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TOXIC METALS IN FISH FROM EGYPT COASTAL WATERS
UPTAKE & DEPURATION OF METALS FROM FISH
METAL BIOASSAY INVESTIGATIONS

By

Khalid M El-Moselhy and Mohamad El-Samra
National Institute of Oceanography & Fisheries
Red Sea Branch, Suez, Egypt

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Chapter I

Introduction

In natural aquatic ecosystems, metals occur in low concentrations, normally at the nanogram to microgram per litre level In recent times, however, the occurrence of metal contaminants, especially the heavy metals in excess of natural loads, has become a problem of increasing concern This situation has arisen as a result of the rapid growth of population, increasing urbanization, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agriculture practice as well as the lack of environment regulation

Trace metals enter the aquatic environment from both natural (geochemical background) and anthropogenic sources Entry may be as a result of direct discharges into both freshwater and marine ecosystems or through indirect routes such as dry and wet deposition and land runoff In view of the toxic nature of the trace heavy metals, the knowledge of their sources and fate in the environment is important The anthropogenic sources of metals include, mining, industrial and petroleum industry activities, domestic effluents and urban storm-water runoff, leaching of metals from garbage and solid wastes dump, metal inputs from rural areas, e g metals contained pesticides and atmospheric sources, e g burning of fossil fuels, incineration of wastes and industrial emission Different examples of potential industrial and agricultural sources for metals in the environment have been reported by FAO (1992)

This report also shows that for most trace metals, anthropogenic emissions are either more than or quite equal to natural emissions The combustion of leaded petrol in automobiles, for instance, is responsible

for the widespread distribution of lead in the world For mercury, however, several reports (Hutchison and Meema, 1987 and GESAMP, 1988) suggest that natural emissions are quantitatively more important than anthropogenic sources

Heavy metals are usually taken up by both fauna and flora This uptake could provoke an increase in the concentration of the metal in the organisms, if the excretion phase is slow, this can lead to the bioaccumulation phenomenon Some of these metals may undergo biomagnification through the food chain Several mechanisms have been reported by Romeril (1971) for uptake and loss of trace elements by marine organisms These mechanisms are

a) Direct absorption of ions at membrane-water interfaces,

b) adsorption by active and/or passive diffusion of metal ions from sea water across semi-permeable membrane into the body fluids, and

c) ingestion of ions with food or in combination with particulate matter and absorption through the gut wall

The loss of heavy metals from biological material may be attained through two mechanisms proposed by Bryan (1971)

1) Excretion across the body surface or gills, and

2) excretion via the gut and urine

Living organisms have dynamic relationship with their environment, therefore, it is frequently observed that a trace element is both accumulated and excreted until steady state has been attained It has been shown by Pringle *et al* (1968), Majori and Petranio (1973 a) using bivalves appear to indicate that rates of uptake for trace elements are proportional to their concentration in the medium Schulz-Baldes (1974) proposed that rates of loss are correlated to internal concentration of the element Direct relationships with the environment may be obscured by slow response time for short-term variation of trace elements in water and tissues

Some heavy metals such as Cu, Zn, Fe and Mn are essential for the growth and well-being of living organisms including man However, they are likely to show toxic effects when organisms are exposed to levels higher than normally required, Bowen (1966) stated that low concentrations of essential trace elements may suppress physiological action, leading to abnormal growth of an organisms Other trace elements such as Cd, Pb and Hg are not essential for metabolic activities and exhibit toxic properties Major elements such as Ca, Mg, Na and K are normally transported as mobile cations in aqueous solutions

Metal contamination of the aquatic environment may lead to deleterious effects from localized inputs which may be acutely or chronically toxic to aquatic life within the affected area Most published data on the effects of metals on aquatic organisms, however, report adverse effects at concentrations higher than usually found in the environment (GESAMP, 1985 and 1988)

Metals may be taken up by organisms either in inorganic or/and organic soluble form For example, arsenic and copper, the inorganic form is most toxic (Ballin, 1988) Others, such as Hg, Sn and Pb, the organic forms are most toxic In ambient water, low concentrations of Hg, Cd, As and Cu directly may inhibit photosynthesis and phytoplankton growth Effects at high trophic levels include delayed embryonic development, malformation and reduced growth of adults of fish, molluscs and crustaceans

The major routs of heavy metal uptake by man are ingestion of food, and water and breathing air Fish, are one of the important sources of metals for human beings, especially those who live by the sea and fishermen and their diets depends mainly on seafood

Acute toxicity of cadmium may result from ingestion of relatively high concentrations of cadmium, as may occur in contaminated beverages or food Nordberg (1972) relates an instance in which nausea, vomiting and abdominal pain occurred from consumption of drinks containing approximately 16 ppm of cadmium Recovery was rapid without apparent long-term effects The principal long-term effects of low-level exposure to cadmium are chronic pulmonary disease and emphysema and chronic renal tubular disease There may also be causes of carcinoma, hypertension and effects on the cardiovascular and skeletal system (Nomiyama, 1980 , Friberg and Kjellstrom, 1981)

Lead poisoning resulting from the consumption of contaminated foodstuffs and water have rarely been reported Lead affects mainly

nervous system, blood, gastrointestinal tract and kidneys Effect on the endocrine, reproductive and pulmonary systems also have been noted

The presence of high concentrations of nickel in specific tissues may be responsible for some adverse biological effects For example, the localization of nickel in the pituitary gland may have caused the reported depression of prolactin secretion (La Bella *et al* , 1973 a, b) Nickel localization in the pancreas may also result in inhibition of insulin secretion (Clary and Vignati, 1973)

Copper, zinc and iron are essential elements which play an important role in different physiological processes, and their deficiency results in sever health consequences Trace of copper is required for utilization of iron in haemoglobin formation, therefore, copper deficiency is characterized by hypochromic, microcytic anaemia resulting from defective haemoglobin synthesis Oxidative enzymes, such as catalase peroxidase, cytochrome oxidase, and others, also require copper Zinc is the structural and function component of some enzymes in the vertebrates It is necessary to maintain the normal concentration of vitamin A in plasma Deficiency of this metal may cause the so-called cirrhoses Iron is a component of haemoglobin, myoglobine and cytochrome, i e it is an essential component of blood pigments in vertebrates Deficiency of iron causes anaemia in most vertebrate animals

Excess amounts of the essential elements in the tissues causes the appearance of various diseases Copper causes hepatolenticular degeneration (Wilson's disease) which is due to excessive accumulation

of copper in brain, kidney and liver Accumulation of Cu in the kidney may cause a renal tubular damage which leads to increase the urinary excretion of amino acids, peptides and occasionally glucose Excess of Zinc is said to cause disruption of hepatic cells which is also the chief storage organ for this element Excess Iron cause a pronounced pigmentation of the skin (Hemochromotosis) Liver damage with signs of cirrhosis, diabetes and a pancreatic fibrosis, frequently occur in human being as the result of excessive doses of iron

Chapter II

Literature Cited

Literature Cited

Because of their hazardous and deleterious effects on the environments, heavy metals have been taken in consideration since several decades In marine environment, particularly for marine organisms, metals were studied by different scientist and for several aims, such as, investigating the levels of metal in the organisms from polluted and non-polluted sites, studying the effects of metals on the organisms by computing the median lethal concentrations (LC_{50}) for individual metal and following up the rate of accumulation in the different organs (bioaccumulation), finding relationships of metals to the chemical composition of the organisms and effect of age and sex on the rate of accumulation

In the present review, the metal studies which serve the objective of the present work are cited and titled according to

1) levels of metal,

2) toxicity studies, and

3) rate of uptake and elimination (exposure and depuration)

I- Metal levels in fish:

The levels of metals in fish from the Egyptian waters were determined by many authors during the last two decades El-Sokkary (1980) studied the accumulation of mercury in fish collected from Mediterranean coast waters in front of Alexandria

Abdel-Salam (1981) measured the contents of Cu, Zn, Pb, Fe and Mn in edible tissues and their accumulation in the internal organs (liver, gonads, gills and heart) of 13 Red Sea fish

Emara (1982) determined the level of copper, cadmium and mercury in different fish species collected from Abu Qir Bay and Lake Idku Hafez (1982) measured the accumulation of heavy metals (Fe, Mn, Zn, Cu and Cd) in liver, muscle and gut of *Tilapia nilotica* collected from both Lake Mariut and Nozha Hydrodrome

