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ENVIRONMENTAL AND FISHERY INVESTIGATIONS ON LAKE BOROLLUS
2.B. RATES OF TRACE ELEMENTS ACCUMULATION IN THE MACROPHYTES AND FISH AT LAKE BOROLLUS.

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ABSTRACT

Concentrations of Zn, Cu, Ni and Pb were determined in three of the Macrophytes at Lake Borollus namely Eichormia crassipes, Potamogeton pectinatus and Ceratophyllum demersum. These elements were determined also in the muscle tissue, liver and gonads of Oreochromis niloticus, Oreochromis aureus, Tilapia zilliii and Sarothoredon galilaeus where these fish species are considered as the most dominant and commercial ones at the lake during the year 2002. The study revealed that higher concentrations of trace elements were found in the roots of Eichormia crassipes in comparison with their concentrations in the leaves or stems. The concentrations of the elements in these roots were 18.33, 6.65, 2.94 and 5.02 mg/kg for Zn, Cu, Ni and Pb, respectively. On the other hand, these concentrations decreased to 10.68, 4.79, 0.49 and 2.20 mg/kg in the stems and to 10.31, 3.94, 2.67 and 1.98 mg/kg in the leaves of the same marine plant at the eastern area, the most polluted area of the lake. It was found also that the concentrations of Zn, Cu and Ni in the muscle tissues of the four fish species were less than the allowable concentrations while the concentrations of the black listed element Pb were higher than the permissible ones.Higher concentrations of Pb were found also in the liver and gonads of the four fish species in comparison with those found in the muscle tissues.It was revealed also that the fish samples collected from the eastern area of the lake exhibited higher concentrations of trace elements if compared with those collected from the middle or western areas.

INTRODUCTION

A knowledge of marine pollution phenomena requires a description of the mechanisms of transport and transformation of the pollutants and of their biological effects as well as quantification of pollution levels. The mechanisms explain how the pollution is produced and develops. The quantification shows weather it has reached toxic levels.

In fact, the marine pollution does not only mean pollution of sea water, but also the possible contamination of its various components, both abiotic and biotic, each of which plays a particular role in the system. These various components, may be contaminated, especially in the case of chemically stable, not very degradable substances such as metals, which may for a long time remain unaltered by the various bio-geochemical cycles that regulate the exchanges of matter in the marine environment.

The aquatic plants are considered as one of the important stages in the food cycle in the marine environment.

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Therefore comparison of chemical composition of macrophytes among water bodies has been given greater attention and resolution by concentrated and improved investigations under continuous changing conditions. The chemical composition of macrophytes reflects the mineral uptake from the water and sediments in the marine environment. Therefore it is interesting to study the effects of water pollution on these macrophytes.

It is a matter of fact also that the problem of water pollution arises and become of more concern when the polluted area is being exploited for fishing as it is the case of the area under investigation.

Before control and prevention of pollution can be attempted in an exploitable fishing area, it is essential to distinguish to what extent are the living resources, specially fish in this area are contaminated.

Over the last 20 years, there has been increasing concern all over the world about the levels of potentially toxic heavy metals released in the marine environment.

The present paper is a part of a whole study on lake Borollus aims to the investigation of the characteristic levels of trace elements in the macrophytes and fishes live at this lake which can allow us to quantify the pollution status at such important fishing area.

This work is a part of the second phase of the research plan of Fisheries Division (National Institute of Oceanography and Fisheries) which aims to study the ecological and fisheries management of the north delta lakes of Egypt. Lake Borollus (Fig. 1) is the second largest delta lake in Egypt, situated at the northern part of the Nile delta. This lake is connected to the Mediterranean with a narrow opening where the water is exchanged between the lake and the sea. Therefore this lake receives its water from two main sources, the drains at the south and the lake sea connections at the north.

According to the variations in the chemical composition of water lake it can be classified into eastern middle and western areas.

MATERIAL AND METHODS

Biota in lake Borollus water is mostly represented by the submerged plants as Potamogeton spp. The floating plants are represented by Eichormia crassipes.

Three species of aquatic plants were regularly collected from the various areas of lake Borollus during 2002. They are Potamogeton pectinatus, Ceratophyllum demerosum and Eichormia crassipes.

The wet plants collected from the lake were flushed for several times in a large plastic bucket containing lake water. Samples were taken from the various parts of the collected plant. In order to minimize contamination of plants a plastic knife was used. Samples were transferred into suitable tightly covered labeled plastic containers ready for chemical analysis.

The number of samples of each species of the plants collected from the various areas of the lake was as follows:

Species	East area	Middle area	Western area
Eichormia crassipes	12	15	11
Potamogeton pectmatus	15	17	16
Ceratophyllum demersum	18	16	14

The following data (Table 1) show the number of fish included in the present study as well as their sizes and weights.

Species	Number	Length (cm)			Weight (gm)		
		Min.	Max.	Av.	Min.	Max.	Av.
O. aureus	34	13.1	18.9	14.72	32	96	56.7
O. niloticus	29	12.9	20.7	16.51	43	112	79.4
T. zillii	32	10.3	14.1	11.91	21	57	33.8
S. galilaeus	30	9.8	20.4	14.25	15	140	58.3

For trace element determination in the water (under publication) and wet samples were digested into a mixture of concentrated nitric and perchloric acids (4:1 v/v) according to (Sawickakapusta, 1978).

The most dominant fish species at lake Borollus are:

Oreochromis aureus, *Oreochromis niloticus*, *Tilapia zillii and Sarotherodon galilaeus*.

Fish samples were seasonally taken from the various areas of the lake through the year 2002. The fish samples were transferred iced in polyethylene bags to the laboratory for sampling their organs.

Preparation of the samples taken from the fish bodies was carried out according to the method described by FAO Technical paper No 158 edited by Bernhard, 1976.

Digestion of samples was undertaken in HNO_3 60% conc. At 60ºC.

Determination of trace elements concentrations was carried out by the use of spectrophotometer Perkins Elmer 2380.

Concentration factor:

The factor of trace metal concentration has been denoted by Donnier (1975) as: Concentration of the element in the weight unit of the fresh organism in relation to concentration of the element in the same weight unit of water.

