25	0.31	-0.09	1.00					
Ni	0.71	0.57	0.65	0.12	0.22	1.00				
E.C	-0.54	-0.62	-0.55	-0.26	-0.27	-0.79	1.00			
Cl.	-0.54	-0.62	-0.55	-0.26	-0.27	-0.79	1.00	1.00		
pH	-0.07	0.14	0.04	0.23	-0.18	0.25	-0.08	-0.08	1.00	
O.M.	0.70	0.72	0.59	0.30	0.38	0.55	-0.62	-0.62	0.09	1.00

E.C. : electric conductivity (mmohs) Cl. : chlorosity (gm / kg)
pH : hydrogen ion concentration O.M. : organic matter (mg O / L)

Table (19) : Correlation coefficient between the concentrations of trace metals and various parameters of the sediment of Lake Borullus during the year 2001.

metal / parameter	Fe	Cu	Zn	Pb	Cd	Ni	E.C	Cl.	pH	O.M
Fe	1.00									
Cu	0.22	1.00								
Zn	0.30	0.87	1.00							
Pb	0.03	0.74	0.60	1.00						
Cd	0.16	0.33	0.38	-0.03	1.00					
Ni	0.12	0.34	0.58	0.13	0.14	1.00				
E.C	0.35	-0.42	-0.51	-0.24	-0.23	-0.73	1.00			
Cl.	0.34	-0.13	-0.36	0.12	-0.21	-0.66	0.87	1.00		
pH	0.19	0.37	0.16	-0.06	0.02	0.15	-0.12	0.04	1.00	
O.M.	0.01	-0.04	0.21	-0.06	-0.02	0.72	-0.66	-0.74	-0.21	1.00

E.C. : electric conductivity (mmohs) Cl. : chlorosity (gm / kg)
pH : hydrogen ion concentration O.M. : organic matter (mg O / L)

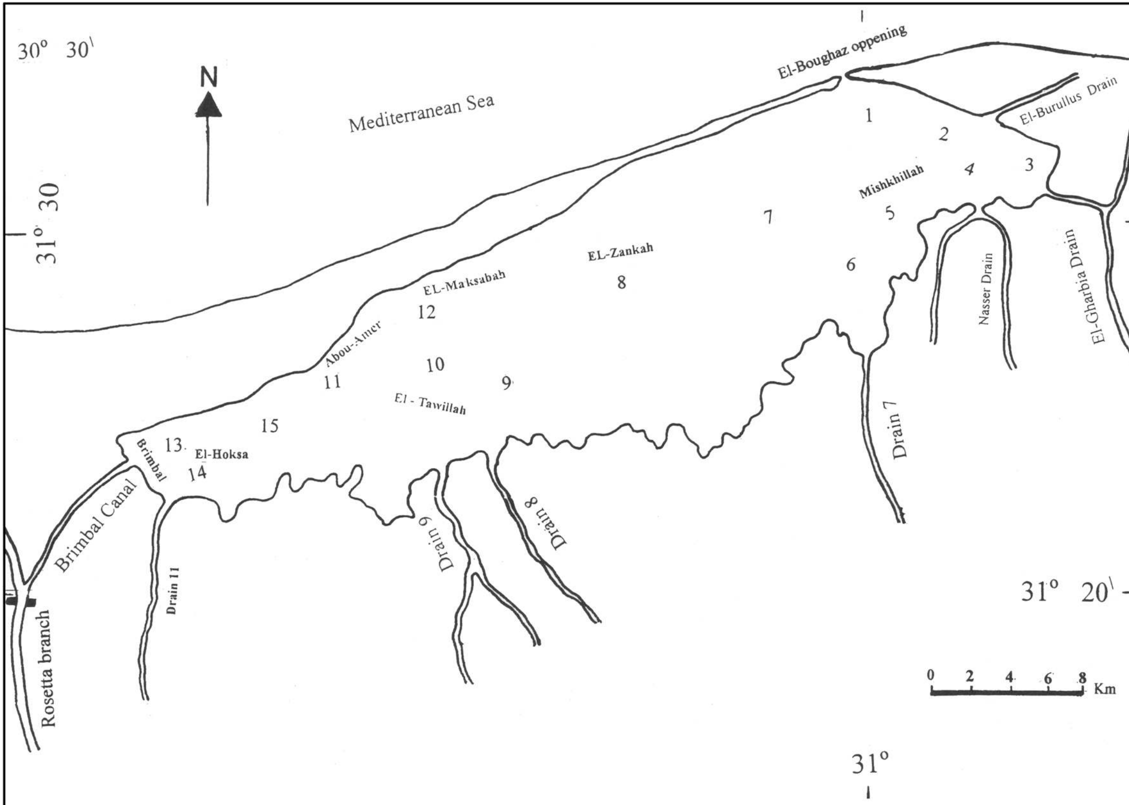


Fig. (1): Sampling stations at Lake Borollus.

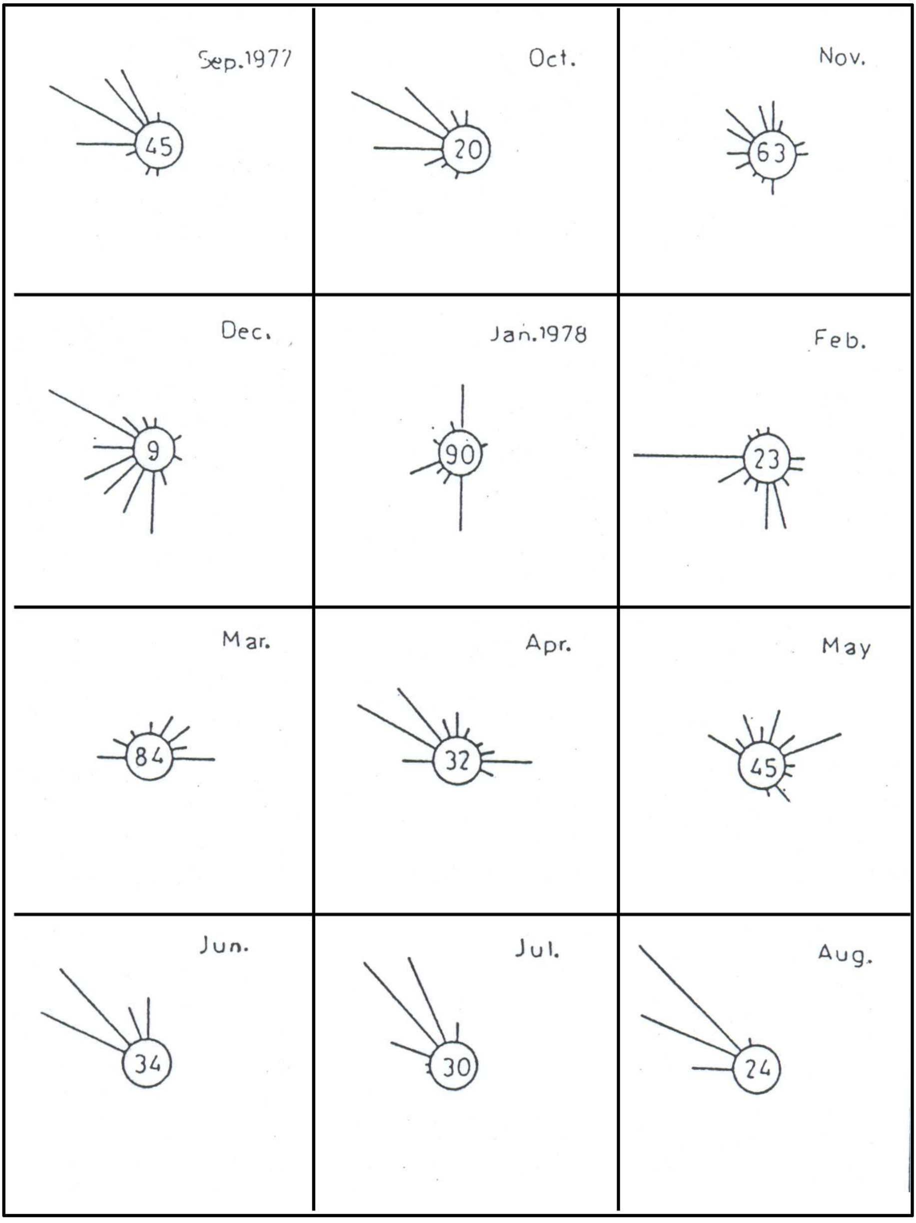


Fig.(**2**) Wind direction and duration (hours) in lake Borullos area (1977 - 78) (number inside circles represents hours of calm wind).

(After Darag 1984)

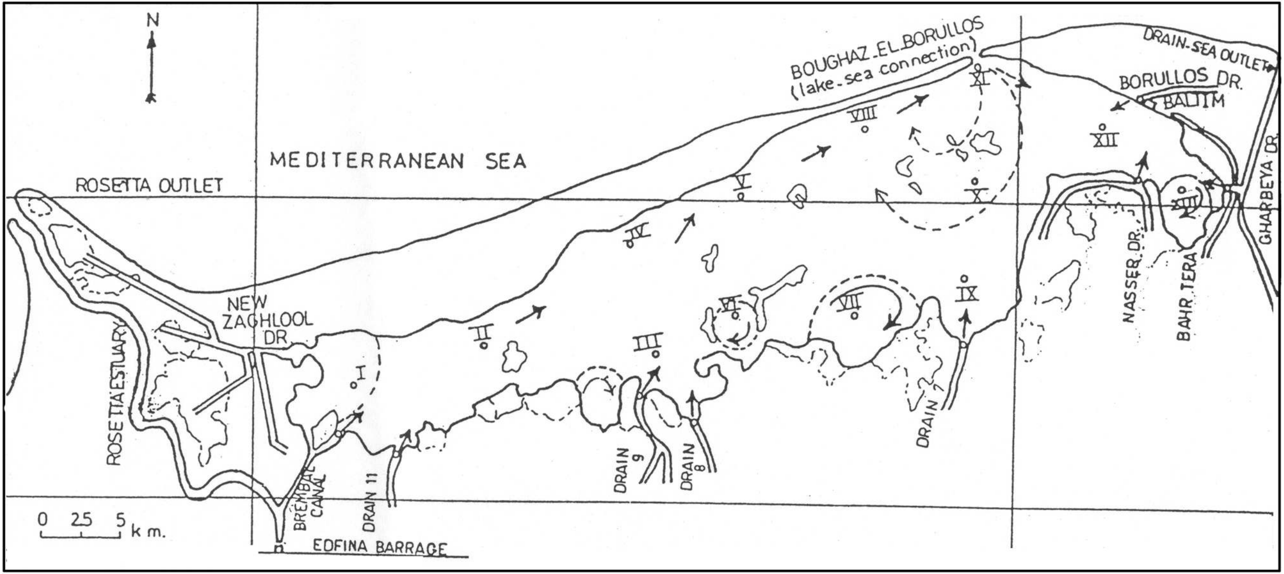
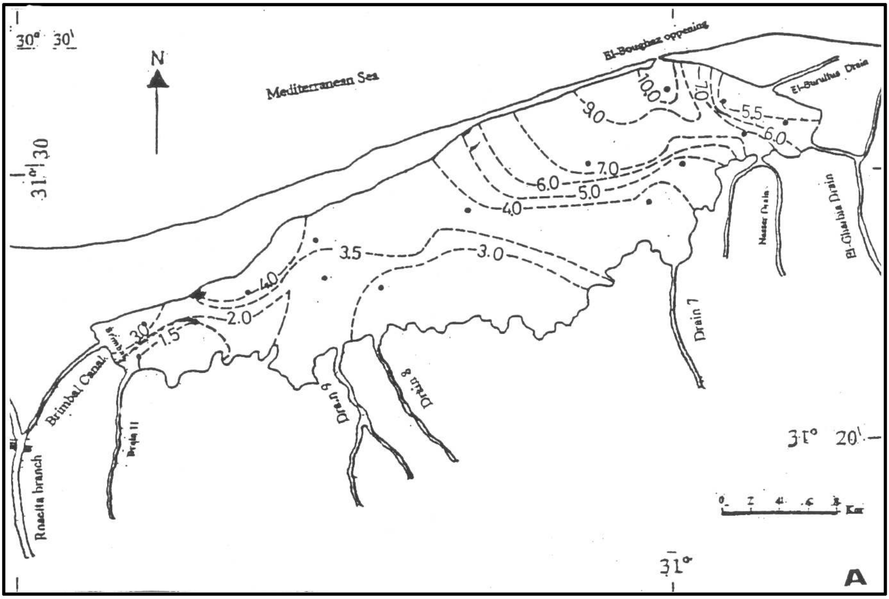