Saad (1985 and 1987) determined the concentration of Cd, Cu, Zn and Fe in finfish from Lake Mariut and Nozha Hydrodrome

El-Nady (1981) and El-Rayis and Ezzat (1986) studied the bioaccumulation of copper, zinc, iron, manganese and cadmium in selected marine animals of different trophic levels (*Sparus auratus, Raja miraletus, Portunus pelagicus* and *Patella vulgata*) as part of a survey on heavy metals pollution in Alexandria waters and effects on marine animals Findings indicated that although the waters have been influenced by increased amounts of industrial, urban and domestic wastes, significant effects are not apparent in samples of the tested animals

El-Nabawi *et al* (1987) determined the concentration of metals (As, Cd, Cu, Pb, Hg and Zn) in fish from Mediterranean at the Alexandria region Fouda (1987) investigated the requirements of farmed fish species for various elements such as Ca, P, Mg, K, Na, Zn, Cu and Fe and composition of *Oreochromis niloticus* tissues

Abdelmoneim and El-Deek (1992) determined the range and natural variations of some important heavy metals (Cu, Zn, Mn, Pb, Cr Cd and Fe) in three organs of two economic fish *Lethrinus mahsenoides* and *Lethrinus nebulosus* from the Red Sea

Shriadah and Emara (1992) studied the effect of water pollution on the concentrations of iron, manganese, nickel, lead and cadmium in some fish and crustacea collected from the Eastern-Harbour and El-Mex Bay of Alexandria Also, they estimated the concentration factors for the tested metals in the studied fish

El-Moselhy (1993) investigated the seasonal variation of Cd, Pb, Cu and Zn in seven organs (liver, gills, muscles, bone, brain, skin and gonads) of four fish species representing all fishing techniques in Suez Gulf and Suez Bay Emara *et al* (1993) compared the level of metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb) in muscle and bone of fish from Mediterranean and Red Seas, and they stated that the accumulation of metals is more pronounced in Red Sea species than in Mediterranean ones

Abdelmoneim *et al* (1994 a) studied the content of trace metals (Cd, Pb, Cu and Zn) in *Sardinella gibbosa, Saurida sp* and *Epinephelus sp* from the Gulf of Suez, and stated that carnivorous fish

recorded highest values of Cd and Pb while Zn was recorded in pelagic herbivorous fish Ahmed *et al* (1994) measured the content of trace metals (Cr, Mn, Fe, Co, Cu and Pb) in muscle and bone of some fish species from Suez Bay and Ghardaqa, they showed that the highest levels in muscle were found in *Upeneus moluccensis* and the lowest in *Plectropomus maculatus* collected from Ghardaqa and Suez, respectively

Abdelmoneim *et al* (1994 b) studied the levels of some heavy metals (Zn, Cu, Pb and Cd) in four fish species collected from El-Mex Bay, the results showed that the essential heavy metals Zn and Cu are accumulated in soft tissues as liver while the nonessential Pb and Cd are more accumulated in hard tissues (bone and gills) Abdelmoneim *et al* (1994 c) studied the distribution of heavy metals (Cu, Zn, Mn, Pb, Cr, Cd and Fe) in the organs of some edible fish species from the Gulf of Suez (Red Sea)

El-Deek *et al* (1994 a) estimated the concentration of Cu, Zn and Pb in three *Epinephelus sp* collected from the Red Sea

El-Moselhy and El Samra (1994) determined the level of metals (Cd, Pb, Cu, Zn, Ni and Fe) in *Saurida sp*, *Nemipterus metopias* and *Nemipterus japonicus* collected from Red Sea and Suez Gulf, and *Saurida sp* from Mediterranean in front of Port Said City for comparison They recorded that the fish collected from the Mediterranean gave higher values of metals than those collected from the Red Sea

Many experts investigated heavy metals in the marine organisms from waters other than Egyptian ones Merancer and Somers (1968) determined the effectiveness of dry-ashing for the atomic absorption analysis of 8 metals (Cd, Co, Cr, Cu, Ni, Pb, Zn and Mn) in a number of typical seafood samples

Lucas and Edgington (1970) determined the concentration of 15 trace elements by nutron activation analysis of samples of whole fish and fish liver from three of the Great Lakes They observed that the concentrations of trace elements varied with species and lakes

Kleinert *et al* (1974) found the concentrations of metals in fillets of fish sampled from Wisconsin waters were less than 0 05 ppm for Cd, not detectable (ND) to 0 42 ppm for Cr, 2 7 to 18 3 for Zn, ND to 4 31 for Pb and ND to 0 35 for As They recommended that these metals, which found in the tested fish, are presented in sufficient amount which did not create any hazards to consumers

Bryan (1980) investigated the contamination of heavy metals in sea, input of metals to sea and their deposition in sediments, and influence of environmental and biological factors on the accumulation of metals by biota

Shiber and Salanki (1981) determined Pb, Cd, Ni, Fe, Zn, Cu and Cr concentrations in 6 species of intertidal organisms common to the coast of Ras Beirut, Lebanon

Salanki *et al* (1982) measured the concentration of Hg, Cd, Cu, Pb, Zn, Fe and Mn in chironomidae larvae, crustacea, plankton, as well as in various organs of mussels and fishes collected from the open water area of Lake Balaton (Hungary) They showed that the values were comparatively low and there were significant differences in the metal concentrations of species and tissues

Honda *et al* (1983) determined the concentrations of Fe, Mn, Zn, Cu, Pb, Ni, Cd and Hg in the muscle, liver and kidney of fifty nine striped dolphins by atomic absorption spectrophotometry They found that the levels of the most metals examined were higher in the liver than the other tissues, also, correlation of the metal concentrations to the body length, weight and age was positive for Fe, Pb, Ni, Cd and Hg and negative for Mn, Zn and Cu

Miklovics *et al* (1985) studied the accumulation and effect of heavy metals in the fishes of Lake Balaton (Hungary) They stated that there was considerable variations in metal levels between different organs of the fish, and the heavy metals did not reach toxic levels in the fish sampled

Maher (1986) measured the concentrations of heavy metals (Cd, Cu, Pb and Zn) in the tissues of fish, molluscs, crustaceans and macrophytes from St Vincent Gulf, South Australia

Blevins and Pancorbo (1986) determined the heavy metals residues (i e , As, Cd, Cu, Pb, Mn, Hg and Zn) in striated muscle of 268 fish specimens harvested during a 5 years period (1980 - 1984) from several aquatic systems in east Tennessee (U S A)

Denton and Burdon-Jones (1986 a) examined trace metals in fish from the Great Barrier Reef They monitored seventeen species of fish for Cd, Cu, Pb, Hg, Ni and Zn to establish a database for the area

Vos *et al* (1986) examined the metal content of Pb, Cd, Hg, Cr, Ni, Zn, Cu, As and Se in fishery products caught in Dutch waters including sole, plaice, cod, herring, eel, pike-perch, mussel and shrimps

Wahbeh and Mahasneh (1987) measured the concentrations of ten metals in livers, gills, gonads and muscles of six species of fish from Aqaba, Jordan, using atomic absorption spectrophotometry They found a significant metal concentration differences between species, tissues and metals

Sex years trend monitoring data of Hg, Cd, Cu, Pb and Zn in flounder (*Platichthys flesus*) from the Sound and Great Belt (Danish coastal waters) were statistically assessed using a series of multilinear, regressive models in terms of the measurements of metal levels and various biological parameters (e g length) for individual fish (Jensen and Cheng, 1987)

Kakulu *et al* (1987) determined the trace metal contents (Cd, Cu, Fe and Zn) in various fish and shellfishes from Niger delta area of Nigeria, and they stated that the levels in the shellfishes were higher than in the fish, which could be due to their being bottom feeders

Romeo (1987) analysed trace metals (Cd, Pb, Hg, Cu, Fe, Mn and Zn) in fish roe "an important fish for the economy" from the northern coast of Mauritania

Hornung and Ramelow (1987) measured the concentrations and distribution of metals (Cd, Cr, Cu and Zn) in muscle tissue of four common fish species, *Mullus barbatus, Upeneus moluccensis, Saurida undosquamis* and *Pagellus erythrinus*, eastern Mediterranean region Also, they plotted the relationships between elements and zinc