RESULTS AND DISCUSSION

1 -Concentrations of trace elements in the macrophytes of Lake Borollus:

The macroflora of lake Borollus is represented by aerial, floating and submerged plants. The Hydrophytes *Potamogeton* spp. And *Ceratophyllum* sp. Represent about 90 to 95% of the submerged plants. The areas covered by this species constitute about 30.4% of the area of the lake. This area is also invaded by aerial plants (Darag, 1984). These plants attain from 90 to 130 cm in length. Fresh water and silt carried out through drains favour the growth of these hydrophytes.

Of the floating hydrophytes *Eichormia crassipes*. Forms a yellowish green thin mat on the surface of the stagnant water along the southern region of the lake. It is a matter of fact that the flora occurring at lake Borollus represent a good shelter and spawning areas for fish living there.

It is attempted in the present investigation to determine the concentrations of trace elements in the different parts of these macrophytes. This will help in understanding the role of these plants in absorbing these elements from the ambient water.

A -Zinc concentrations:

Zinc is an essential component of the enzyme carbonic anhydrase which catalyzes the dehydration of carbonic acid and participates in the flux of carbon dioxide within the cell. Hence Zinc is found in all green plants and essential for their growth. The uptake of Zinc by marine plants depends to a large extent on the water temperature, as well as light intensity. Parry and Haward (1973) pointed out that Zinc was uptaken by the marine algae *Dunaliella tertiolecta* at 8ºC. Initial uptake was rapid at 2ºC but ceased after approximately 2 hours. At 20ºC the uptake was slightly less rapid but this was followed by a slower constant rate for the duration of the experiment. They demonstrated also that Zinc uptake was the same in the light and in the dark conditions at about 2ºC and 20ºC. It was thought that if cells of such algae were subjected to a carbon starvation by being kept in the dark for 12 hours before the experiment then Zinc uptake might prove to be more rapid in the light than in the dark.

The effect of pH on the uptake of Zinc from the marine environment was demonstrated by Davis (1970) who pointed out that the marine flagellate *Dunaliella tertiolecta* absorbed the Zinc from the water at pH 9.0 where its cells took up 50% more Zinc in 5 hours than at pH 7.0. At pH greater than 9.0 Zinc uptake was markedly increased.

Gutknecht (1961) reported that the Zinc uptake by *ulva* and other benthic marine algae varied with the pH. It seems probably that the effects of illumination and metabolism on Zinc uptake are best explained as the consequences of their effects upon the pH of the medium. The change in pH in turn affects the uptake of Zinc which takes place mainly by passive process.

Gutknecht (1963) attributed the effect of pH on Zinc uptake to its effect on the ionisation of cationic absorbing groups associated with the algae. It should be denoted that at pH values greater than 7.0 Zinc will be present in other forms than Zn^{++} and as the pH increases, so will the proportions of the other forms of Zinc vary.

The concentrations of Zinc in the various macrophytes of Lake Borollus are indicated in Table (2).

It can be pointed out from such data that the roots of *Eichormia crassipes* accumulated this metal with higher concentrations than its stem or leaves. It can be indicated also that in most cases the rates of accumulation were higher at the eastern parts of Lake Borollus in comparison with its concentration at either the middle or west areas.

The environmental parameters at the lake, especially pH, transparency, water temperature, this as well as the concentration of Zinc in the ambient water are believed to be the main factors that have affected the uptake of Zinc from the surrounding water.

It was pointed out by the authors of the present investigation in their study on the concentrations of Zinc in the water of Lake Borollus (under publication) that the concentrations of this element were higher in the eastern part of the lake in comparison with its concentrations at the middle and western areas. They found that the average concentrations of this element during the year 2002 were 19.58 μg/L at the eastern area while it was only 12.78 and 11.26 μg/L at the middle and western areas respectively.

It was found also that the average values of pH at the eastern area of the lake were higher if compared with these values at either the middle or western areas. The increased values of pH may have played a role in increasing the uptake of Zn by macrophytes from the ambient water.

B -Copper concentrations:

Copper occurs in the marine plants where it is found with appreciable concentrations in certain enzymes as it acts as an oxidation catalyst (Darag, 1984).

The average concentrations of Copper in the various parts of macrophytes living at Lake Borollus are indicated in Table (3).

It can be point out from the data given that the concentrations of Copper attained their highest values in the roots of *Eichormia crassipes* in comparison with its concentrations in either the stem or leaves of this floating macrophyte.

Lower concentrations of Cu were also detected in the various organs of the plants growing in the middle area of Lake Borollus if compared with those growing in either the eastern or western areas of the lake.

The concentrations of this element were found to be 6.65, 4.76 and 6.92 mg/kg in the roots of *Eichormia crassipes* growing at the eastern, middle and western areas respectively. The corresponding concentrations were 4.79, 1.42 and 6.42 mg/kg in the stems and 3.94, 2.85 and 3.96 mg/kg in the leaves of the same plant growing at the same areas of the lake in respective. This indicates that the rate of accumulation lower at the middle area in comparison with other two areas.

On the other hand the concentrations of Cu in the stems of *Potamogeton pectinatus* were found as 3.47, 2.25 and 3.10 mg/kg in the plants grown at the eastern, middle and western areas of the lake respectively.

These concentrations were 3.03, 2.53 and 2.85 mg/kg in the stems of *Ceratophyllum demersum* grown at the three areas of Lake Borollus respectively.

These concentrations are comparable with the concentrations of this element in the sea weeds at other parts of the world. Black and Mitchell (1952) found that the cooper content of ten species of sea weeds lies between 0.7 to 5.7 mg/kg wet weight indicating 100-600 times that in equal volume of the sea water in which they were living.

El-Saraf (1995a) in his study on trace metals concentration of aquatic macrophytes in Lake Manzalah found that the concentrations of cooper ranged from 4.1 to 15.1 mg/kg dry weight of *Potamogeton pectinatus* and from 2.1 to 16.1 mg/kg in *Ceratophyllum demersum*. Variations in these concentrations were mainly dependant on the area from which the plant was collected where the concentrations of Cu in water and sediments were different from one area to another.

The present figures do not differ greatly from the figures given by El-Saraf (1995b).

C- Nickel concentrations in the macrophytes:

Data concerning the concentrations of Ni in the three macrophytes investigated are given in Table (4).

It appears that in all cases the average concentrations of this element in the roots of *Eichormia crassipes* were higher than that in either leaves or stem.

The highest concentration of Ni was found to be 5.20 mg/kg wet weight in the roots of *Eichormia crassipes* collected from the middle area of Lake Borollus. Its concentrations were 1.17 and 2.30 mg/kg in the stem and leaves of the plant collected from the same area.