Fig.(3) Simplified diagram showing the direction of **out**flowing lake water (solid arrows), inflowing sea water (dotted arrows) and areas of partial stagnation (dotted circles) (1977 - 78)

(After Darag 1984)



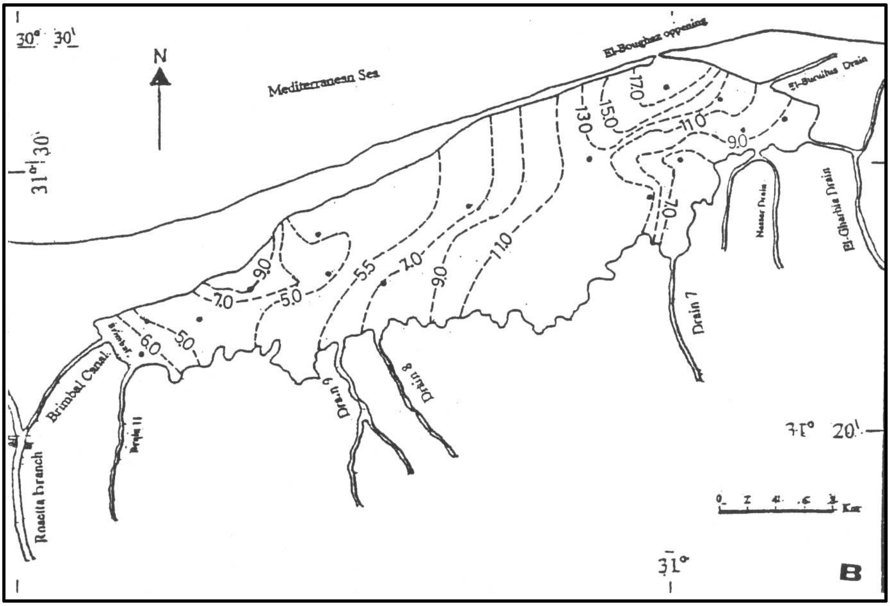


Fig. (4): Spatial distribution of Zn concentrations in the water of Borollus during the Summer (A), and Autumn (B) of the year 2000.

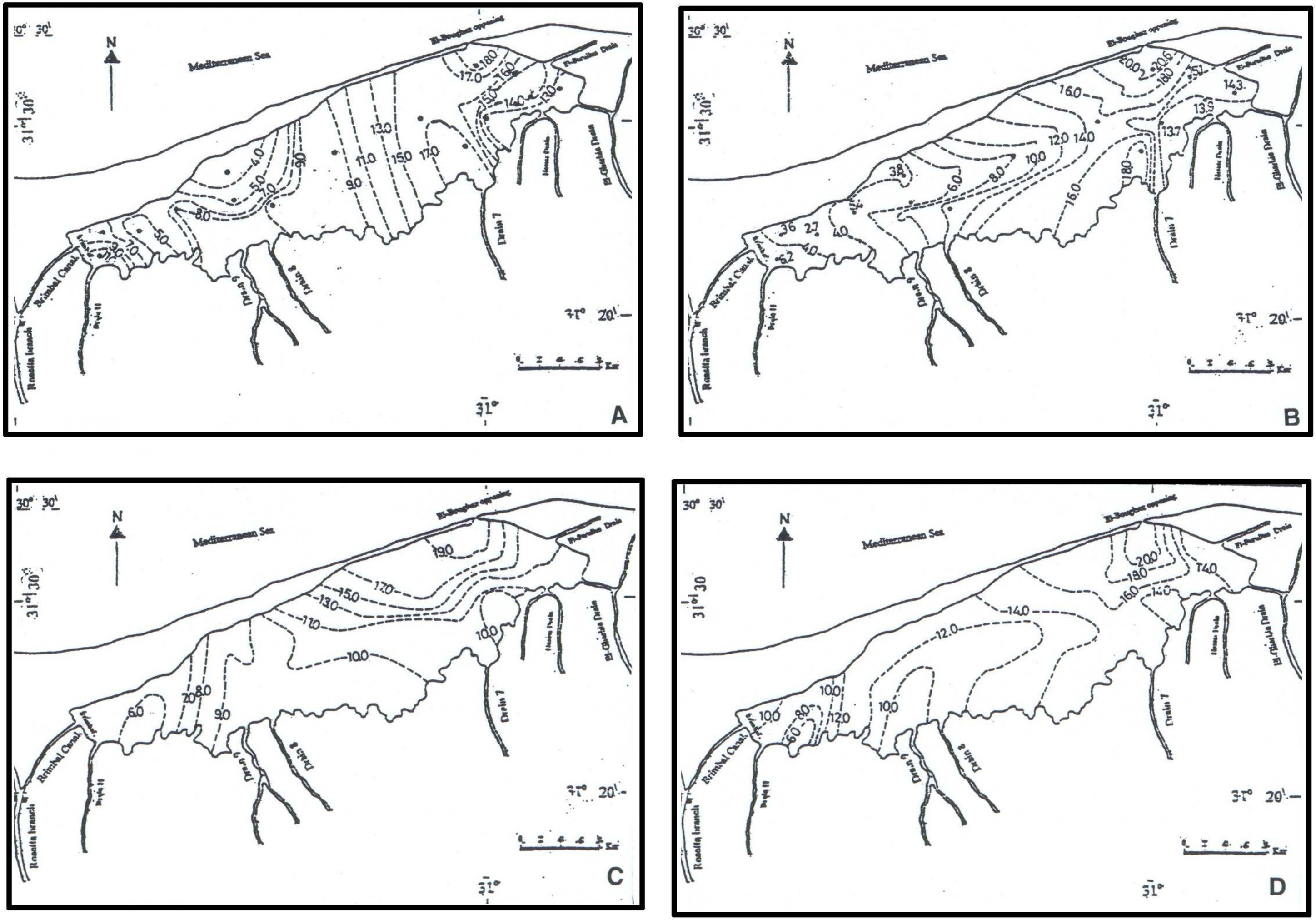


Fig. (5): Spatial distribution of Zn concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2001.

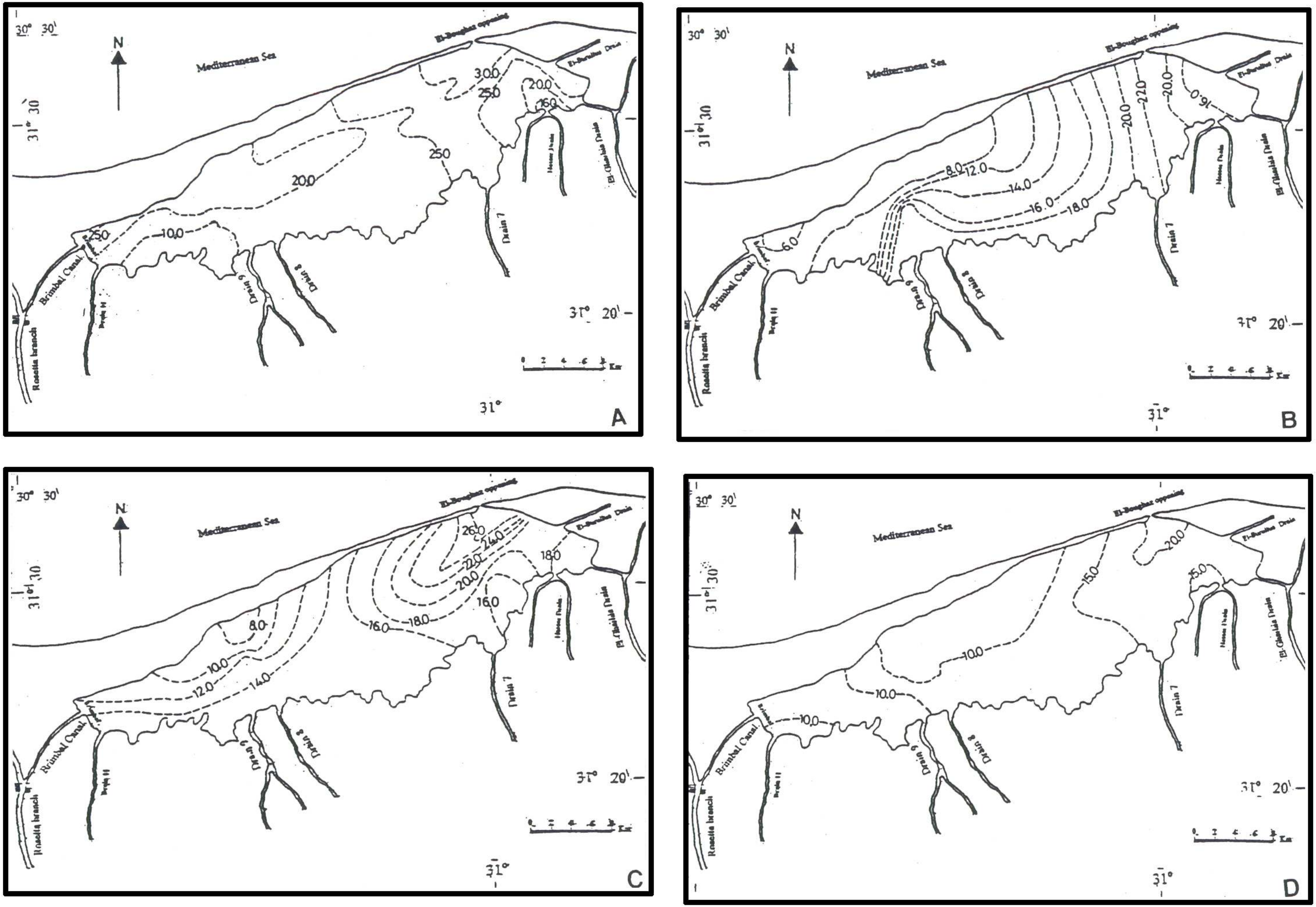
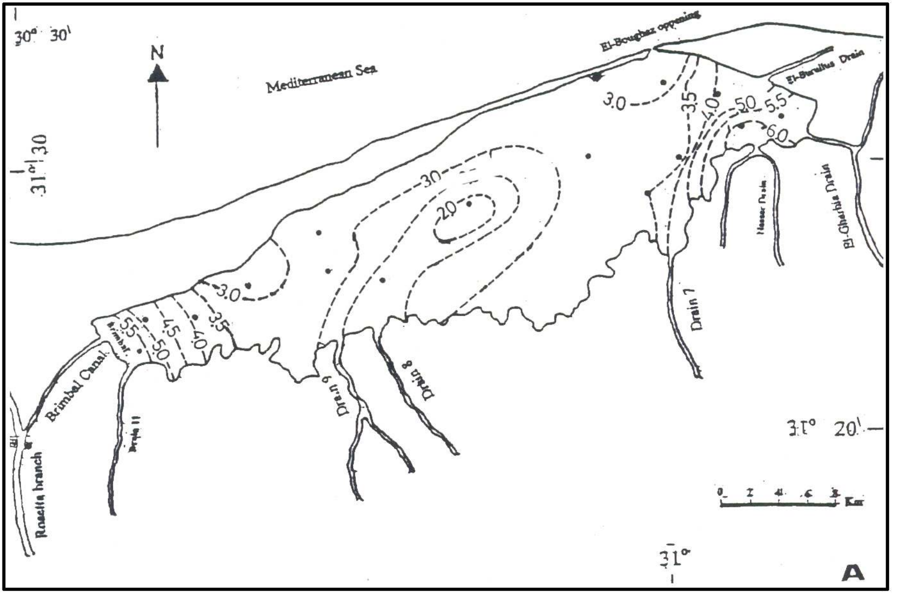