Ismail *et al* (1988) investigated the metals (Pb, Cu, Cd and Ni) in muscle, gills and liver of fish, crustaceans and molluscs collected from South China Sea Sarawak waters

Marcovecchio *et al* (1988) determined the total Hg, Cd and Zn in the muscles of 19 species of marine organisms (including prawns, shrimps and various fish) from the Bahia Blanca Estuary, Argentina, during the period of 1985 - 1986)

Peterson *et al* (1989) analyses three species of fish (brook trout, *Salvelinus fontinalis,* white sucker, *Catostomus commersonii*, and yellow perch, *Perca flavescens*) collected from lakes in New Brunswick and Nova Scotia (Canada) for whole body concentration of trace metals (Pb, Cd, Hg, Cu and Zn) Also, he investigated the influence of pH and other chemical parameters on the accumulation of the metals

Tsoukali-Papadopoulou *et al* (1989) determined the concentration of copper, iron, chromium and nickel in fish and shellfish

harvested from Geras Gulf, Lesvos Island, Greece, during different seasons of the year

Devi (1989) studied the levels of heavy metals (Cu, Zn, Cd, Pb and Hg) to monitor metal levels in Malaysian fish and shellfish collected from various landing station (number of fish samples were three to five for each species)

Karbe *et al* (1989) studied the regional distribution of heavy metals (Hg, Cd, Cu, Zn, Ag, Pb, Fe and Mn) in the abdominal parts of hermit crab, *Pagurus bernhardus*, from the North and Irish Seas

Dai-Quanyu *et al* (1990) determined the contents of 26 metal elements for commercial fishes from lakes in Suzhou region (China) The magnitudes of metal contents were in the order benthic fishes > mid-water fishes > upper-layer fishes, and with respect to food chain, the order was Carnivorous fishes > omnivorous fishes > herbivorous fishes

Hernandez *et al* (1990) determined the levels of Hg, Cd, Cr and Pb in several marine organisms collected from the Mediterranean Sea on the Castellon coast, Spain, during 1986 and 1987 They analysed different tissues in order to know the degree of accumulation of heavy metals

Barak and Mason (1990) measured the concentration of Hg, Cd and Pb in liver and flesh of 885 eels (*Anguilla anguilla*) and 338 roach (*Rutilus rutilus*) collected from four sites on the Rivers Brett and Chelmer, eastern England, over the period November 1985 to

November 1987 They also studied the effects of length, sites and season on the metal concentrations

Bezuidenhout *et al* (1990) investigated the bioconcentration of the heavy metals zinc and copper in the intestine, spleen, liver, kidney, body fat, gonads, heart, muscle, brain, vertebrae and gills of the sharptooth catfish, *Clarias gariepinus*, in a lake contaminated by effluents and seepage water from mines and metal processing industries

Wagemann *et al* (1990) analyzed samples of liver, kidney and muscle tissue from beluga (*Delphinapterus leucas*) from 5 locations across the Canadian Arctic and the St Lawrence Estuary for copper, zinc, cadmium, mercury, lead and selenium They found that, mercury was positively associated with selenium and age in all animals, cadmium in kidney was positively associated with selenium and age, and copper concentrations declined with age

Tariq *et al* (1991) reported the concentrations of eleven heavy metals (Ag, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Hg) and four major cations (Na, K, Ca and Mg) in the muscle of *Loligo duvauceli*, *Sardinella longiceps* and *Lapturacanthus savala* harvested from ten near-shore and offshore coastal sites of the Arabian Sea, Pakistan Significant correlation between the concentrations of trace metals and major cations were estimated to identify the pollution status of the area in terms of fish-specificity and site-specificity

Law and Singh (1991) studied the relationships between body weight of fish and heavy metal (Cu, Zn, Pb and Hg) content of the

edible tissue for three Malaysian fish species (*Arius thalassinus, Plotosus anguillaris* and *Dasyatis zugeri*) caught in the Kelang estuary

Ashraf *et al* (1992) determined the concentrations of ten metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Hg) in the edible muscle of *Arius maculatus* captured from eight different near-shore and offshore sites of the south west coast of the Arabian Sea, Pakistan

Al-Mohanna (1994) analyzed five commercially important fishes of Saudi Arabia from Jizan, Red Sea coast for certain metals (Cu, Hg, Cd, Cr, Pb and Zn) in different organs of fish tissue, viz , liver, kidney, gut, gills and muscle

Kucuksezgin and Balci (1994) investigated the concentrations of heavy metals (Hg, Cd, Pb, Cr, Cu and Zn) in different marine organisms (macroalgae, mollusca, crustacea and fish) collected from Izmir Bay, Turkey

II- Toxicity of metals

Toxic effects of the individual metals depend mainly on the chemical structure of the metal, conditions of water, and on the animal species Generally, median lethal concentration (LC_{50}) is measured for more species to drive the safe environmental condition for different pollutants In the present review, the available studies which carried out to detect LC_{50} for metals are cited

Ahsanullah *et al* (1981) determined the acute toxicity of zinc, cadmium and copper to the marine shrimp, *Callianassa australiensis* in tests lasting up to 14 days, to compare the 4, 7, 10 and 14 days LC_{50} values for each metal

Ward (1984) assessed the concentration of acute toxicity of the metals to the species distribution pattern in the area located at Port Pirie, Spencer Gulf, South Australia

El-Nady (1981) and Ezzat *et al* (1985) studied the effect of Cu, Zn and Cd on the fish, *Mugil capito* and the crab, *Portunus pelagicus* to determine LC_{50} and bioaccumulation of the metals

Denton and Burdon-Jones (1986 b) examined the acute toxicity of Hg, Cu, Cd, Zn, Ni and Pb to adult and juvenile glass perch (*Priopidichthys marianus*) and juvenile diamond-scaled mullet (*Liza vaigiensis*), and the effects of water quality on the toxicity of metals

Prabhudeva and Menon (1986) studied the effect of metal mixture (zinc and copper) on the mortality rate of *Perna viridis*

(Mollusca Pelecypoda), and they stated that, the mixture of zinc and copper recorded enhanced toxicity of one metal in the presence of another metal

de Nicola Giudici *et al* (1987) investigated the acute and long-term toxicity of cadmium in different stages of the life cycle of an *Idothea baltica* (crustacea) population from the Bay of Naples

Krishnaja *et al* (1987) evaluated the toxic effects of certain heavy metals (Hg. Cd. Se, As and Pb) on *Scylla serrata*, the common edible Indian marine crab, and determined the 24 to 96 h LC_{50} values for each metals

Hilmy *et al* (1987) determined the acute toxicity of Cu, Zn, and mixture of the two metals to juvenile *Clarias lazera* over a 96 h exposure period, also they assessed the toxic effects of the mixture on the physiological parameters

Mukhopadhyay *et al* (1987) studied the toxicity behaviour of heavy metals on estuarine organisms, and the sensitivity of crustaceans and fishes to the zinc, copper and chromium Also, they studied the effect of desalinization of media to the metal toxicity

Cui-Keduo *et al* (1987) studied the effects of six heavy metals (Hg, Cu, Cd, Zn, Pb and Cr) on hatching the eggs and survival of larvae of flatfish, *Paralichthys olivaceus* and *Cynoglossus semilaevis*, taken from Jiaozhou Bay, Qingdao, China

Rani and Ramamurthi (1987) determined the median lethal concentration (LC_{50}) of Cu to crab *Oziotelphusa senex senex*, snail *Pila globosa* and fish *Tilapia mossambica* They stated that the relative of toxicity varied among the organisms

Thorpe *et al* (1989) studied the effect of cadmium to survival, growth and moulting frequency of mud crab *Rhithropanopeus harrisii* and grass shrimp *Palaemonetes pugio* when the newly hatched larvae of the two species were exposed for 96 h to a range of cadmium free-ion concentrations using metal-buffered seawater

Gaikwad (1989) studied the acute toxicity of three different heavy metals salt, mercury chloride, copper sulphate and selenium oxide, to the fish *Etroplus maculatus* collected from Mansunda Lake situated in Thane city, India