It was fond also that the stems accumulate Ni with less concentrations than that in the leaves of *Eichormia crassipes*.

However, it was found by several authors that the leaves of macrophytes accumulate some trace elements with higher concentrations than the stem. El-Saraf (1995a) found that the leaves of *Potamogeton pectinatus* collected from Lake Mariut accumulated the trace elements with higher concentration, than the stem. Present results agrees, also with Heydt (1977) who reported that high concentrations of trace elements were found in the leaves of macrophytes.

It appear also that in all cases the plants collected from the middle part of the lake contained higher concentrations of Ni in comparison with those collected from either the eastern or western areas.

D -Lead concentrations:

The toxicity of lead to estuarine and marine organisms is a function in part of its chemical form. Inorganic lead compounds for example are generally less toxic than organo lead compounds (Pain, 1995).

Under many test conditions it was found that inorganic lead is moderately toxic to aquatic plants. These compounds were also less toxic than cadmium, mercury and cooper. Although growth limitation typically occurs at lead concentrations of 0.1 to 8.0 mg/L some species such as the micro green algae *Chlorella saccharophila* can tolerate concentrations of Pb over 63 mg/L (US EPA, 1985).

Starodub *et al*. (1987) pointed out that, as most metals, complexation with humic acid and other organic molecules and inorganic legends, reduces toxicity to most plant species studied. It is generally assumed that organo leads, particularly tetra ethyl lead are more toxic to aquatic plants than either methylated derivatives or inorganic compounds.

The rate of uptake of inorganic lead is generally rapid and increases with exposure concentration. Sorption is generally suppressed by H^+ and Humic acids (Vymazal, 1984).

The average concentrations of lead in the various measured species of aquatic plants collected from lake Borollus are given in Table (5).

It can pointed out from the data given that the roots of *Eichormia crassipes* accumulated lead with higher concentrations than the stems or leaves of this plant. The average concentrations of Pb in these roots were found to be 5.02, 3.28 and 6.14 mg/kg wet weight at the eastern, middle and western area of the lake. The concentrations of this metal were in all cases less than half of these concentrations in either the stem or leaves of *Eichormia crassipes*.

The bodies of both *Potamogeton pectintus* and *Ceratophyllum demersum* accumulated in all cases less concentrations of lead.

This points out to the fact that *Eichormia crassipes* which is widely spreading at the lake adsorbs repeated quantities of the lead discharged to the lake through the land drainage. This contributes in the removal of such toxic element from the ambient sea water and sediments. Radwan (2000) indicated that the concentration of Pb in the drainage water to Lake Borollus ranged from 0.45 to 11.76 μg/kg.

Removal of certain minerals from water reservoirs by submerged macrophytes was observed as a practical method for water purification (Hillman and Culley, 1978).

El-Saraf, 1995a in his study on the chemical composition of macrophytes at Edku and Mariut lakes found that the concentration of lead in *Potamogaton pectinatus* ranged from 15.1 to 22.8 mg/kg dry weight for the plants collected from lake Mariut. He found also that these concentrations ranged from 13.7 to 55.9 mg/kg in the plant samples of *Ceratophyllum demersum* collected from the same lake. It appears therefore that the concentrations of Pb in the plants collected from lake Borollus (present study) are less than these in the plants collected from lake Mariut (El-Saraf, 1995b).

2 -Concentration of trace elements in the organs of various fish species:

A simulataneous study on the concentrations of trace elements in the water and sediments of Lake Borollus were carried out (under publication). This investigation indicates that the concentrations of heavy elements in the water of lake Borollus varies from one area to another. Mostly the highest levels were found at the eastern area. The lake water showed lower concentrations in both the middle and western areas in comparison with those recorded at the east.

According to Bryan and Uysal (1978), the feeding type and environmental conditions of the aquatic animals have an effect on the concentration of elements. In general animals take the heavy elements directly from the sea water or through the food chain.

The concentrations of Zn, Cu, Ni and Pb in the flesh, liver and gonads of the four species namely *Oreochromis niloticus, Oreochromis aureus, Tilapia zillii* and *Sarotharedon galilaeus* caught from the various areas of Lake Borollus were measured, Tables (6,7,8 and 9) and graphically represented in Figs. 2, 3, 4 and 5).

A -Zinc concentrations:

The essentiality of Zinc to marine organisms have been shown according to Tucker and Salmon (1955), hence this element is required for normal growth, development and function for all animal species. Severe deficiency of Zinc include growth retardation, delayed sexual maturation, skeletal abnormalities and fetal abnormalities.

Portman (1968), suggested that although Zinc is one of the more abundant toxic heavy metals, the oral toxicity in humans to most Zinc compounds is relatively low. Zinc should be monitored because its effect on marine life.

Table (6) shows the concentrations of Zn in the flesh, liver and gonads of the four Tilapias fish species caught from the various areas of lake Borollus.

The data given in this table indicate that the concentrations of Zn varies from one species to another. Such variations depend to great extent on the differences in feeding habits as well as the ability of fish for Zinc regulation.

Mostly *O. niloticus* accumulated high concentrations of Zinc in comparison with the other Tilapia species, particularly at the eastern and middle parts.

The data given in Table (6) indicate also that the concentrations of Zinc in the liver and gonads of the various fish species were higher than its concentrations in the muscle tissues.

These concentrations ranged from 34.70 to 41.06 mg/kg, from 21.15 to 37.72 mg/kg, from 29.40 to 40.08 mg/kg and from 31.87 to 53.18 mg/kg in the liver of *O. niloticus*, *O. aureus*, *T. zillii* and *S. galilaeus* respectively.

On the other hand, Zn concentrations ranged from 79.04 to 92.07 mg/kg, from 61.28 to 80.70 mg/kg, from 51.41 to 63.74 mg/kg and from 41.09 to 72.25 mg/kg in the gonads of the previously mentioned fish species respectively.

The higher concentrations of Zinc in the liver and gonads of fish in comparison with its concentrations in the flesh has been reported by various authors.

This agrees with the conclusions of Shakweer *et al*. (1993) who indicated that *O. niloticus* living at lake Edku accumulated higher concentrations of Zinc in comparison with *O. aureus*, *T. Zillii* and *S. galilaeus* living at the same lake.

Bryan (1964) observed that the two lobster species namely *Homorus* and *Carcinus* can regulate the Zinc concentration in muscle tissues when exposed to high concentrations of such trace element.