Fig. (6): Spatial distribution of Zn concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2002.



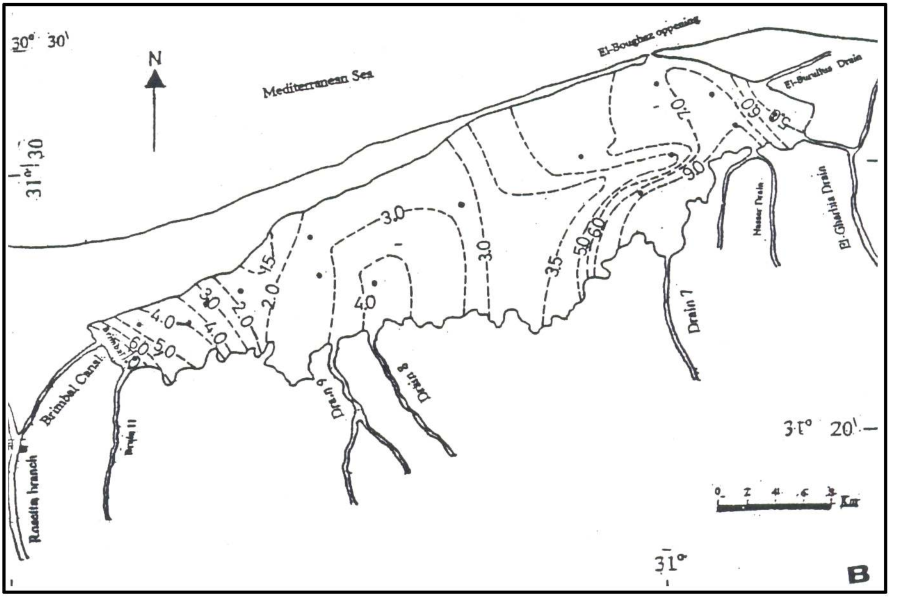


Fig. (7): Spatial distribution of Cu concentration sin the water of Lake Borollus during the Summer (A), and Autumn (B) of the year 2000.

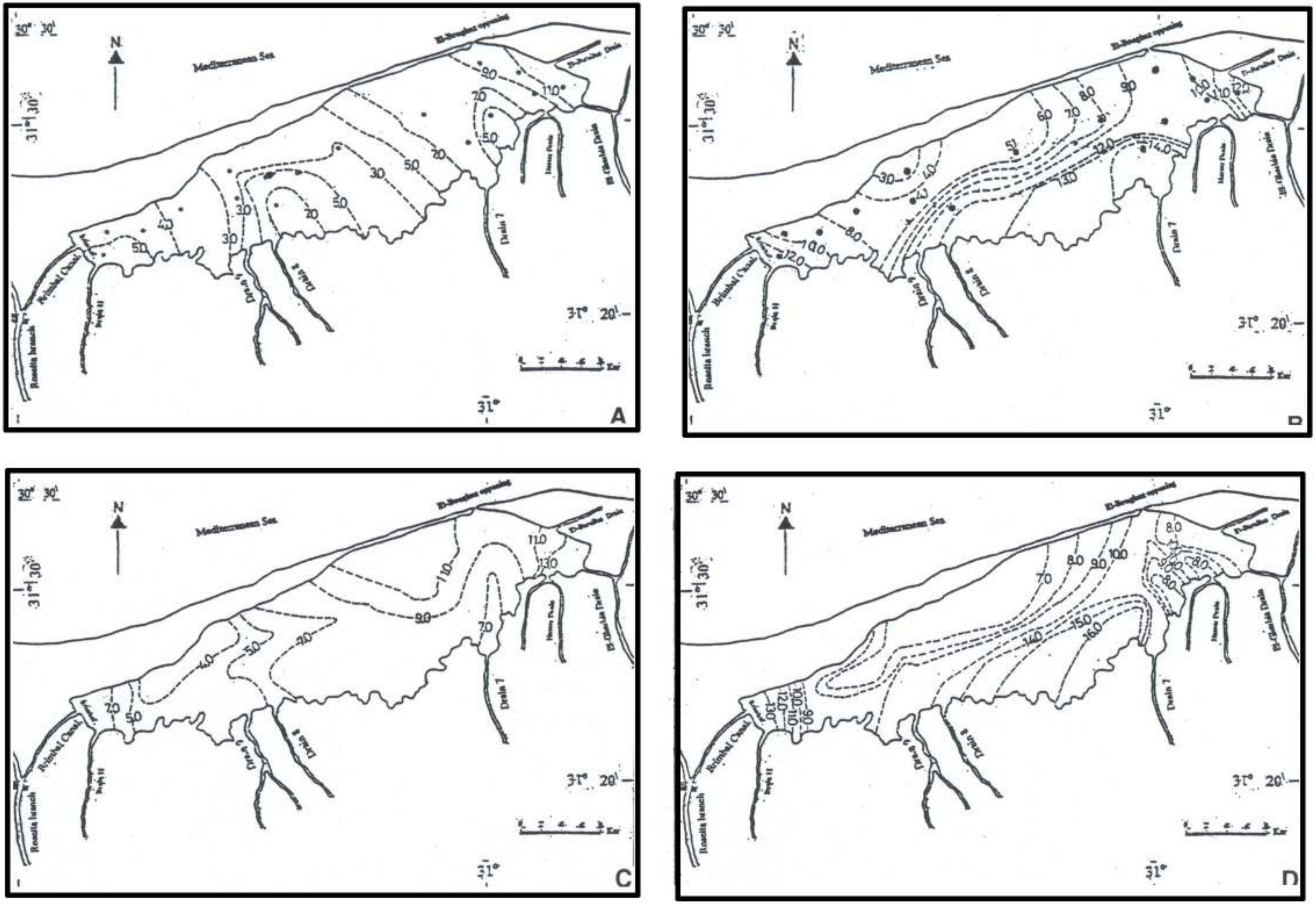


Fig. (8): Spatial distribution of Cu concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2001.

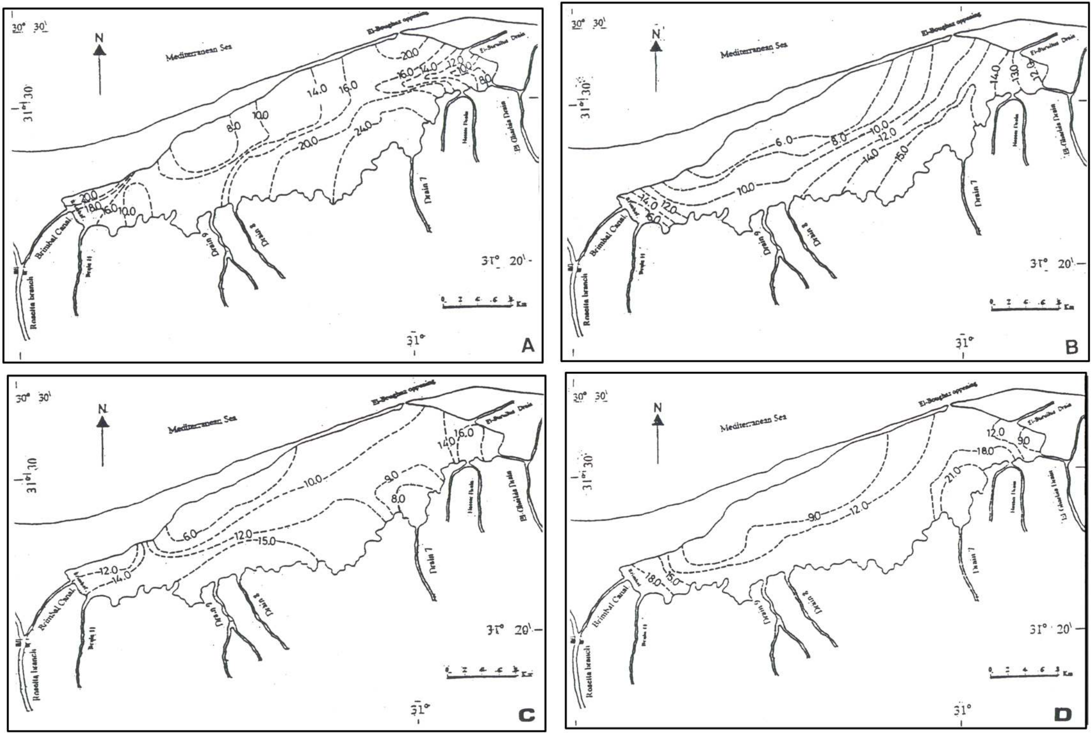
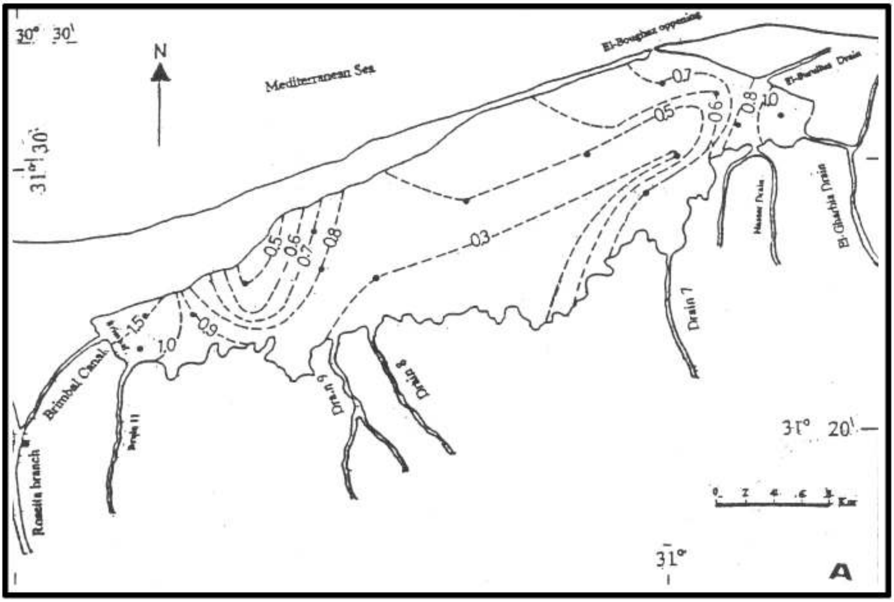