Hamilton and Buhl (1990) determined the acute toxicity of arsenate, arsenite, cadmium, chromium, copper, mercury, silver, vanadium and zinc (individually and in two environmentally relevant mixtures) to two life stages of Chinook salmon in reconstituted fresh and brackish waters that simulated potential conditions in the San Joaquin Valley, California

Wu-Yulin *et al* (1990) studied the effects of heavy metals (Cu, Zn, Cd, Pb and Cr) on early life stages of the flat fish, *Paralichthys olivaceus*

Hamed (1992) determined the acute toxicity (72 h LC_{50}) of Cd and Pb to juvenile *Mugil seheli*

III- Accumulation and depuration of metals:

Miettinen (1973) studied the mechanisms and rates of absorption and excretion of heavy metals in organisms, with particular reference to biological half-time and accumulation

Ward (1982) examined the distribution and accumulation rate of cadmium in the Sydney rock oyster, *Saccostrea commercialis* after a long-term sublethal challenge with the metal (10, 25, 50 and 150 µg/l)

The uptake of cadmium by sticklebacks and its distribution between the body tissues was compared following two methods of exposure, i e , natural exposure to the heavy metals in water and direct intraperitoneal injection (Woodworth and Pascoe, 1983)

Borchardt (1983) investigated the kinetics of cadmium uptake and loss via food and seawater in *Mytilus edulis* and its dependence on food quantities

Ahsanullah *et al* (1984) examined the accumulation of cadmium by the shrimp *Callianassa australiensis* in laboratory microcosms containing contaminated water and sediments, also they determined the effects of sublethal cadmium concentrations on their growth, and the relative importance of the exposure route for cadmium accumulation, that was, water versus sediments and detritus

Thomas *et al* (1985) studied the accumulation rate of cadmium in the tissues of rainbow trout (*Salmo gairdneri*) after pre-exposed to

either cadmium (9 µg/l) or zinc (100 µg/l) In both cases, more than 99% of the total body of cadmium was found in the liver, kidney and gills of the animals

Brown *et al* (1986) determined the distribution of the cadmium accumulation in the major body organs of three species of freshwater fish, *Salmo gairdneri*, *Rutilus rutilus* and *Noemacheilus barbatulus*, when exposed to cadmium dissolved in their aquarium water

Robinson and Ryan (1986) determined the accumulation rate and depuration of cadmium and metal interactions within the kidney, gill and digestive gland of the hard clam, *Mercenaria mercenaria*, after exposed to cadmium

A large scale study was currently undetway to evaluate the combined effects of the "best" environmental conditions on the elimination of cadmium, zinc, copper, arsenic, selenium and tin by adult and juvenile eastern oysters, Pacific oysters, softshell clams and hardshell clams (Siewicki *et al* , 1986)

Ikuta (1987) determined the metal concentrations in visceral and muscular parts of abalone (*Haliotis discus*) by exposure to different concentration levels of cadmium, copper, lead and manganese for 120 days

Amiard *et al* (1987) studied the patterns of accumulation of essential (Cu, Zn) and nonessential (Cd, Pb) trace metals in worms, crustaceans, and fish exposed to short-term experimental contamination and low chronic contamination in a polluted environment

Skul'-skii *et al* (1987) studied the cadmium accumulation in tissues of mussels kept within 20 - 60 days in water artificially enriched by cadmium up to 20 - 100 µg/l

Adult rainbow trout, *Salmo gairdneri*, were exposed to 3 6 and 6 4 µg Cd/l for 178 d to determine the accumulation pattern of cadmium in the different organs, gill, liver, kidney, gut, skin and muscle, of the fish (Giles, 1988) He stated that, the levels of Cd were differed from organ to other according to the ability of uptake, while no increase was recorded in white muscle

Gould *et al* (1988) studied the uptake of copper and cadmium and its effects in the gonad of the sea scallop *Placopecten magellanicus* in early gametogenesis from the southern shelf of Hudson Canyon, New Jersey, USA They reported that, copper had a strongly inhibitory effect on gamete production and maturation

Liao-IChiu and Hsieh (1988) studied the acute toxicity, growth effects, accumulation and elimination of copper, cadmium and zinc on *Penaeus japonicus*, One of the more important commercial shrimp species in Taiwan

Lakshmanan and Nambisan (1989) reported the bioaccumulation and depuration rates of trace metals (Hg, Cu, Zn and Pb) by the mussel *Perna viridis* from seawater and explored its suitability as an indicator organisms for metal pollution

Accumulation and distribution of cadmium were studied in the organs of the marine prosobranch *Littorina littorea* exposed to two

ambient concentrations and for 74 days (Marigomez and Ireland, 1989)

Norey *et al* (1990 a) compared the accumulation rates and tissue distribution of cadmium in different species of freshwater fish (rainbow trout, *Salmo gairdneri* and stone loach, *Noemacheilus barbatulus*) after exposed to cadmium in their aquarium water, and the ability of fish to secrete the metal from its tissues

Norey *et al* (1990 b) determined the distribution of cadmium accumulated in the major body organs of pike, *Esox lucius*, after exposed to cadmium dissolved in their aquarium water at separate concentrations of 60, 125 and 225 µg/l

Das and Kaviraj (1990) studied the accumulation patterns of cadmium in the organs of air-bearthing fish, *Heteropneustes fossilis* after exposed to three different concentrations of cadmium (2 5, 6 4 and 55 5 mg/l) They found that the accumulation pattern of cadmium in liver, gills and kidney changed with ambient concentration of cadmium in water

Liao-IChiu *et al* (1990) studied the effects of Cu, Cd and Zn on the survival and growth of juveniles of prawn, *Macrobrachium rosenbergii* and determined the acute toxicity of these metals to various larval stages of the prawn They also showed the patterns of accumulation and elimination of the metals in young prawn

In chronic 7 days experiments, fasted catfish, *Ictalurus punctatus*, were found to accumulate the toxic metal (cadmium) in their

liver and kidney from external media with Cd concentrations as low as 10^{-9} M (about 0 1 μg/l), and the concentrations of Cd were found in the kidney greater than the liver (Bentley, 1991)

Regoli *et al* (1991) investigated the ability of the seawedge shell *Donacilla cornea* (bivalve) to concentrate copper, cadmium and manganese when exposed to these metals in its aquarium, and the effect of these heavy metals on total calcium content in gills, digestive gland and whole soft parts

Ringwood (1991) evaluated the short-term accumulation of cadmium by embryos, veligers, pediveligers and adults of an Hawaiian bivalve, *Isognomon californicum*, over 24 h period He stated that, the differences in stage-specific accumulation rates suggest that there may be important differences in metal metabolism during development that are essential to developmental process

Holwerda (1991) determined the Cd and Cu-accumulation factors (AF) for the freshwater clams (*Anodonta cygnea*) after exposed to cadmium chloride, copper chloride, or to a mixture of the salts He found that, the Cd-AF for whole animals was reduced by 90% in the presence of Cu, while Cu-AF was reduced by 50% in the presence of Cd

Handy (1992) assessed the effects of cadmium and copper enriched diets on the levels of these metals in the tissues of rainbow trout (*Oncorhynchus mykiss*) during a period of 32 days and allowed to recover on normal food for 12 days to evaluate the elimination rates of the metals from the body tissues of the animals

Zorba *et al* (1992) investigated the heavy metals (Hg, Cu, V, Cd and Pb) accumulation rate for 36 days and depuration rate for 60 days in small and big clams, *Circenita callipyga* They stated that, the rates of metal accumulation and depuration differed in relation to clam size class

Dodoo *et al* (1992) tested the effects of cupric ion activity on calcium accumulation by exposure juvenile flounder (*Paralichthys sp*) to five different activities of ionic copper for 14 days

del Ramo *et al* (1993) studied the effect of pre-exposure to cadmium on the accumulation of this metal from seawater by brine shrimp *Artemia* They reported that, in the first and third days of exposure, higher levels of cadmium were found in pre-exposure animals than in the non-pre-exposure, but, after six days, there were no differences in cadmium content between these groups

Aim of the work

Red and Mediterranean Sea are frontier of the eastern and northern sides of Egypt, urbanization and industrial development especially during the last 40 years lead to exposure of the coastal belt of Egypt to pollution directly or indirectly from different sources including different industrial effluents, agricultural and sewage drains These sources of pollution results in a constitution of certain polluted regions differ according to the type and amount of pollution reject

This work is focused on metals especially those which are sorted out as toxic metals and cause different hazardous effects to organisms and man Ghardaqa, Suez, Ismailia, and Port Said and Alexandria are the areas, representing Red Sea, Gulf of Suez, Suez Canal, and Mediterranean, and are selected to study the variation of metals in tissues of the commercial fish and their response to pollution at these different sites To manage the problem of metal accumulation in fish, depuration patterns were studied in a long-term experimental work

The studies were carried out in two ways

I- Field research, and

II- Bioassay

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Chapter III

Materials and Methods

Material and Methods

I- Level of metals in fish:

1- Collection of fish samples.