The ability of fish to regulate Zinc concentration in its internal body organs plays therefore important role in its rate of accumulation from one species to another.

In this concern Millington and Walker (1983) indicated that in the River Murray there is high variation in Zinc content among individuals and between populations, part is systematic associated with body weight and age but a larger part remains statistically unexplained.

Concerning the allowable maxima for the quantities of Zinc which food may contain, it has been recommended by the current state food standard regulations in Tasmania Public Health (Food and Drugs Standards Regulations, 1971) that such allowable maxima for Zinc is 40 ppm.Marks *et al* (1980).

On the other hand, the National Health and Medical Research Council (NHMRC) has recommended that the allowable maxima for Zinc be changed to 1000 ppm (Anon, 1980).

It can therefore be concluded that, based on the above statements and recommendations given by the international organizations that the fish flesh of the examined species at Lake Borollus contained Zinc in concentrations far below the allowable concentrations.

Ahdy (1982) in her study on the accumulation of Zinc in the liver gut and muscle of some fish species from Lake Mariut, found that higher accumulation of Zinc in *Tilapia nilotica* occurred in the fish liver while minimum values were found in the muscles. This agrees with the present results.

Chipman *et al.* (1958) demonstrated that the uptake of Zn^{65} following oral administration to Croakers showed a rapid entry of the isotope into the blood with great accumulation in the internal organs particularly the liver and spleen.

The higher concentrations of heavy metals in fish liver has been attributed according to Saleh *et al*. (1983) to the fatness of liver and also to the fact that the fish liver extracts the poisons from the blood through its circulation inside the body of the living organism.

The highest Zinc concentrations in the gonads of the four species examined at Lake Borollus agrees with the results of many authors. Shakweer (1993) indicated that the gonads of fish accumulated very high concentrations of Zinc in comparison with its other organs. From the 27 species included in her investigation she found that nine species accumulated Zinc in their organs with concentrations ranging from 100 to 200 mg/kg while 12 species accumulated this element with concentrations ranging from 200 to 400 mg/kg and six species only contained Zinc below 100 mg/kg in their gonads. Mawson and Fischer (1953) pointed out that high Zinc concentrations are associated with the reproductive organs in the vertebrates.

B -Copper concentrations:

In recent years the concentration of Copper in fish have received much interest. This interest has been directed to fish since high levels of Copper in the various species of the commercial catch represent a potential hazard to human health.

The study of toxicity of Copper element to fish is important not only for its occurrence in trade wastes disposed to the marine environment but also Copper sulphate is used in some places on a large scale as an algicide in drains and streams running and following into the sea.

In the present paper Copper concentrations were determined in various organs of the four Tilapia species caught from lake Borollus (Table 7).

The data given indicate that the concentrations of Copper varied from 3.97 to 9.81 mg/kg in the flesh, from 32.24 to 62.14 mg/kg in the liver and from 10.83 to 21.72 in the gonads of the various species investigated. The highest concentrations of Copper were found in the liver of the four species investigated and this agrees with the conclusions of many authors.

Grimanis *et al*. (1980) determined the concentration of Copper in the flesh of different fish species taken from the gulfs of Greece, receiving industrial and agricultural wastes. They indicated that in general, there is high variability in Copper concentration among the fish species examined. It was possible to attribute the differences in Copper concentrations to the mode of living and feeding habits of fish.

The World Health Organization (WHO, 1973) recommended that the allowable Copper concentration for human consumption is 30 mg/kg wet weight. It can be emphasized therefore that the concentrations of Cu in the flesh of various Tilapia species caught from Lake Borollus are blow the tolerable concentrations admitted by the International Organizations.

Lauren and McDonald (1987) pointed out that the fish liver can not be treated as the sole site of internal Copper accumulation. The Copper binding capacity of trout liver reached the highest level after about 7 days of exposure to a solution containing 55 μg Cu/L. Further Copper uptake was distributed to other internal tissues.

C -Nickel concentrations:

The concentrations of Ni in the different organs of the four Tilapias at lake Borollus are shown in Table (8). It can be indicated from the data given that the concentration of Ni does not differ greatly from one species to another.

The least values were found in the flesh of fish while the highest were found in the gonads.

The lowest concentration of Ni in the fish muscle was found to be 4.65 mg/kg in case of *T. zillii* caught from the western area of the lake while the highest concentration was found as 9.82 mg/kg in case of the same fish species caught from the eastern area. On the other hand, the concentrations of this element in the liver and gonads *T. zillii* were higher in case of fish caught from the eastern area in comparison with those caught from the west. This indicates that the variation of Ni concentrations in the different areas of the lake plays an important role in determining the concentrations of Ni in the various parts of the fish within the same species.

The maximum concentration of Ni was found to be 38.12 mg/kg in the gonads of *O. niloticus* caught from the western area of the lake.

It appears therefore that the average concentrations of Ni in the fish flesh ranged from 4.65 and 9.82 mg/kg.

The National Health and Medical Research Council (NHMRC) as well as Australian Food and Drug Regulation (WAFDR) in Marks *et al*. (1980) recommended the allowable concentrations at Ni for the human consumption as 5.5 mg/kg.

However, it was found that the concentrations of this element in the flesh of fish caught from Lake Borollus not higher from the allowable concentrations in most cases.

D -Lead concentrations:

The concentrations of lead in the marine environment has been considerably increased by human activities. It has been estimated that the rate of introduction of lead into the sea has increased 27 fold since the Pleistocene period (Tatsumoto and Patterson, 1963). Part of this has been caused by increased leaching of the land caused by the development of agriculture and later by industrial activity. However by far the greatest increase has taken place in the last four decades as a result of the use of lead tetra ethyle as an additive to petrol

The concentrations of Pb in the flesh, liver and gonads of the four Tilapia species are given in Table (9).

It can be pointed from the data given that Pb has been accumulated with lower concentrations in the flesh of fish in comparison with its concentrations in either the liver or gonads of fish.

These concentrations ranged from 5.85 to 9.09 mg/kg in the flesh of fish caught from the eastern area of the lake while it ranged from 4.78 to 7.42 mg/kg and from 6.77 to 10.47 mg/kg in the flesh of fish caught from the middle and western areas of the lake respectively.

The allowable concentrations of Pb in the fish flesh for human consumption was recommended according to NHMRC (1980) as 2.0 mg/kg wet weight.Marks *et al* (1980).