Fig. (9): Spatial distribution of Cu concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D)



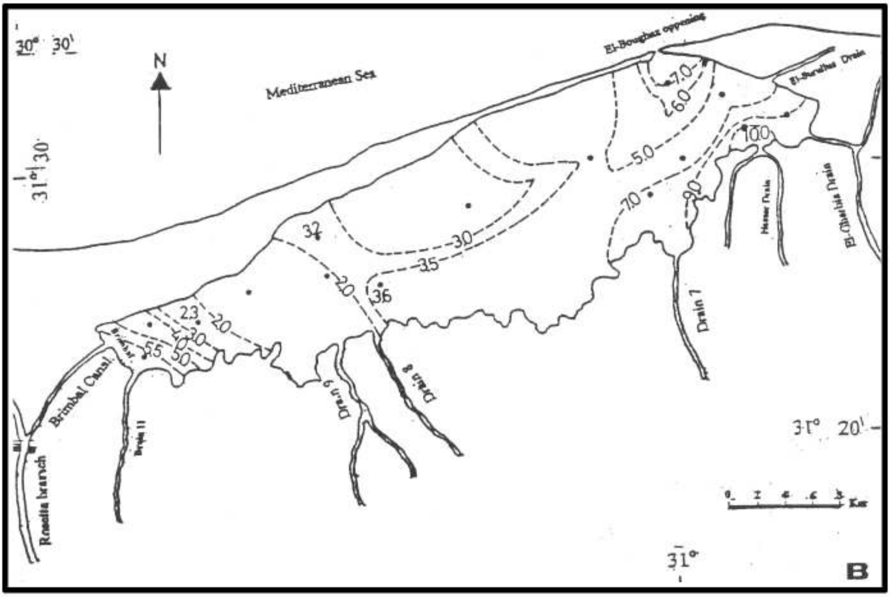


Fig. (10): Spatial distribution of Fe concentrations in the water of Lake Borollus during the Summer (A), and Autumn (B) of the year 2000.

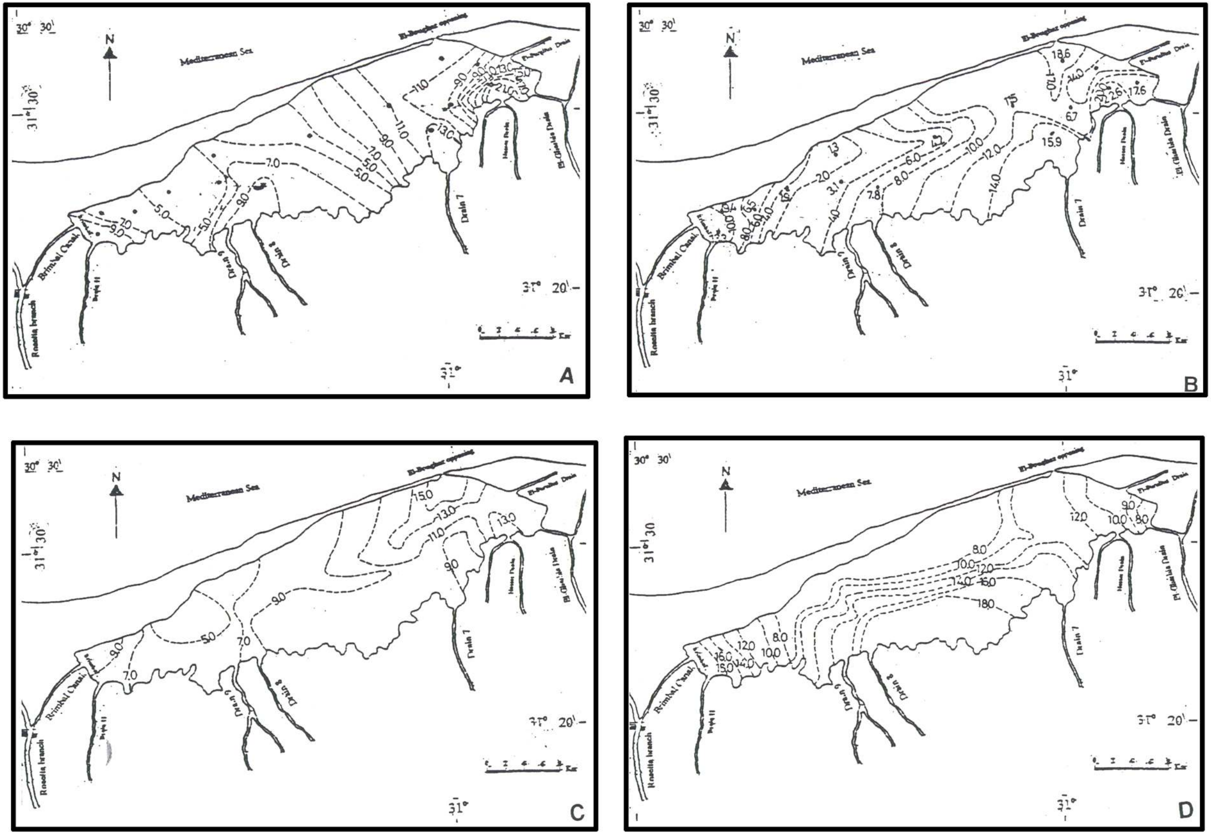


Fig. (11): Spatial distribution of Fe concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2001.

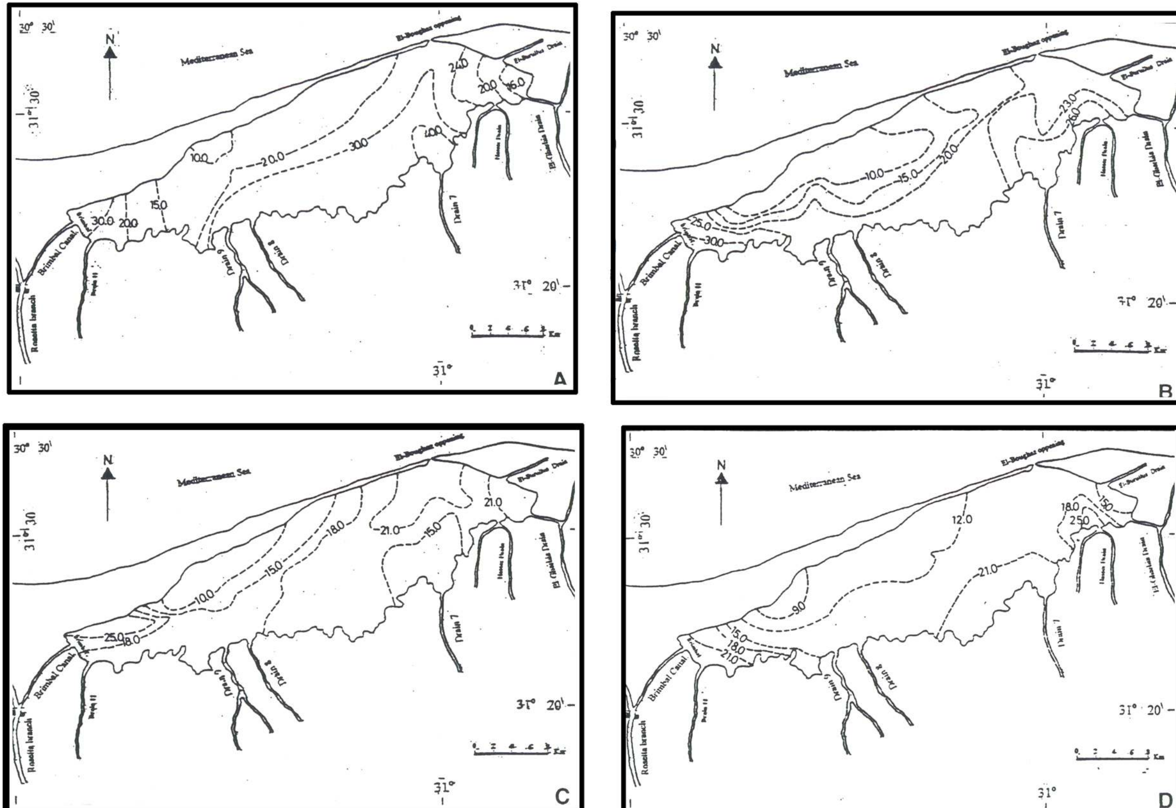


Fig. (12): Spatial distribution of Fe concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2002.

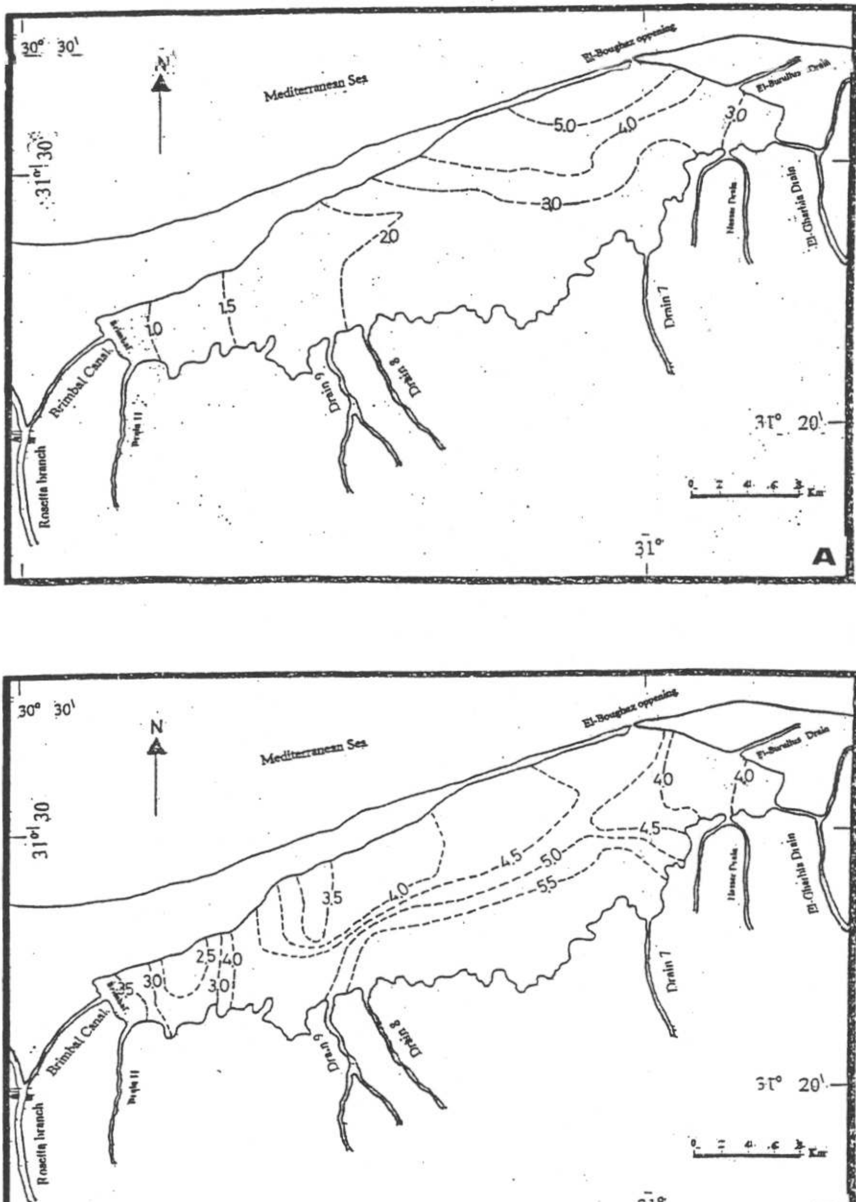


Fig. (13): Spatial distribution of Ni concentrations in the water of Lake Borollus during the Summer (A) and Autumn (B) of the year 2001.