19-Fish species listed in Table 1 were collected during the period from September 1993 to May 1994 from the local commercial fishermen and fish markets at the different areas of the study Most of the collection was carried out during winter season

The fish were handled according to FAO (1983) and UNEP (1984) Damaged fish specimens were discarded, washed each individual in clean water The samples were weighed and measured to record the range of fish weight and length (Table, 1) Then the fish samples were placed in polyethylene bags, labelled and stored in deep freezer until the time of analysis

2- Metal standards:

Metal standards (Cd, Pb, Cu, Zn, Co, Ni, Fe, Ca, Mg, Na and K) with high purity were prepared from stock solution of metals (1 g metal/1 litre) By using deionized distilled water, a series of different concentrations of metal standards were prepared then calibration curves were evolved

Table (1) Number of specimens, and range of total length and total weight of the different fish species from different sites along the Egyptian coast

Species	Location	Specimens number	Total length	Total weight
Saurida undosquamis	Red Sea	5	20 5 - 27 6	50 3 - 131 7
	Gulf of Suez	5	21 0 - 30 8	56 8 - 189 1
	Port Said	9	13 5 - 28 7	14 1 - 204 6
	Alexandria	5	13 5 - 28 0	124 6 - 161 7
Siganus rivulatus	Red Sea	5	16 9 - 22 5	65 4 - 171 4
	Suez Bay	5	11 8 - 13 2	26 6 - 36 0
	Port Said	5	12 5 - 14 7	25 8 - 44 8
	Alexandria	5	17 8 - 19 2	66 7 - 87 4
Rhabdosargus hafara	Gulf of Suez	5	13 9 - 16 0	34 3 - 54 0
	Suez Bay	8	9 6 - 11 8	15 0 - 27 5
Mugil seheli	Gulf of Suez	5	15 5 - 17 0	44 9 - 66 7
	Suez Bay	5	13 6 - 15 6	28 0 - 50 3
	Suez Canal	5	13 8 - 15 2	30 6 - 41 8
Mugil cephalus	Suez Canal	6	25 5 - 27 0	131 6 - 223 5
Mugil auratus	Port Said	5	13 7 - 15 8	21 5 - 26 8
Nemipterus japonicus	Red Sea	5	17 8 - 22 0	67 6 - 113 8
	Gulf of Suez	3	18 0 - 20 5	63 2 - 94 5
Pomadysis stridens	Gulf of Suez	5	13 1 - 14 9	31 0 - 42 2
	Suez Bay	5	10 9 - 11 3	19 9 - 22 3
Pagrus pagrus	Gulf of Suez	5	11 0 - 12 8	26 6 - 41 5
	Port Said	5	19 5 - 22 1	120 5 - 150 6
	Alexandria	5	21 6 - 23 5	141 4 - 170 2
Upenaeus sp	Gulf of Suez	5	11 4 - 15 6	17 4 - 43 8
	Port Said	5	11 2 - 13 6	15 8 - 28 2
Mullus barbatus	Alexandria	5	17 4 - 18 7	62 5 - 68 0
Sardinella gibbosa	Gulf of Suez	2	17 1 - 18 7	43 5 - 48 6
	Suez Bay	6	16 5 - 18 3	41 3 - 53 2

Table (1) Cont

Species	Location	Specimens number	Total length	Total wight
Etrumeus teres	Gulf of Suez	5	15 1 - 16 3	27 7 - 31 2
Scomber japonicus	Gulf of Suez	5	17 6 - 20 0	53 0 - 80 5
Trachurus indicus	Gulf of Suez	5	15 5 - 17 5	37 5 - 57 1
Tilapia sp	Suez Canal	5	19 0 - 22 7	128 3 - 246 9
Trachinotus ovatus	Alexandria	5	20 5 - 22 3	67 6 - 88 8
Caranx cryzs	Alexandria	5	19 8 - 21 1	90 5 - 105 8
Diplodus sargus	Alexandria	5	15 1 - 16 0	60 0 - 69 6

3- Cleaning of the equipment·

Clean equipment should be used to avoid any contamination for the samples The cleaning procedures are as the following

1- Soaking in tap water with detergent

2- Rinsing with in running tap water

3- Soaking the equipment for some minutes in concentrated HNO_3 H_2O = 1 6

4- Then, wash with quartz distilled water befor dryness in an oven at temperature of 105 °C

4- Preparation of fish samples for analysis:

The concentrations of metals studied were referred to the wet weight Fish samples were removed from deep freezer and allowed time for them to thaw before opening the plastic bags The samples were dissected for separating the organs, muscle, gills and liver Composite samples for small fish and organs were taken

The method explained in FAO Fisheries Technical Paper No 158 (1976) for determination of metals in the biological materials was adopted, which is summarized as follows

- A known weight of sample (single or composite) was placed in a Teflon crucible which was previously cleaned

- Added an amount of concentrated HNO_3 (AR degree), covered the crucible and allowed to stand for 30 minutes or longer (predigestion) to avoid the foam

- The crucible was then transferred to a hot plate with thermostatic control and heat it to about 100 °C for 60 minutes

- Let the crucible cool at room temperature

-If the solution was not clear, reheated for another 60 minutes at 100°C

After digestion of all samples by using the previous method, dilute the samples to a known volume in a volumetric flask More dilution of samples was needed for measuring the major elements (Ca, Mg, Na and K)

Metals Cd, Pb, Cu, Zn, Co, Ni, Fe, Ca, Mg, Na and K were determined in acidic solution using AAS (Atomic Absorption Spectrophotometer), Buck Scien , model 200A, presented in a dust free lab at the NIOF, Suez and Aqaba Gulfs branch, Suez The results were expressed in ppm (µg / g) wet weight for heavy metals (Cd, Pb, Cu, Zn, Co, Ni and Fe) and ppt (mg / g) wet weight for major elements (Ca, Mg, Na and K)

II- Toxicity tests (Cadmium and Copper):

1- Collection and acclimatization of fish, *Mugil seheli*, juveniles:

Live *Mugil seheli* juveniles were collected from the Dersa Pond in the Suez Canal during February and March 1994 The fish fry were transported to the wet lab of the NIOF, Suez and Aqaba Gulfs branch, Suez, in aerated tanks containing seawater from the same area of collection In the laboratory conditions, the fish were kept in a holding tank filled with seawater as stock Acclimatize to the conditions of the experiment was restricted to 7 days

2- Preparation of the toxicants:

Stock solutions of 1000 mg Cd / l and 1000 mg Cu / l were prepared freshly using Cd SO_4 and Cu SO_4 $5H_2O$ of pure grade pH of the stock solutions was adjusted to about 7 to prevent adsorption of the metals on the wall of the container

3- Experimental procedures:

Several experimental glass tanks 40 x 20 x 30 cm (length x width x height) in dimension (including one as control) were prepared (cleaned in tap water with detergent, washed in running tap water and then in sea water as used in the experiments, and filled with a known volume of sea water) before adding the test solutions A serious of

concentrations for each metal were used Thirty minutes after adding the toxicants, ten randomly picked fish from the stock tank were introduced to each of the experimental tanks, and experimental timing started Observations for mortality were made four times daily at regular intervals Dead fish were removed at each observation The number of dead fish were then recorded The test was terminated after 96 h Duplication of the experiments were taken into consideration to confirm the results

4- Data analysis:

The percentage mortality in each concentration were corrected for control mortality using Abbott's formula (Finney, 1971), however, mortalities in controls were never greater than 10 % Abbott's formula was as follow

$$C = \frac{O - X}{100 \ X}$$

Where,

C is the corrected mortality

O is the percentage of observed mortality

X is the percentage of the control animals which have died at the relevant observation time