It can be indicated therefore that the four Tilapia fish species living at lake Borollus accumulate Pb in their tissues with higher concentrations if compared with the permissible concentrations of this element.

On the other hand, it can be pointed out from the data given in table (9) that the gonads of the four fish species accumulated lead with high concentrations. These concentrations ranged from 24.23 mg/kg in case of *O. niloticus* caught from the middle part of the lake and 40.17 mg/kg in case of *T. zillii* caught from the same part.

Careful is advisable therefore in using the gonads of fish for human nutrition specially those caned or dried gonads of some fish species which are expected to contain higher rates of Pb concentrations after being dried.

3 -Concentration factors of the various trace elements:

Many of the trace elements occurring at great dillution in the sea are found concentrated several hundred fold or several thousand fold in one or more species of marine plants or animals (Noddack, 1940).

Vingradov (1953) indicated that trace elements introduced in the marine environments from effluents and river run off may be concentrated in the marine organisms by a factor ranging from 1000 to 10000.

Uysal and Tancer (1987) stated that: the marine organisms accumulate the chemicals as well as the heavy elements in large quantities in their bodies as compared to their surroundings in the sea water. This results in an increase in the heavy metal levels of these organisms as well as in the fish through feeding adsorption and absorption.

The factor of trace element concentration by marine organisms has been denoted by Donnier (1975) as: Concentration of the element in the weight unit of the fresh organism in relation to concentration of the element in the same weight of the water.

In the present investigation the factors of various elements in the bodies of macrophytes and fish living at Lake Borollus are given in Tables (10 to 16).

The calculation of such factors have been based on lake water analysis carried out by the same authors of the present study part (A) (under publication).

It is obvious from the data given in these tables (10-16) that these factors were mostly higher in the roots and leaves of *Eichormia crassipes* in comparison with the stems of such plant.

It is indicated also that these factors attained their highest values at the western area of the lake in case of Zinc in the plants while in other elements it varied from one area to another.

However the concentration factors of the four elements under investigation in the present study ranged between few hundreds to one thousand in the marine plants living at Lake Borollus. In some cases this factor exceeded one thousand as it was the case of Zinc, Nickel and Lead accumulation in the stems and roots of plants.

Comparable values for the correlation coefficient were indicated by various authors in other parts of the world.

Bernhard and Zatera (1975) indicated that similar to the other heavy metals the first trophic level (plankton and in macrophytes enrich Copper to about the same order as the higher trophic levels. Plankton contains around 1000 µg Cu/kg fresh weight which is with few exceptions similar to the concentrations of the macrophytes and fishes.

Eisler (1983) found that a selection of macrophytes including edible sea weeds exhibit accumulation factor for Pb from 12000 to 82000.

As for the concentration factors of the four investigated elements in the various organs of Tilapia fish, it was found that these factors attained much higher values than those attained in the macrophytes.

The values of this factor were in all cases more than one thousand with the exception of its values in case of the accumulation of Copper in the fish flesh. It can be indicated also that the gonads of fish in all cases showed high values of the factor. This means that care has to be taken in consuming this fish organ for human nutrition specially those caned ones. Caning may increase the factor of concentration of trace elements in such organ of the fish. On the other hand, the fish flesh exhibited the least values for concentration factor of the various elements in the four fish species under investigation.

Summary and Conclusions

Lake Borollus the second largest lake among the Nile delta lakes of Egypt; is an important fishing ground and contributes with respected percentage in the annual fish yield of the country. It receives agricultural as well as industrial wastes which can not be naturally processed to become harmless to the living resources at this lake. This will sooner or later become of real danger.

The present paper concerns with the rates of trace metals accumulation in the dominant macrophytes and commercial fish species.

The following conclusions can be pointed out from the present study:

(1) The variations in the concentrations of Zn, Cu, Ni and Pb were considerably observed from one species to another for both the macrophytes and fish species. These variations can be related to the area of the lake where the concentrations of these elements differed from one area to another according to the chemical composition

of the water discharged. On the other hand, the mode of living and feeding habits as well as the physiology of various organs in case of fishes are believed to play an important role in the rates of trace elements accumulation.

(2) The roots of *Eichormia crassipes* accumulated the four measured trace elements with higher concentrations than leaves and stem.

(3) The plants collected from the eastern part of lake Borollus contained higher concentrations of trace elements in comparison with those collected from the middle or western parts.

(4) than those allowed for human consumption according to the recommendations of the international organizations.

(5) The liver of fish contained trace elements with higher concentrations specially Copper and lead. It is not recommended to use them as a category of the trash fish used for the preparation of fish meals for chickens nutrition.

(6) The gonads of fish accumulated high concentrations of Zinc and lead if compared with the other organs. It is not advisable therefore to consume these gonads regularly for human nutrition.

(7) The factor of concentration of trace elements in the various macrophytes living at lake Borollus was mostly below 1000 to that in water.

(8) Fishes concentrated the trace elements with higher factors in relation to the ambient water. The values of this factor was in most cases below 2000 in the fish flesh while it increased to reach more than 10000 in the liver and gonads of fish.

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Table (2) : Concentration of Zn (mg/kg) in the plants living in Lake Borullus during 2002

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	*Eichormia crassipes*	18.33	10.68	10.31
	Potamogeton pectinatus		7.20	
	Ceratophyllum demersum		7.26	
Middle area	*Eichormia crassipes*	13.68	4.10	8.80
	Potamogeton pectinatus		9.50	
	Ceratophyllum demersum		6.30	
Western area	*Eichormia crassipes*	14.18	13.26	10.76
	Potamogeton pectinatus		10.20	
	Ceratophyllum demersum		5.27	

Table (3) : Concentration of Cu (mg/kg) in the plants living in Lake Borullus during 2002.

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	Eichormia crassipes	6.65	4.79	3.94
	Potamogeton pectinatus		3.47	
	Ceratophyllum demersum		3.03	
Middle area	Eichormia crassipes	4.76	1.42	2.85
	Potamogeton pectinatus		2.25	
	Ceratophyllum demersum		2.53	
Western area	Eichormia crassipes	6.92	6.42	3.69
	Potamogeton pectinatus		3.10	
	Ceratophyllum demersum		2.85	

Table (4) : Concentration of Ni (mg/kg) in the plants living in Lake Borullus during 2002.