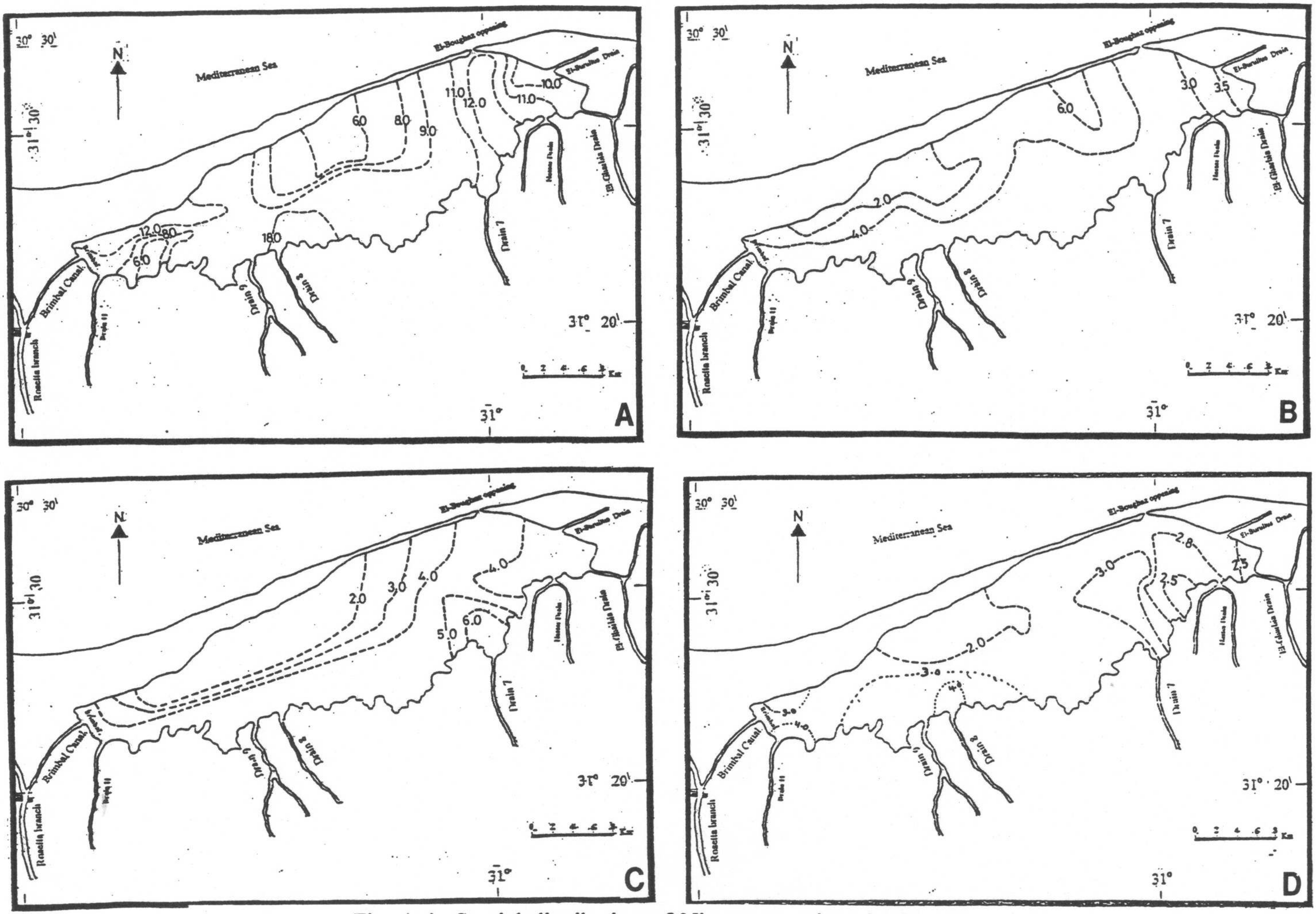
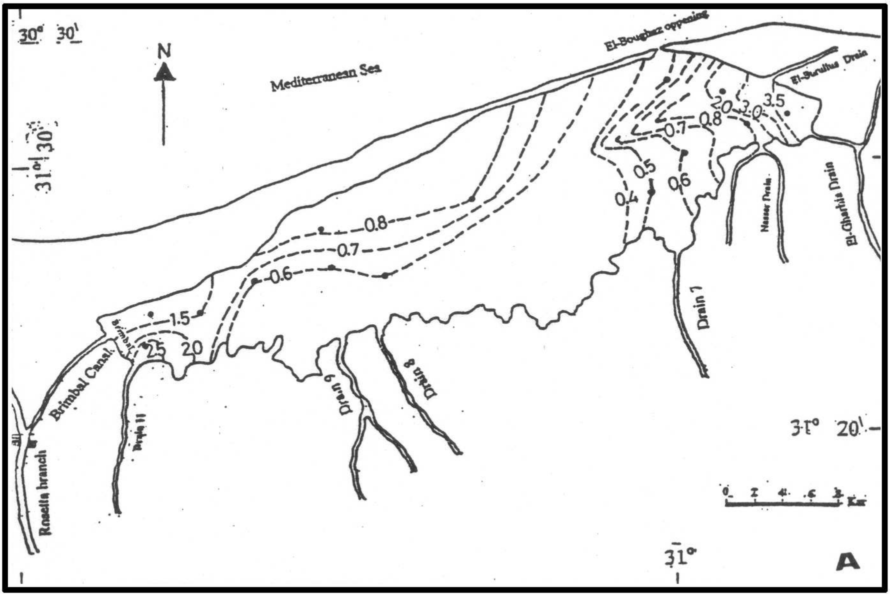


Fig. (14): Spatial distribution of Ni concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2002.



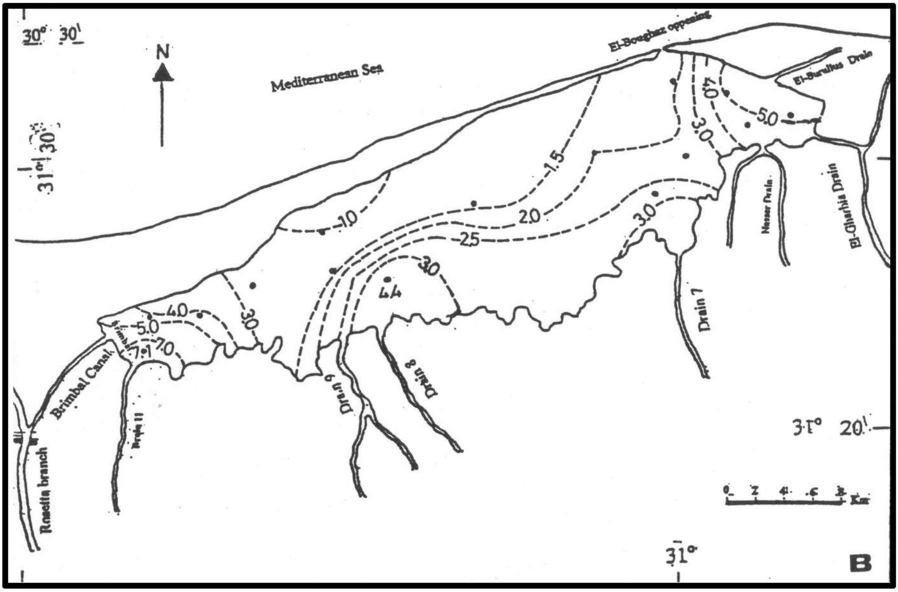


Fig. (15): Spatial distribution of Pb concentrations in the water of Lake Borollus during the Summer (A), and Autumn (B) of the year 2000.