96 h LC_{50} for each metal was estimated by probit methods (Finney, 1971) using graphical analysis To construct the graph, plot percentage mortality as the ordinate against log concentration as the abscissa Read the concentration causing 50 % mortality from the fitted line, this is the estimated LC_{50} for the exposure time

III- Accumulation and depuration of Cd and Cu:

Live adult fish of *Mugil seheli* were collected in October 1994 from fish farm feeding with seawater from Suez Canal The fish were transported to the wet lab of the National Institute of Oceanography and Fisheries, Suez and Aqaba Gulfs branch, Suez, in aerated tanks containing seawater from the same area of collection In the laboratory conditions, the fish were acclimatized in the laboratory for about two weeks in tanks, similar to the experimental tanks, filled with seawater

Metals, Cd (Cd SO4) and Cu (Cu SO_4 $5H_2O$), were prepared freshly as stock solutions of 1000 mg metals / l pH of the stock solutions was adjusted to about 7 to prevent precipitation of the metals

In four experimental tanks (2500 litres), 100 fish for each tank were exposed to 0 5 and 2 0 mg Cd / l, and 0 2 and 0 5 mg Cu / l, a fifth group was kept with no metals added to the water (control) About 100 litres of the seawater were statically renewed each two days

After 12 weeks of accumulation period, fish were transferred to tanks filling with clean seawater for another 12 weeks

For each treatment, 4 - 7 individuals were sampled at different times intervals for metal analysis The samples were prepared according to FAO (1976) to measure the metals by AAS Metals were analyzed in fish organs, blood, liver, gills and muscle, and the results were expressed in ppm (µg / g) wet weight

Conditions of metal measurement (technical):

The metals were determined in the extracts by using cathode lamps at specific slit and wave lengths as shown in Table 2

Table (2) Wave length, cathode lamp current and slit width for determination of heavy metals

Element	Wave length (nm)	Current (mA)	Slit width (nm)
Cadmium (Cd)	228 8	7 5	0 7
Lead (Pb)	217 0	7 5	0 7
Copper (Cu)	324 7	10 0	0 7
Zinc (Zn)	213 9	10 0	0 7
Cobalt (Co)	240 7	15 0	0 2
Nickel (Ni)	232 0	15 0	0 2
Iron (Fe)	248 3	15 0	0 2
Calcium (Ca)	422 7	7 5	0 7
Magnesium (Mg)	285 2	7 5	0 7
Sodium (Na)	589 0	7 5	0 2
Potassium (K)	766 5	7 5	0 2

The precision of analytical method was checked by replicate measurements for cadmium and copper in fish muscles, results are shown in Table (3)

Table (3) Reproducibility of cadmium and copper in fish muscle samples

Samples	concentrations (µg/g) wet wt	
	Cd	Cu
1	0 115	0 310
2	0 118	0 300
3	0 104	0 307
4	0 119	0 330
5	0 096	0 281
6	0 114	0 291
7	0 120	0 277
Mean	0 112	0 299
± S D	0 008	0 017
C V %	7 14 %	5 69 %

Chapter IV

Results and Discussion

I- Field Research

I- Field research

(1) Level of metals in fish organs:

For effective water pollution control and management, there is a need for a clear understanding of the loads and distribution of contaminants In particular, the quantities and qualities need to be considered together with the distribution and the effects on biota

In recent times, metals have become a problem of increasing concern due to, a) their presence in excess of natural loads, b) their toxic effects to aquatic organisms, c) their high persistence to natural degradation and d) their high affinity of bioaccumulation in aquatic organisms

Metals may accumulate, unnoticed, to toxic levels Thus problems associated with metal contamination were first highlighted in the industrially advanced countries (Minamata disease in Japan, Kutsuna, 1968) Shimazu (1972) reported that eating cadmium-contaminated fish by man caused the "Itai-Itai" which considered as a cadmium poisoning disease Other heavy metals such as chromium, copper and zinc, when discharge into water, can enter food chain, bioaccumulated in fish and hence become one of the threating factor for human beings

The need to make an assessment of the level of metal contamination in the Egyptian marine environments has led to the

initiation of the present pollution monitoring programme This programme has accomplished for the compilation of an inventory of the sources and the quantification of metals in fish on a country basis Thus, important fish catching areas along the Egyptian coast such as, Alexandria and Port Said at the Mediterranean, Ismailia at Suez Canal, The Gulf of Suez including Suez Bay and Ghardaqa at the Red Sea proper were selected to get samples from

The present part is a contribution towards the formulation of rational management policies for marine fish resources in Egypt It, thus, will help to cover the need to have a data base that could be effective in future control strategies

1- Muscle

Table (4) shows the concentration of each of the seven heavy metals (µg / g = ppm wet wt) and the four major elements (mg / g = ppt wet wt) in muscles of the tested fish species

The minima and maxima for each metal were underlined in the table It is well noticed that the highest values of cadmium (0 09 ppm), magnesium (0 465 ppt) and potassium (4 995 ppt) was in fish *Pagrus pagrus* Copper (1 36 ppm) was in fish *Mugil auratus* Na (2 891 ppt) was in fish *Upenaeus sp* All these fish samples were collected from the Mediterranean in front of Port Said Gulf of Suez, on the other

Table (4) Mean and standard deviation of metals level in the muscle of the fish collected from different sites along the Egyptian coast (minimum and maximum values are underlined)

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Saurida undosquamis	Red Sea	0 023 ±0 002	0 172 ±0 017	0 566 ±0 093	4 43 ±0 519	0 053 ±0 007	0 952 ±0 966	10 726 ±11 368	0 08 ±0 005	0 075 ±0 015	1 07 ±0 176	0 895 ±0 045
	Suez Gulf	0 013 ±0 01	0 133 ±0 10	0 129 ±0 03	2 582 ±0 41	0 127 ±0 03	0 317 ±0 17	3 008 ±0 34	0 196 ±0 037	0 271 ±0 056	1 05 ±0 153	1 867 ±0 229
	Mediterranean "Port Said"	0 052 ±0 03	0 182 ±0 031	1 019 ±0 39	2 99 ±0 41	0 067 ±0 007	0 557 ±0 44	9 529 ±6 24	0 084 ±0 013	0 254 ±0 097	1 112 ±0 423	0 922 ±0 087
	"Alexandria"	0 027 ±0 004	0 50 ±0 157	0 614 ±0 244	4 412 ±1 364	0 058 ±0 005	0 671 ±0 234	3 762 ±1 078	0 069 ±0 024	0 195 ±0 037	0 767 ±0 05	2 132 ±0 317
Siganus rivulatus	Red Sea	0 039 ±0 006	0 226 ±0 081	0 245 ±0 029	2 653 ±0 288	0 108 ±0 018	0 312 ±0 149	3 353 ± 87	0 063 ±0 011	0 19 ±0 028	0 743 ±0 23	1 629 ±0 427
	Suez Bay	0 026 ±0 002	0 255 ±0 081	0 333 ±0 082	4 383 ±0 574	0 074 ±0 009	0 25 ±0 053	2 97 ±0 373	0 09 ±0 021	0 146 ±0 034	0 851 ±0 171	1 222 ±0 321
	Port Said "Alexandria"	0 02	0 06	0 69	3 49	0 14	0 50	5 557	0 05	0 364	1 625	1 926
		0 026 ±0 002	0 566 ±0 112	0 743 ± 182	5 40 ±1 633	0 082 ±0 017	0 607 ±0 133	4 888 ±0 768	0 035 ±0 016	0 162 ±0 015	0 955 ±0 095	2 416 ±0 121
Rhabdosargus hafara	Suez Gulf	0 024 ±0 005	0 216 ±0 02	0 342 ±0 04	5 412 ±0 56	0 092 ±0 007	1 846 ±1 05	6 51 ±0 57	0 037 ±0 005	0 373 ±0 029	1 094 ±0 126	2 712 ±0 287
	Suez Bay	0 03 ±0 004	0 217 ±0 024	0 247 ±0 005	5 463 ±0 841	0 067 ±0 002	1 083 ±1 007	3 523 ±0 331	0 09 ±0 005	0 159 ±0 024	0 389 ±0 035	2 304 ±0 186