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	*Eichormia crassipes*	2.94	0.49	2.67
	Potamogeton pectinatus		1.57	
	Ceratophyllum demersum		2.52	
Middle area	*Eichormia crassipes*	5.20	1.17	2.30
	Potamogeton pectinatus		2.47	
	Ceratophyllum demersum		3.14	
Western area	*Eichormia crassipes*	3.45	2.52	3.21
	Potamogeton pectinatus		2.45	
	Ceratophyllum demersum		2.71	

Table (5) : Concentration of Pb (mg/kg) in the plants living in Lake Borullus during 2002

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	*Eichormia crassipes*	5.02	2.20	1.98
	Potamogeton pectinatus		1.79	
	Ceratophyllum demersum		2.03	
Middle area	*Eichormia crassipes*	3.28	1.64	1.15
	Potamogeton pectinatus		1.14	
	Ceratophyllum demersum		1.10	
Western area	*Eichormia crassipes*	6.14	2.16	1.38
	Potamogeton pectinatus		2.03	
	Ceratophyllum demersum		1.92	

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Table (6) : Concentrations of Zn (mg/kg) in the different organs of various fish species living in Lake Borullus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	36.89	41.06	92.07
	Oreochromis aureus	18.06	21.15	61.28
	Tilapia zilli	21.26	38.17	51.41
	Sarothoredon galilaeus	20.16	53.18	72.25
Middle area	*Oreochromis niloticus*	16.41	36.22	83.10
	Oreochromis aureus	17.92	28.14	72.80
	Tilapia zilli	15.33	29.40	60.14
	Sarothoredon galilaeus	17.04	33.07	41.09
Western area	*Oreochromis niloticus*	16.92	34.70	79.04
	Oreochromis aureus	19.88	37.72	80.70
	Tilapia zilli	17.49	40.08	63.74
	Sarothoredon galilaeus	13.84	31.87	60.07

Table (7) : Concentrations of Cu (mg/kg) in the different organs of various fish species living in Lake Borullus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	9.81	62.14	21.72
	Oreochromis aureus	5.62	41.15	11.15
	Tilapia zilli	5.35	53.29	10.83
	Sarothoredon galilaeus	3.97	32.24	18.67
Middle area	*Oreochromis niloticus*	4.02	38.63	14.07
	Oreochromis aureus	2.88	35.09	16.08
	Tilapia zilli	5.19	39.14	19.27
	Sarothoredon galilaeus	3.75	36.75	17.40
Western area	*Oreochromis niloticus*	6.81	43.65	18.71
	Oreochromis aureus	3.83	35.18	19.95
	Tilapia zilli	4.58	38.63	21.03
	Sarothoredon galilaeus	3.36	47.18	23.70

Table (8) : Concentrations of Ni (mg/kg) in the different organs of various fish species living in Lake Borullus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	8.84	17.68	30.14
	Oreochromis aureus	7.57	19.46	33.30
	Tilapia zilli	9.82	25.93	35.12
	Sarothoredon galilaeus	5.30	18.73	26.15
Middle area	*Oreochromis niloticus*	5.46	28.21	35.68
	Oreochromis aureus	4.67	30.93	37.12
	Tilapia zilli	6.14	25.14	30.80
	Sarothoredon galilaeus	5.89	22.40	30.17
Western area	*Oreochromis niloticus*	6.74	26.90	38.12
	Oreochromis aureus	5.14	28.20	30.93
	Tilapia zilli	4.65	19.72	23.60
	Sarothoredon galilaeus	5.92	26.17	31.41

Table (9) : Concentrations of Pb (mg/kg) in the different organs of various fish species living in Lake Borullus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	9.09	14.45	36.23
	Oreochromis aureus	8.13	14.56	35.44
	Tilapia zilli	5.85	11.14	38.69
	Sarothoredon galilaeus	7.45	16.45	30.14
Middle area	*Oreochromis niloticus*	6.35	12.25	24.23
	Oreochromis aureus	7.42	15.14	31.36
	Tilapia zilli	4.78	16.36	40.17
	Sarothoredon galilaeus	6.16	16.08	31.81
Western area	*Oreochromis niloticus*	10.06	16.23	38.51
	Oreochromis aureus	9.19	16.17	39.26
	Tilapia zilli	10.48	15.06	33.63
	Sarothoredon galilaeus	6.77	14.85	36.42

Table (10): Concentration factor of Zn in the plants living in Lake Borullus during 2002 .

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	*Eichormia crassipes*	1261	735	710
	Potamogeton pectinatus		495	
	Ceratophyllum demersum		500	
Middle area	*Eichormia crassipes*	1588	476	1022
	Potamogeton pectinatus		1103	
	Ceratophyllum demersum		732	
Western area	*Eichormia crassipes*	1964	1837	1490
	Potamogeton pectinatus		1412	
	Ceratophyllum demersum		730	

Table (11) : Concentration factor of Cu in the plants living in Lake Borullus during 2002.

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	*Eichormia crassipes*	599	431	355
	Potamogeton pectinatus		313	
	Ceratophyllum demersum		273	
Middle area	*Eichormia crassipes*	834	249	500
	Potamogeton pectinatus		394	
	Ceratophyllum demersum		443	
Western area	*Eichormia crassipes*	725	672	386
	Potamogeton pectinatus		325	
	Ceratophyllum demersum		298	

Table (12) : Concentration factor of Ni in the plants living in Lake Borullus during 2002.

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	*Eichormia crassipes*	670	112	608
	Potamogeton pectinatus		358	
	Ceratophyllum demersum		574	
Middle area	*Eichormia crassipes*	1656	373	732
	Potamogeton pectinatus		787	
	Ceratophyllum demersum		1000	
Western area	*Eichormia crassipes*	1082	790	1006
	Potamogeton pectinatus		768	
	Ceratophyllum demersum		850	

Table (13) : Concentration factor of Pb in the plants living in Lake Borullus during 2002.