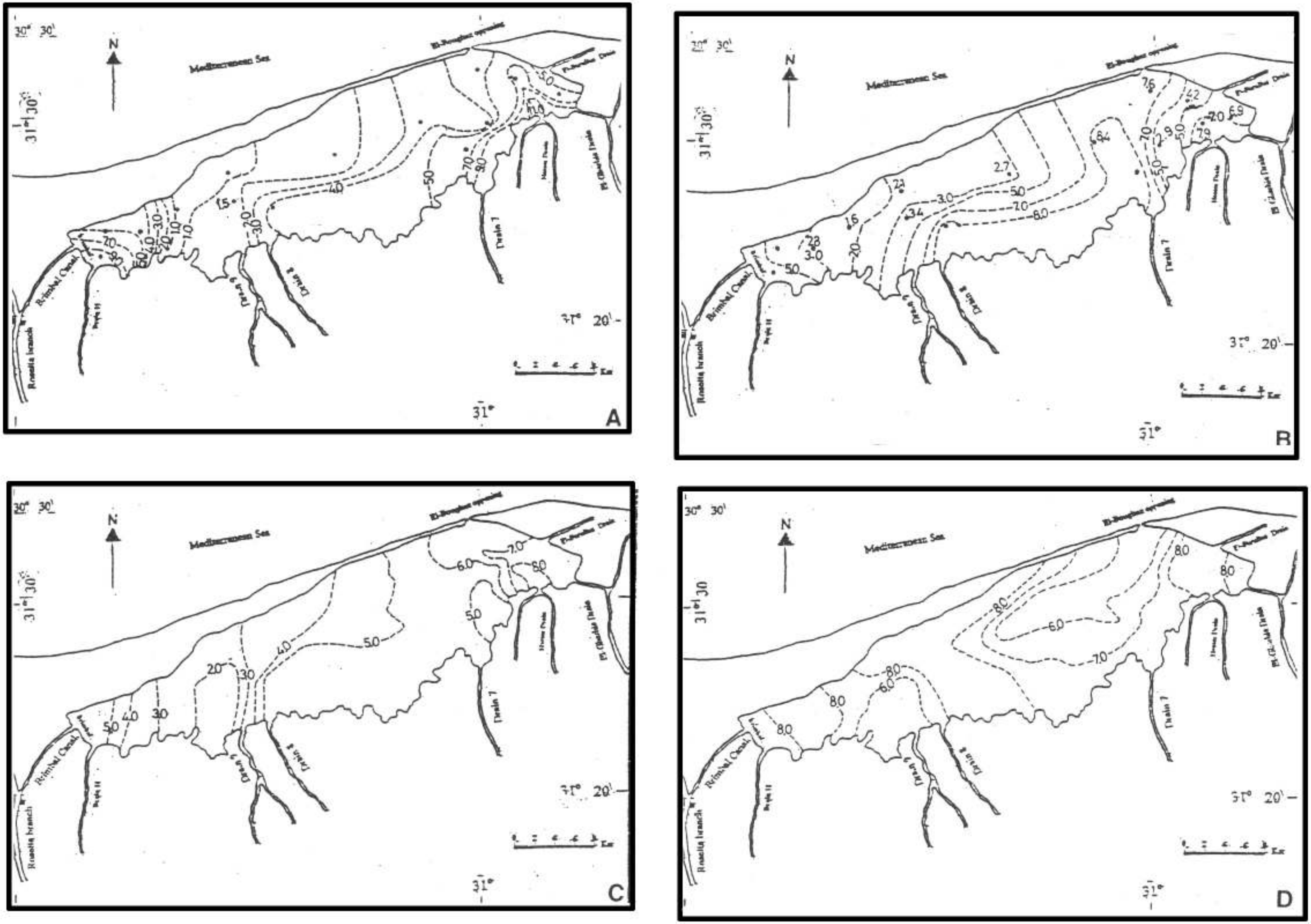


Fig. (16); Spatial distribution of Pb concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2001.

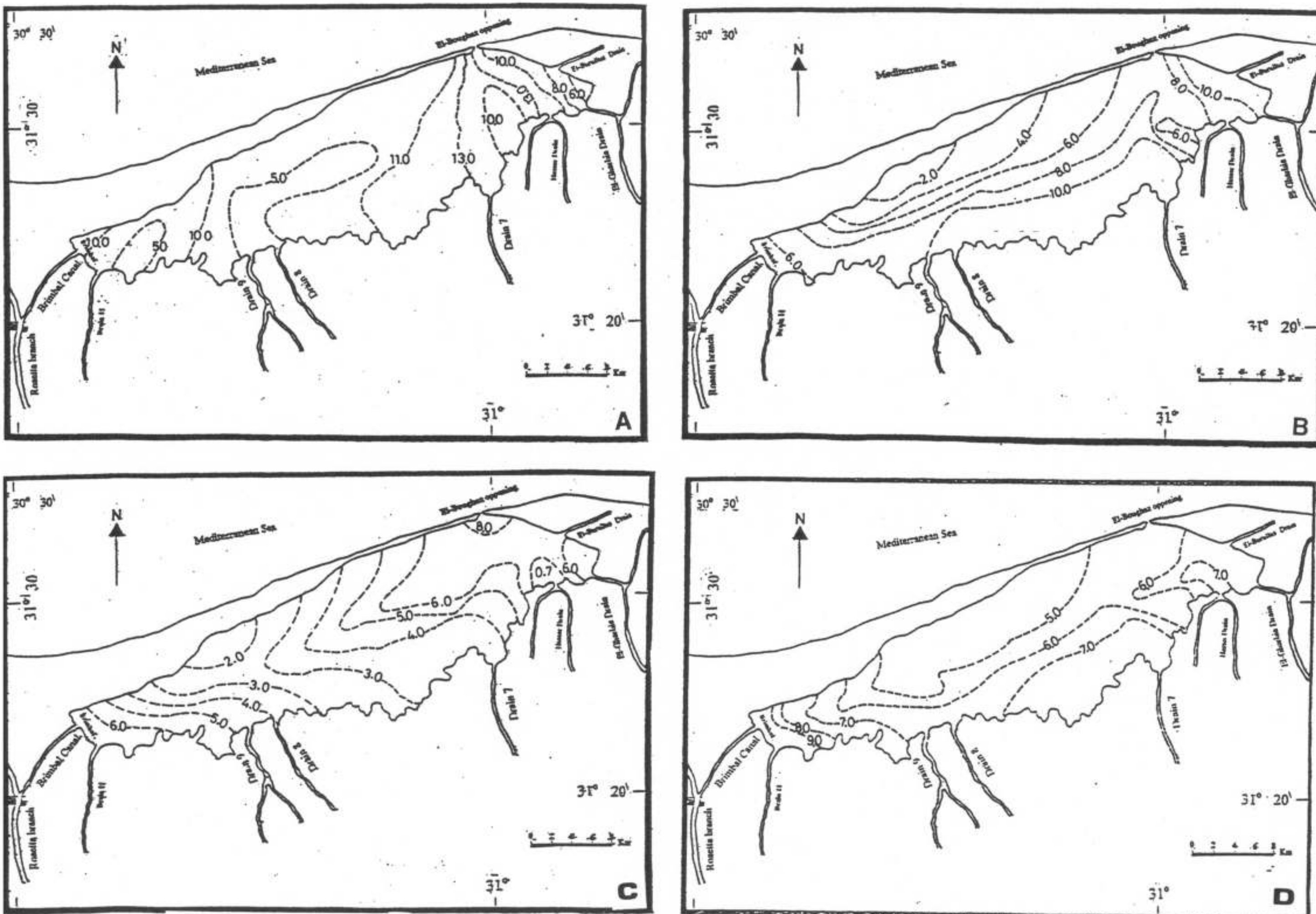


Fig. (17): Spatial distribution of Pb concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2002.

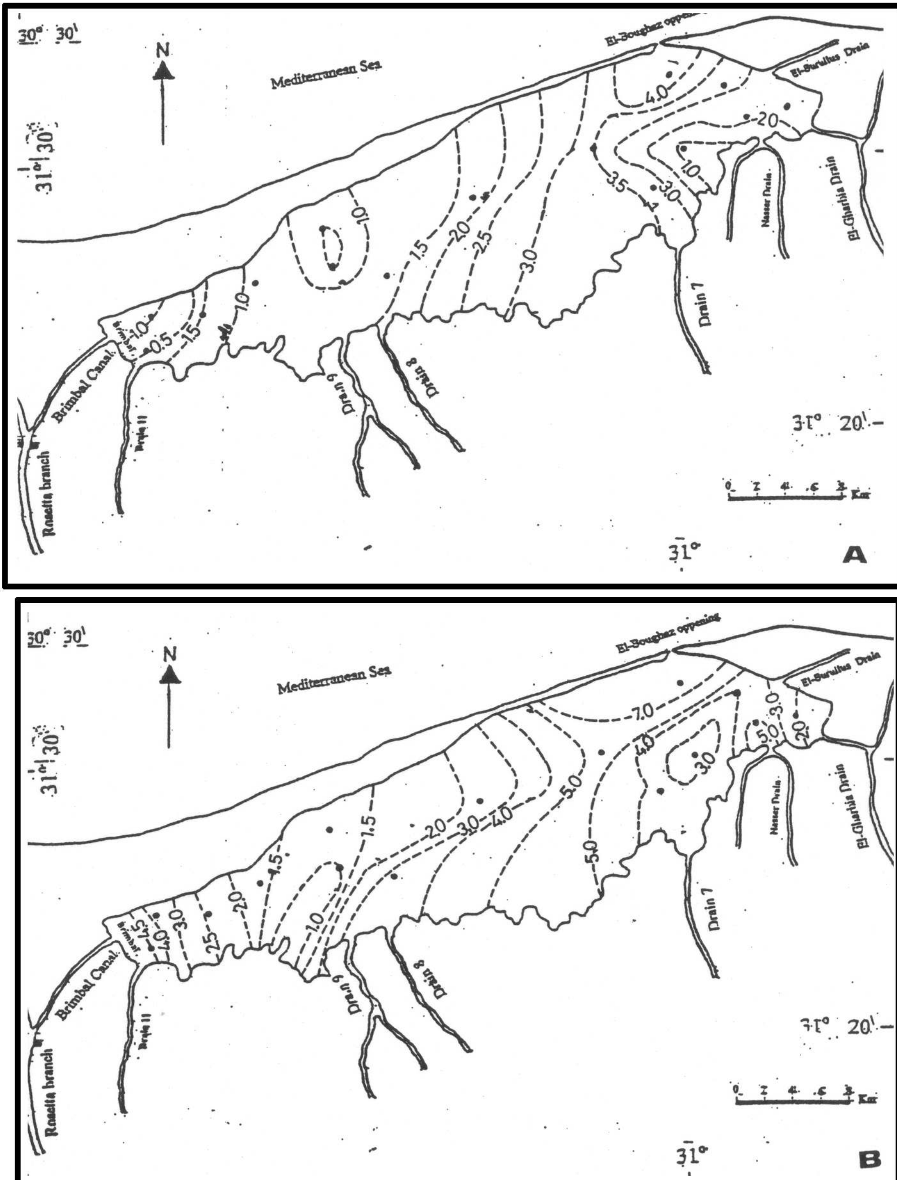


Fig. (18): Spatial distribution of Cd concentrations in the water of Lake Borollus during the Summer (A), and Autumn (B) of the year 2000.