Table (4) Cont

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Mugil seheli	Suez Gulf	0 023 ±0 003	0 194 ±0 021	0 38 ±0 067	3 156 ±0 34	0 035 ±0 003	0 331 ±0 179	5 478 ±0 827	0 063 ±0 013	0 203 ±0 037	0 669 ±0 111	1 369 ±0 227
	Suez Bay	0 033 ±0 009	0 268 ±0 066	0 418 ±0 137	4 088 ±0 759	0 058 ±0 01	0 224 ±0 072	3 773 ±0 481	0 146 ±0 034	0 14 ±0 021	0 596 ±0 217	1 353 ±0 374
	Suez Canal	0 02 ±0 006	0 186 ±0 008	0 738 ±0 12	8 212 ±2 44	0 064 ±0 005	1 966 ±0 51	17 934 ±9 37	0 065 ±0 004	0 19 ±0 015	0 737 ±0 121	1 977 ±0 174
Mugil cephalus	Suez Canal	0 03	0 188 ±0 02	0 61 ±0 14	4 745 ±1 13	0 065 ±0 01	1 935 ±0 86	6 297 ±0 91	0 052 ±0 028	0 206 ±0 008	0 616 ±0 054	2 395 ±0 675
Mugil auratus	Port Said	0 02	0 09	1 36	5 58	0 12	0 50	8 54	0 057	0 244	1 32	1 047
Nemipterus japonicus	Red Sea	0 022 ±0 006	0 336 ±0 07	0 288 ±0 085	2 13 ±0 113	0 093 ±0 023	0 251 ±0 109	6 31 ±4 547	0 16 ±0 058	0 165 ±0 008	0 764 ±0 13	1 621 ±0 361
	Suez Gulf	0 03 ±0 02	0 169 ±0 12	0 228 ±0 05	1 921 ±0 22	0 111 ±0 02	0 444 ±0 08	3 629 ±0 62	0 114 ±0 012	0 235 ±0 01	0 82 ±0 025	1 941 ±0 398
Pomadysis stridens	Suez Gulf	0 02	0 124 ±0 03	0 568 ±0 15	5 022 ±1 03	0 06 ±0 02	0 492 ±0 08	6 382 ±1 04	0 106 ±0 006	0 259 ±0 019	0 686 ±0 063	1 913 ±0 311
	Suez Bay	0 033 ±0 001	0 304 ±0 024	0 44 ±0 06	3 49 ±0 32	0 055 ±0 006	0 256 ±0 065	3 46 ±0 23	0 131 ±0 015	0 156 ±0 026	0 832 ±0 05	1 312 ±0 483

Table (4) Cont

Species	Area	Trace metals (µg/g wet wt.)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Pagrus pagrus	Suez Gulf	0 028 ±0 007	0 27 ±0 03	0 404 ±0 09	3 234 ±0 16	0 082 ±0 004	2 468 ±0 56	47 46 ±7 75	0 045 ±0 004	0 345 ±0 021	1 198 ±0 168	2 367 ±0 202
	Port Said	0 09 ±0 06	0 192 ±0 05	1 116 ±0 21	2 798 ±0 25	0 076 ±0 01	0 32 ±0 02	7 188 ±3 43	0 082 ±0 033	0 465 ±0 286	1 934 ±1 478	4 995 ±3 556
	Alexandria	0 035 ±0 004	0 191 ±0 027	0 272 ±0 08	4 322 ±0 992	0 037 ±0 003	0 306 ±0 024	4 272 ±0 269	0 082 ±0 007	0 215 ±0 02	0 522 ±0 09	1 567 ±0 046
Upenaeus sp	Suez Gulf	0 032 ±0 004	0 226 ±0 03	0 542 ±0 15	3 084 ±0 59	0 064 ±0 01	2 402 ±0 68	6 09 ±1 67	0 114 ±0 016	0 217 ±0 013	0 979 ±0 079	2 006 ±0 143
	Port Said	0 044 ±0 01	0 17 ±0 01	0 906 ±0 12	3 38 ±0 32	0 064 ±0 007	0 30 ±0 02	7 096 ±0 27	0 078 ±0 027	0 459 ±0 342	2 891 ±3 076	3 259 ±2 86
Mullus barbatus	Alexandria	0 027 ±0 001	0 272 ±0 031	0 366 ±0 034	2 708 ±0 182	0 039 ±0 006	0 491 ±0 165	4 218 ±0 361	0 042 ±0 007	0 229 ±0 014	0 717 ±0 089	1 589 ±0 048
Sardinella gibbosa	Suez Gulf	0 023 ±0 005	0 144 ±0 01	0 407 ±0 09	6 28 ±0 07	0 09 ±0 008	0 417 ±0 09	9 89 ±2 50	0 149 ±0 003	0 257 ±0 009	0 438 ±0 011	2 214 ±0 223
	Suez Bay	0 016 ±0 009	0 059 ±0 03	0 549 ±0 11	6 344 ±1 29	0 189 ±0 03	0 445 ±0 13	6 894 ±1 76	0 19 ±0 015	0 286 ±0 025	0 667 ±0 088	2 441 ±0 112
Etrumeus teres	Suez Gulf	0 022 ±0 007	0 156 ±0 02	0 87 ±0 17	13 512 ±1 53	0 078 ±0 02	1 534 ±1 22	16 752 ±4 73	0 166 ±0 017	0 325 ±0 062	0 665 ±0 059	2 077 ±0 105

Table (4) Cont

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Scomber japonicus	Suez Gulf	0 024 ±0 005	0 126 ±0 02	0 484 ±0 15	7 21 ±0 48	0 06 ±0 01	0 378 ±0 03	12 142 ±2 75	0 068 ±0 008	0 275 ±0 034	0 864 ±0 10	1 296 ±0 136
Trachurus indicus		0 028 ±0 008	0 61 ±0 159	0 782 ±0 189	7 754 ±1 071	0 062 ±0 008	0 86 ±0 672	6 974 ±0 581	0 06 ±0 002	0 19 ±0 026	1 145 ±0 31	1 458 ±0 416
Tilapia sp	Suez Canal	0 034 ±0 008	0 234 ±0 01	0 618 ±0 09	3 182 ±0 32	0 06 ±0 006	0 342 ±0 10	5 262 ±1 33	0 065 ±0 015	0 148 ±0 026	0 607 ±0 098	1 355 ±0 178
Trachinotus ovatus	Alexandria	0 028 ±0 003	0 404 ±0 036	0 964 ±0 09	5 346 ±1 446	0 062 ±0 007	2 261 ±2 065	8 242 ±3 831	0 027 ±0 015	0 231 ±0 027	1 336 ±0 226	1 669 ±0 146
Caranx cryzes		0 028 ±0 003	0 48 ±0 063	0 752 ±0 073	5 932 ±0 718	0 064 ±0 005	0 561 ±0 09	11 208 ±4 255	0 015 ±0 01	0 175 ±0 023	1 051 ±0 117	2 034 ±0 122
Diplodus sargus		0 031 ±0 003	0 356 ±0 087	0 892 ±0 151	4 864 ±1 222	0 064 ±0 005	0 594 ±0 174	15 872 ±9 947	0 084 ±0 017	0 187 ±0 034	0 937 ±0 026	1 619 ±0 159

hand, showed highest values of Ni (2 468 ppm), Fe (47 46 ppm) in fish *Pagrus pagrus* Lead (0 61 ppm) was in fish *Trachurus indicus*, Zn (13 512 ppm) in fish *Etrumeus teres*, cobalt (0 189 ppm) in *Sardinella gibbosa* and Ca (0 196 ppt) in *Saurida undosquamis*

Fish from Alexandria region showed no any maximum However, lead, in particular, showed high values in fish muscles, the average of which was 0 396 ppm which is considerably higher than that of the Gulf of Suez (av 0 217 ppm)

2- Liver

The concentrations of heavy and major metals in liver of fish species collected from different areas along the Egyptian coasts are present in Table (5)

It is well noticed that the highest values of cadmium (1 16 pp) was in fish *Scomber japonicus* Lead (1 851 ppm) in fish *Mugil seheli* Cobalt and nickel (1 11 and 19 76 ppm) were in fish *Sardinella gibbosa* and *Pagrus pagrus*, respectively The major elements, Ca, Mg, Na and K (1 875, 0 731, 9 633 and 2 603 ppt) were in fish *Sardinella gibbosa* All these fish species were catched from the Gulf of Suez Copper showed its highest level (81 17 ppm) in fish *Mugil auratus* collected from Port Said *Siganus rivulatus* from Alexandria regions and Red Sea proper at Ghardaqa had an elevate amount of zinc (102 90 ppm) and iron (573 59 ppm)