Area	Species	Part of the plant		
		Roots	Stem	Leaves
Eastern area	*Eichormia crassipes*	896	393	354
	Potamogeton pectinatus		320	
	Ceratophyllum demersum		363	
Middle area	*Eichormia crassipes*	877	439	307
	Potamogeton pectinatus		305	
	Ceratophyllum demersum		295	
Western area	*Eichormia crassipes*	1090	384	245
	Potamogeton pectinatus		361	
	Ceratophyllum demersum		341	

Table (14) : Concentrations of Zn (mg/kg) in the different organs of various fish species living in lake Burollus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	36.89	41.06	92.07
	Oreochromis aureus	18.06	21.15	61.28
	Tilapia zilli	21.26	38.17	51.41
	Sarothoredon galilaeus	20.16	53.18	72.25
Middle area	*Oreochromis niloticus*	16.41	36.22	83.10
	Oreochromis aureus	17.92	28.14	72.80
	Tilapia zilli	15.33	29.40	60.14
	Sarothoredon galilaeus	17.04	33.07	41.09
Western area	*Oreochromis niloticus*	16.92	34.70	79.04
	Oreochromis aureus	19.88	37.72	80.70
	Tilapia zilli	17.49	40.08	63.74
	Sarothoredon galilaeus	13.84	31.87	60.07

Table (15) : Concentrations of Cu (mg/kg) in the different organs of various fish species living in lake Burollus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	9.81	62.14	21.72
	Oreochromis aureus	5.62	41.15	11.15
	Tilapia zilli	5.35	53.29	10.83
	Sarothoredon galilaeus	3.97	32.24	18.67
Middle area	*Oreochromis niloticus*	4.02	38.63	14.07
	Oreochromis aureus	2.88	35.09	16.08
	Tilapia zilli	5.19	39.14	19.27
	Sarothoredon galilaeus	3.75	36.75	17.40
Western area	*Oreochromis niloticus*	6.81	43.65	18.71
	Oreochromis aureus	3.83	35.18	19.95
	Tilapia zilli	4.58	38.63	21.03
	Sarothoredon galilaeus	3.36	47.18	23.70

Table (16) : Concentrations of Ni (mg/kg) in the different organs of various fish species living in lake Burollus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	8.84	17.68	30.14
	Oreochromis aureus	7.57	19.46	33.30
	Tilapia zilli	9.82	25.93	35.12
	Sarothoredon galilaeus	5.30	18.73	26.15
Middle area	*Oreochromis niloticus*	5.46	28.21	35.68
	Oreochromis aureus	4.67	30.93	37.12
	Tilapia zilli	6.14	25.14	30.80
	Sarothoredon galilaeus	5.89	22.40	30.17
Western area	*Oreochromis niloticus*	6.74	26.90	38.12
	Oreochromis aureus	5.14	28.20	30.93
	Tilapia zilli	4.65	19.72	23.60
	Sarothoredon galilaeus	5.92	26.17	31.41

Table (17) : Concentrations of Pb (mg/kg) in the different organs of various fish species living in lake Burollus during 2002.

Area	Species	Fish organs		
		Flesh	Liver	Gonads
Eastern area	*Oreochromis niloticus*	9.09	14.45	36.23
	Oreochromis aureus	8.13	14.56	35.44
	Tilapia zilli	5.85	11.14	38.69
	Sarothoredon galilaeus	7.45	16.45	30.14
Middle area	*Oreochromis niloticus*	6.35	12.25	24.23
	Oreochromis aureus	7.42	15.14	31.36
	Tilapia zilli	4.78	16.36	40.17
	Sarothoredon galilaeus	6.16	16.08	31.81
Western area	*Oreochromis niloticus*	10.06	16.23	38.51
	Oreochromis aureus	9.19	16.17	39.26
	Tilapia zilli	10.48	15.06	33.63
	Sarothoredon galilaeus	6.77	14.85	36.42

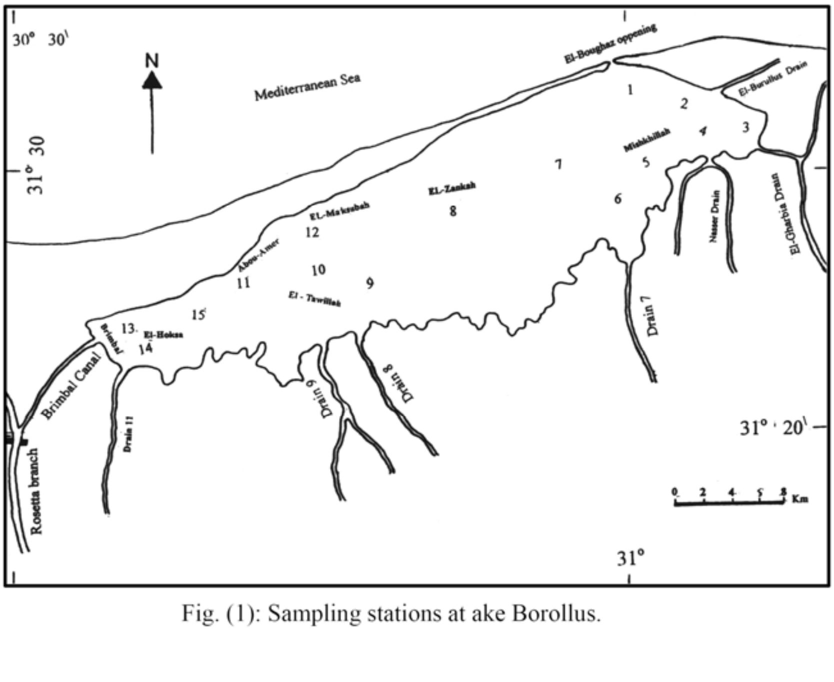

Fig. (1): Sampling stations at ake Borollus.

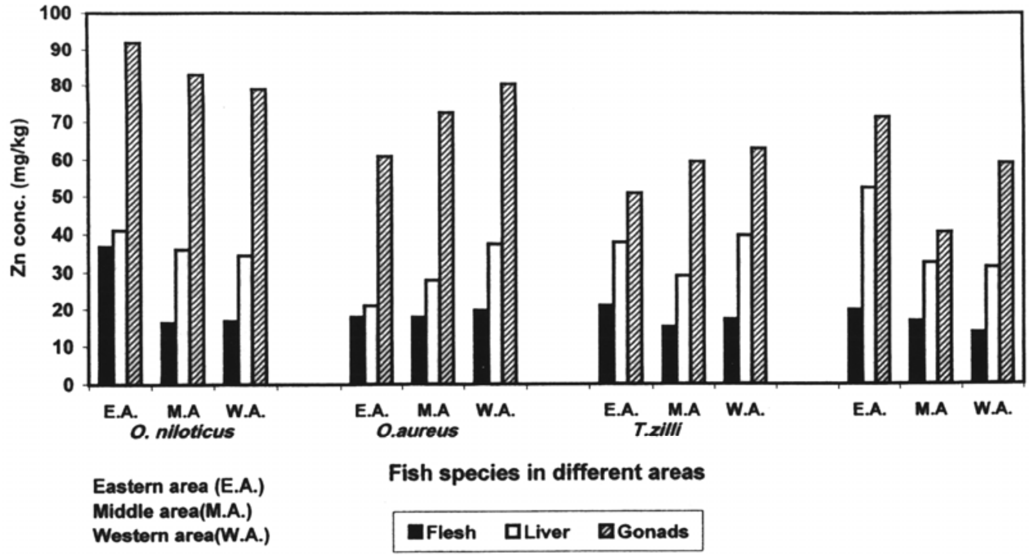

Fig. (2) : Concentrations of Zn (mg/kg) different organs of various fish species living in Lake Burollus during 2002