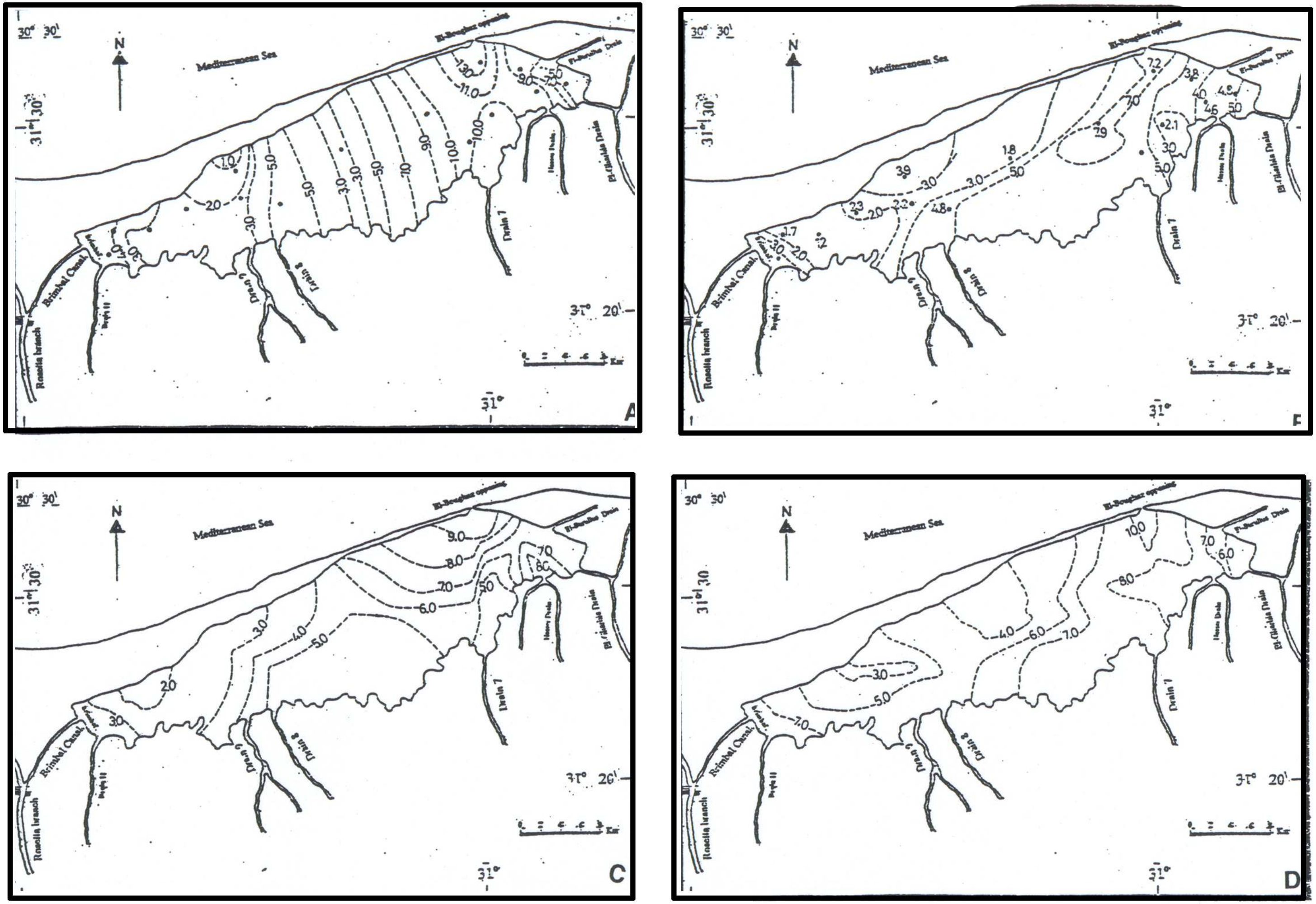


Fig. (19): Spatial distribution of Cd concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2001.

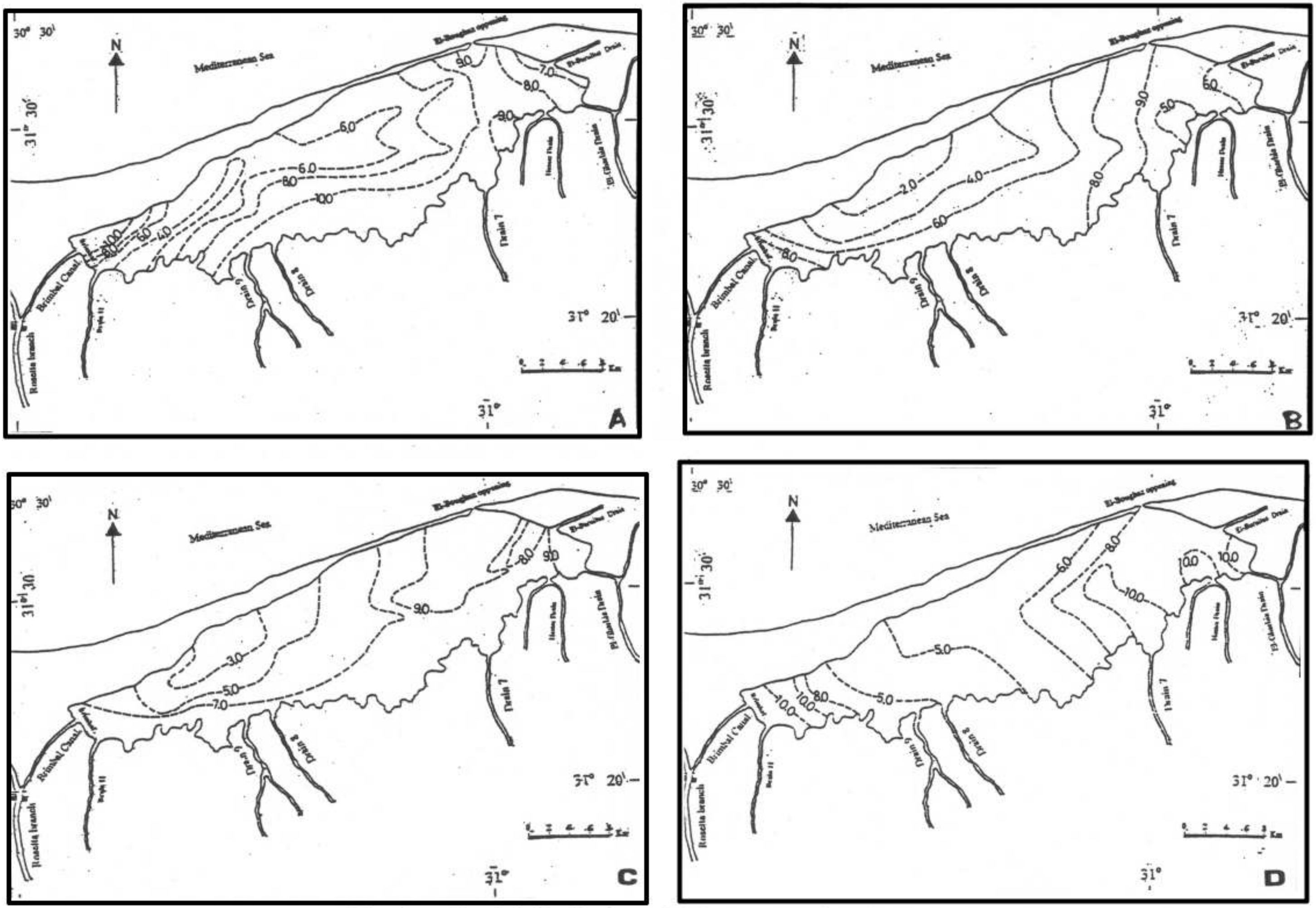


Fig. (20): Spatial distribution of Cd concentrations in the water of Lake Borollus during the Winter (A), Spring (B), Summer (C) and Autumn (D) of the year 2002.

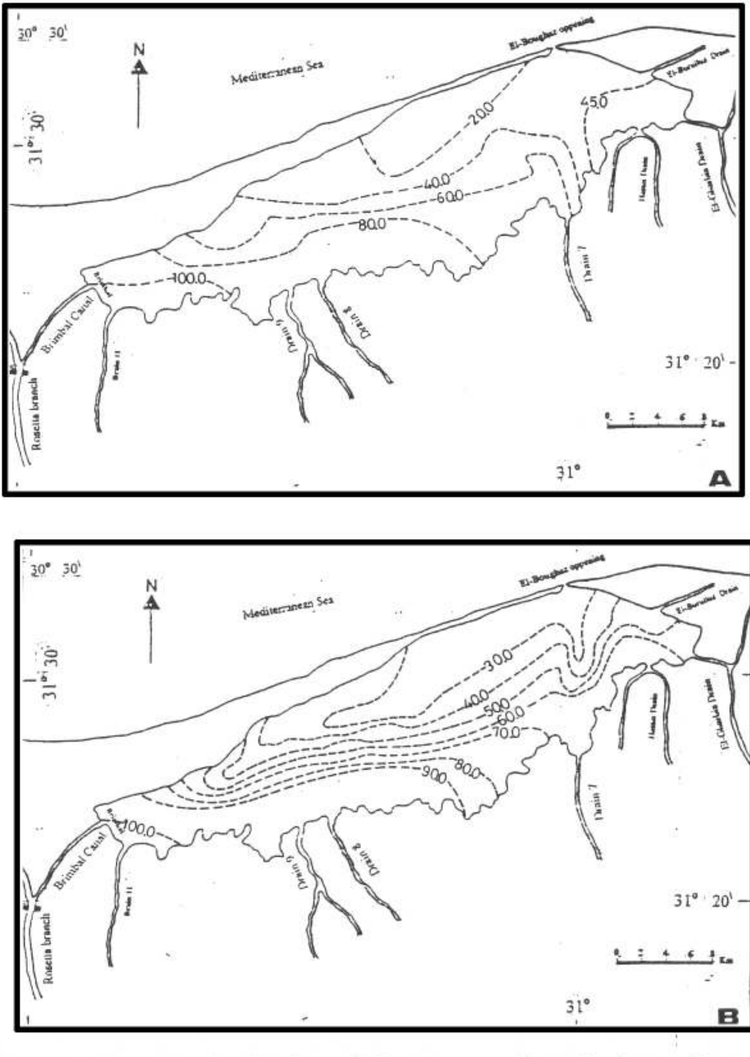


Fig. (21): Spatial distribution of Zn concentrations in the sediments Lake Borollus during the years 2000 (A), and 2001 (B).

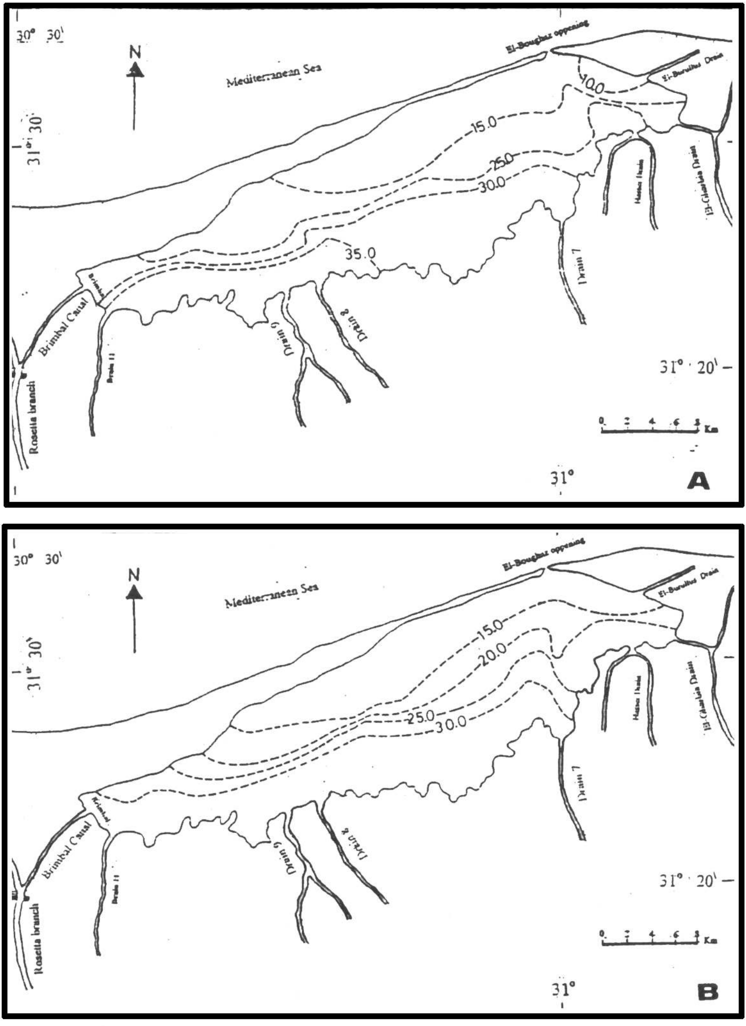


Fig. (22): Spatial distribution of Cu concentrations in the sediments of Lake Borollus during the years 2000 (A), and 2001 (B).