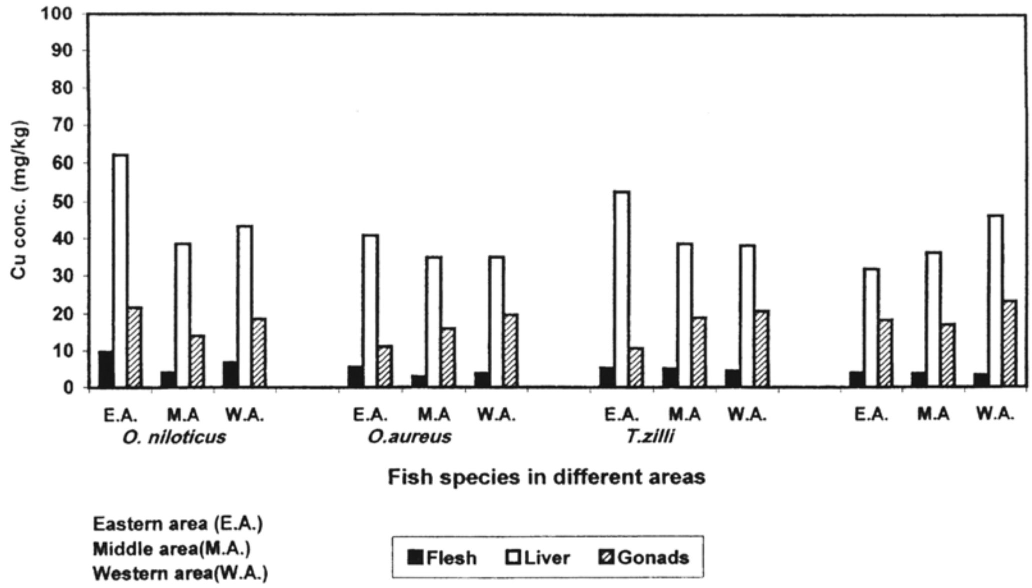

Fig. (3) : Concentrations of Cu (mg/kg) different organs of various fish species living in Lake Burollus during 2002

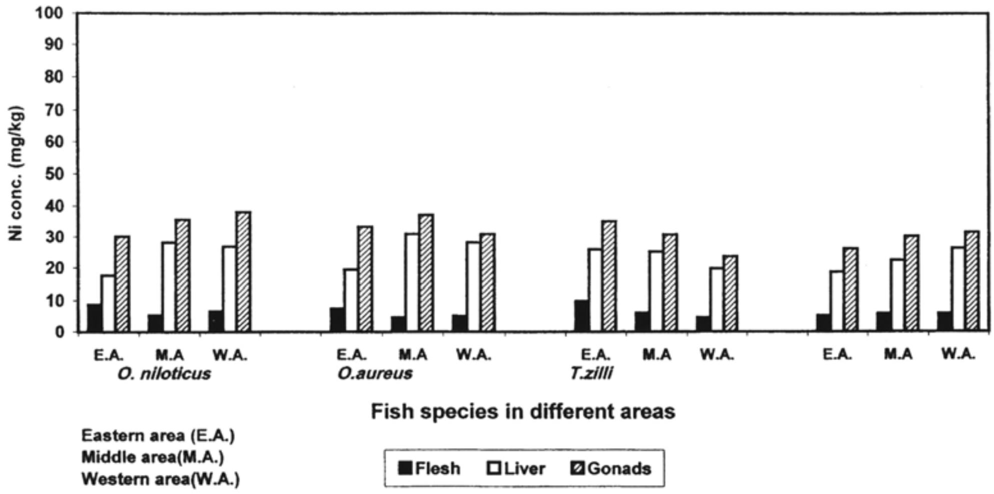

Fig. (4) : Concentrations of Ni (mg/kg) different organs of various fish species living in Lake Burollus during 2002

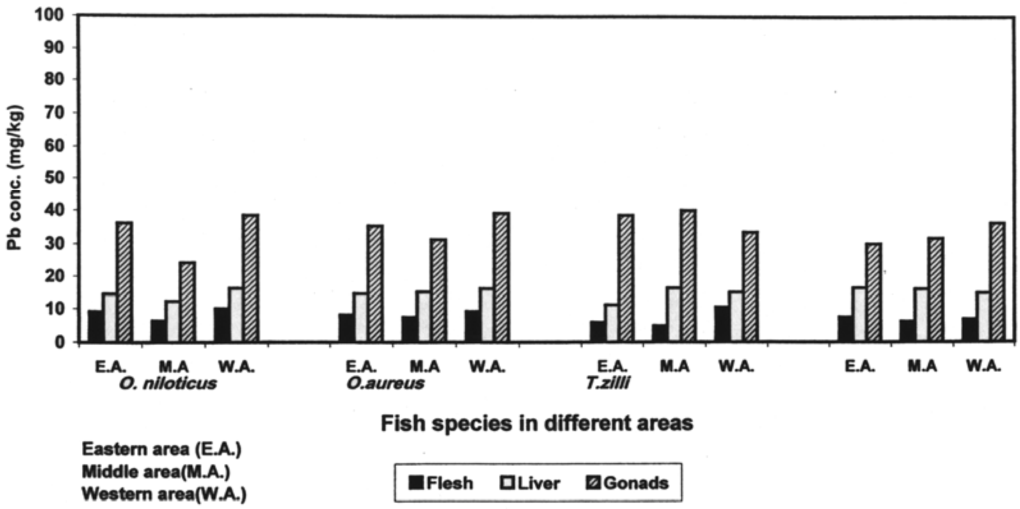

Fig. (5) : Concentrations of Pb (mg/kg) different organs of various fish species living in Lake Burollus during 2002