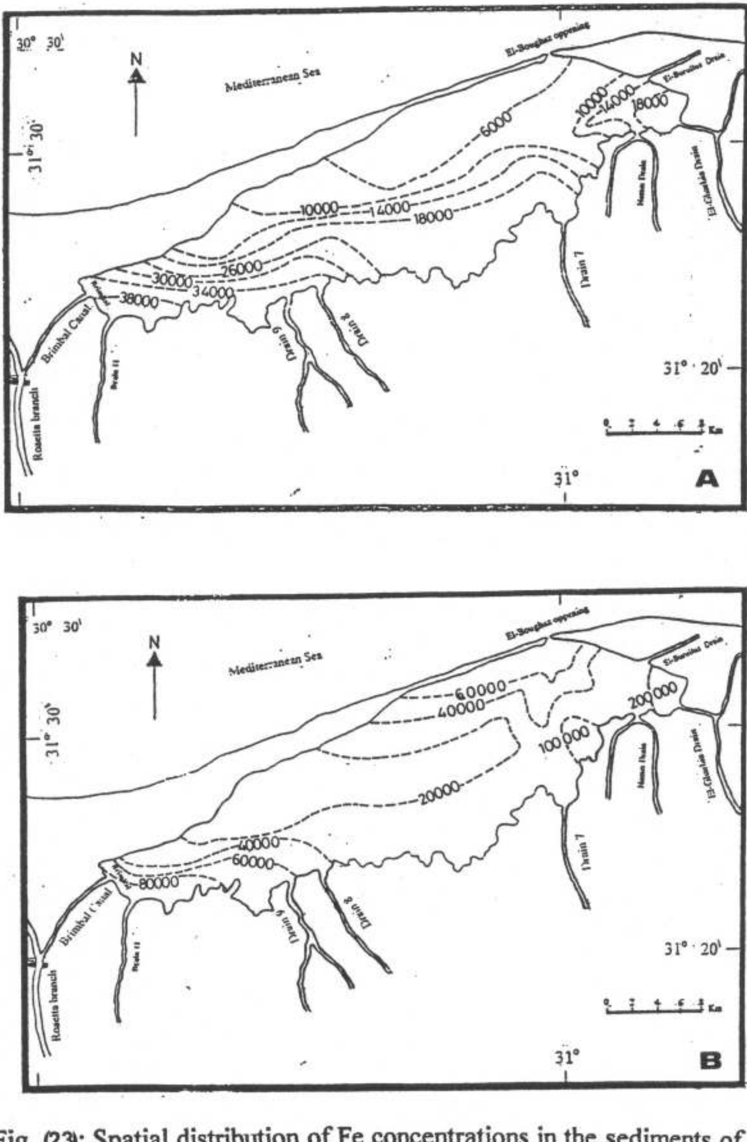


Fig. (23): Spatial distribution of Fe concentrations in the sediments of La
Borollus during the years 2000 (A), and 2001 (B).

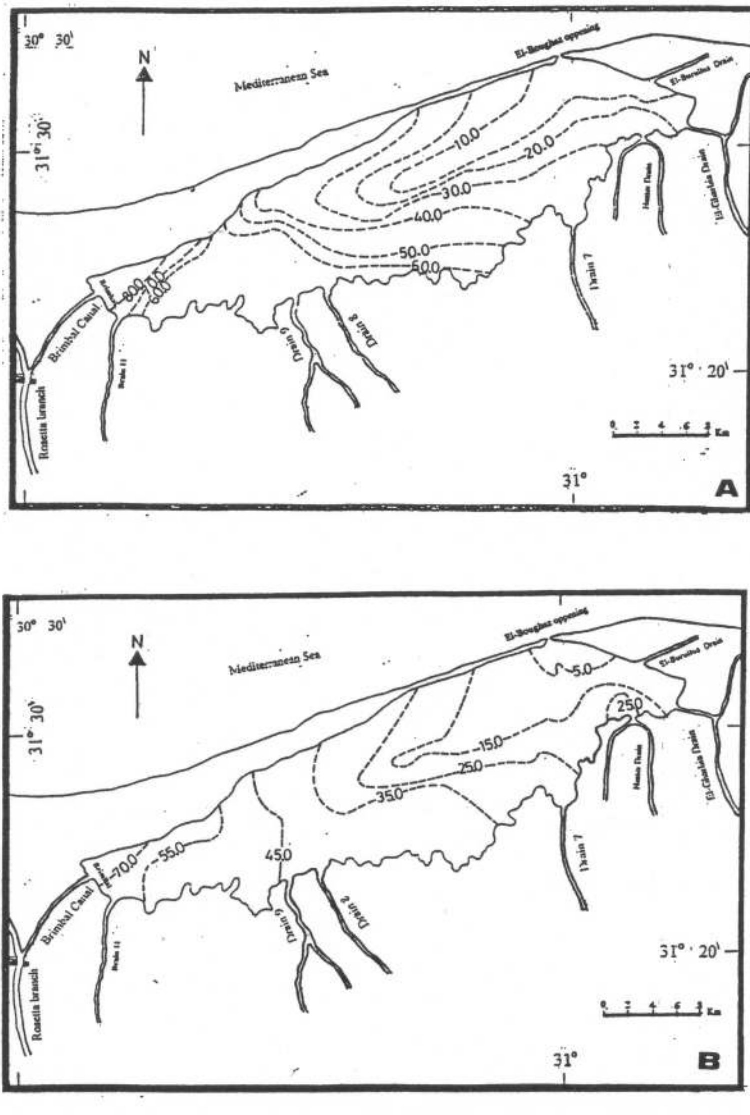


Fig. (24): Spatial distribution of Ni concentrations in the sediments of Lake Borollus during the years 2000 (A), and 2001 (B).

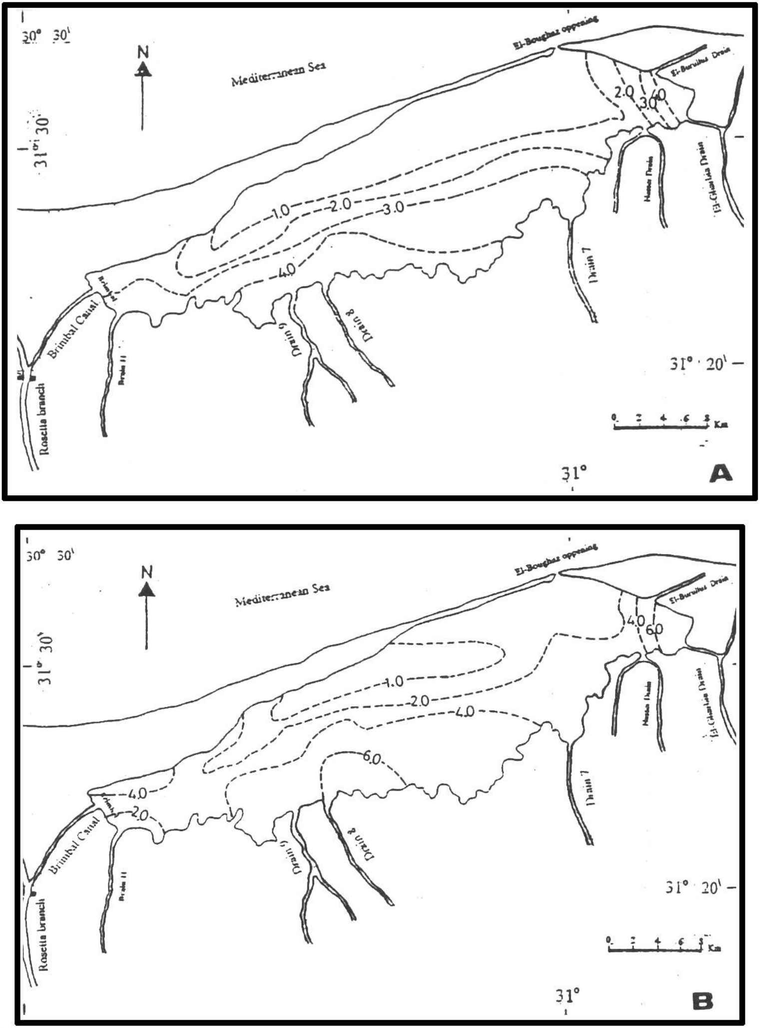


Fig. (25): Spatial distribution of Cd concentrations in the sediments of Lake Borollus during the years 2000 (A), and 2001 (B).

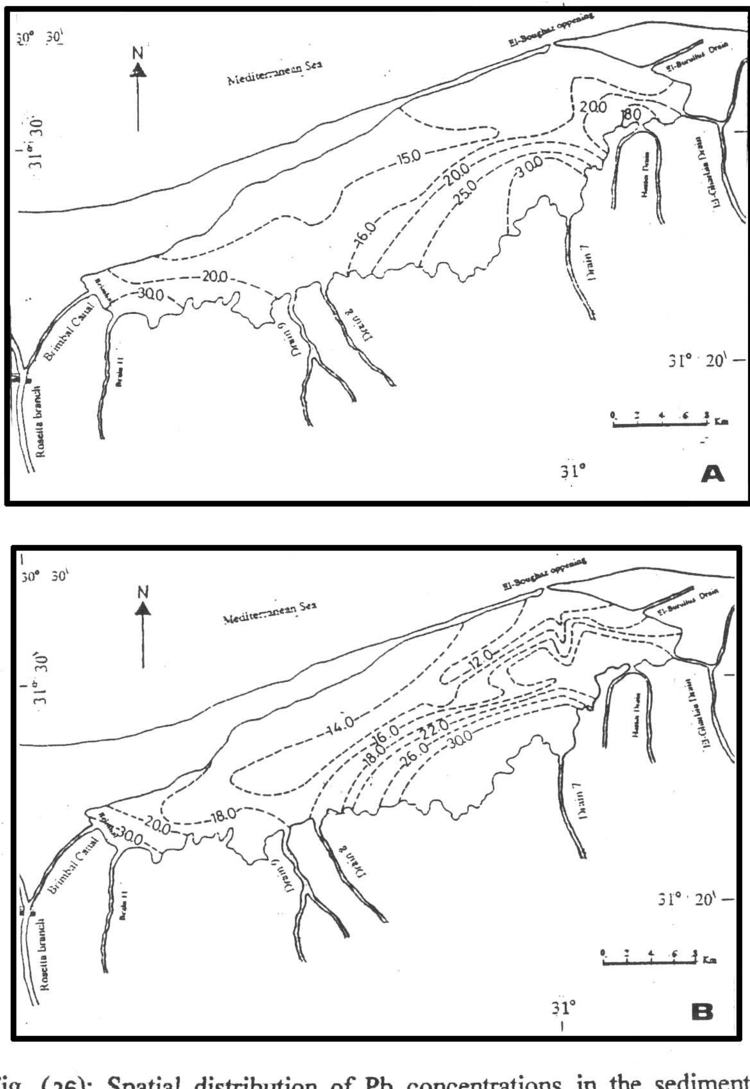


Fig. (26): Spatial distribution of Pb concentrations in the sediments of Lake Borollus during the years 2000 (A), and 2001 (B).