Table (5) Mean and standard deviation of metals level in the liver of the fish collected from different sites along the Egyptian coast (minimum and maximum values are underlined)

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Saurida undosquamis	Red Sea	0 113	0 16	1 76	21 10	0 092	0 81	107 54	0 319	0 157	0 978	0 396
	Suez Gulf	0 041 ±0 06	0 173 ±0 11	7 847 ±3 51	44 55 ±20 70	0 316 ±0 07	0 379 ±0 22	187 41 ±70 16	0 201 ±0 146	0 342 ±0 107	1 743 ±0 474	1 767 ±0 266
	Port Said	0 41 ±0 26	1 03 ±0 43	12 117 ±2 20	21 977 ±9 05	0 199 ±0 05	0 585 ±0 15	144 308 ±60 51	0 138 ±0 234	0 351 ±0 115	2 149 ±0 927	1 876 ±1 438
	Alexandria	0 067 ±0 022	0 712 ±0 481	4 084 ±2 144	35 916 ±25 10	0 059 ±0 021	0 751 ±0 309	48 29 ±19 644	0 071 ±0 066	0 191 ±0 07	1 038 ±0 312	1 887 ±0 568
Siganus rivulatus	Red Sea	0 888 ±0 161	0 622 ±0 077	15 87 ±3 13	70 305 ±8 445	0 646 ±0 045	1 753 ±0 298	573 59 ±164 93	0 207 ±0 047	0 249 ±0 034	0 80 ±0 073	1 179 ±0 118
	Suez Bay	0 018	0 731	9 90	25 28	0 201	0 365	147 73	0 226	0 153	0 877	1 069
	Port Said	0 05	0 06	3 43	26 57	0 25	0 36	121 43	0 132	0 353	1 723	1 137
	Alexandria	0 043	0 95	25 95	102 90	0 32	1 53	280 30	0 056	0 264	1 213	1 555
Rhabdosargus hafara	Suez Gulf	0 13	0 61	5 38	40 37	0 25	3 07	232 25	1 268	0 59	1 907	1 917
	Suez Bay	0 089	1 111	2 28	31 36	0 222	1 30	129 75	0 168	0 157	1 185	1 723

Table (5) Cont

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Mugil seheli	Suez Gulf	0 035	0 347	32 97	21 79	0 139	0 764	345 77	0 073	0 151	1 199	1 053
	Suez Bay	0 10 ±0 008	1 851 ±0 016	6 845 ±2 075	17 24 ±0 81	0 222 ±0 009	0 662 ±0 049	30 595 ±8 205	0 151 ±0 098	0 16 ±0 024	1 085 ±0 018	1 406 ±0 01
	Suez Canal	0 03	0 39	7 87	13 21	0 11	12 04	205 94	0 13	0 159	1 482	1 393
Mugil cephalus	Suez Canal	0 072 ±0 03	0 31 ±0 06	18 844 ±8 51	24 572 ±10 53	0 10 ±0 03	0 982 ±0 47	73 494 ±56 26	0 169 ±0 148	0 159 ±0 027	1 131 ±0 314	1 515 ±0 224
Mugil auratus	Port Said	0 18	0 06	81 17	24 26	0 51	0 79	216 00	0 131	0 345	2 486	1 028
Nemipterus japonicus	Red Sea	0 864 ±0 645	1 148 ±0 164	2 88 ±0 20	34 505 ±11 43	0 192 ±0 028	0 984 ±0 11	225 62 ±36 94	0 132 ±0 036	0 245 ±0 059	1 278 ±0 054	1 712 ±0 184
	Suez Gulf	0 02	0 08	1 59	14 55	0 33	0 83	85 56	0 495	0 38	2 925	1 63
Pomadysis stridens	Suez Gulf	0 04	0 22	2 51	16 42	0 06	1 00	90 97	0 552	0 154	1 78	1 595
	Suez Bay	0 035	0 708	1 72	7 52	0 071	0 236	22 87	0 548	0 136	1 416	0 898
Pagrus pagrus	Suez Gulf	0 17	0 57	9 01	28 55	0 18	19 76	306 85	0 274	0 425	2 041	1 66
	Mediterranean "Port Said"	0 74	0 49	7 49	39 28	0 28	1 21	124 61	0 073	0 307	1 75	2 439
	"Alexandria"	0 094	0 335	5 22	46 21	0 089	0 381	323 20	0 112	0 268	1 073	1 755

Table (5) Cont

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Upenaeus sp	Suez Gulf	0 19	0 69	6 89	55 93	0 13	11 00	122 06	0 278	0 226	1 704	1 612
	Port Said	0 19	0 54	2 64	30 67	0 24	1 52	183 95	0 125	0 341	2 667	0 984
Mullus barbatus	Alexandria	0 019	0 14	1 31	10 49	0 056	1 178	290 11	0 026	0 071	0 445	0 737
Sardinella gibbosa	Suez Gulf	0 33	0 40	7 57	50 38	1 11	4 17	232 31	1 875	0 731	9 633	2 603
	Suez Bay	0 07	0 25	3 29	31 98	0 27	0 56	112 26	0 064	0 32	1 217	2 004
Scomber japonicus	Suez Gulf	1 16	0 11	2 28	18 14	0 20	0 49	220 83	0 515	0 274	1 776	1 384
Trachurus indicus		0 033	0 714	3 36	26 71	0 20	2 105	294 82	0 196	0 221	2 24	1 84
Tilapia sp	Suez Canal	0 06	0 75	25 34	28 92	0 22	0 80	220 74	0 101	0 154	1 119	0 948
Trachinotus ovatus	Alexandria	0 043	0 60	4 34	24 29	0 156	13 99	92 06	0 009	0 245	1 834	1 369
Caranx cryzes		0 033	0 51	4 71	19 59	0 115	0 647	71 62	0 006	0 175	1 585	1 209
Diplodus sargus		0 061	1 15	7 07	36 36	0 136	1 196	163 90	0 016	0 176	1 637	1 077

3- Gills

Table (6) shows the levels of the measured 11 metals in the gills of each of 19-fish species

The minima and maxima for each metal were underlined in the table It is well noticed that the highest values of cadmium (0 194 ppm), zinc (49 10 ppm) and calcium (5 306 ppt) was in fish *Scomber japonicus* Lead (1 24 ppm) was in fish *Mugil seheli* Cobalt (0 81 ppm) was in fish *Sardinella gibbosa* Nickel (3 13 ppm) was in fish *Pomadysis stridens* Potassium (2 411 ppt) was in fish *Etrumeus teres* All these fish were collected from the Gulf of Suez Mediterranean infront of Port Said, on the other hand, showed highest values of Cu (3 02 ppm) and Fe (1191 30 ppm) in fish *Mugil auratus* Magnesium (1 32 ppt) and sodium (2 845 ppt) were in fish *Saurida undosquamis*

Generally, fish from Alexandria region showed the lowest values of metals in all organs except lead in muscle While other areas (Red Sea, Gulf of Suez and Port Said) had the highest levels of tested metals with different concentrations

High levels of copper which were observed in muscle, liver and gills of fish collected from Port Said region reflect contribution of paint effect of dense traffic ships while, high values of nickel presented in the organs of fish from the Gulf of Suez are mainly due to pollution influence of petrochemical industries, petroleum refineries and many of the oil fields in the Gulf waters

Table (6) Mean and standard deviation of metals level in the gills of the fish collected from different sites along the Egyptian coast (minimum and maximum values are underlined)

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Saurida undosquamis	Red Sea	0 07	0 25	1 00	35 10	0 22	0 92	70 50	1 581	0 536	0 648	0 448
	Suez Gulf	0 081 ±0 06	0 501 ±0 26	0 521 ±0 05	30 084 ±2 58	0 701 ±0 16	1 404 ±0 43	48 94 ±23 39	2 514 ±1 244	0 615 ±0 079	1 594 ±0 253	0 922 ±0 195
	Port Said	0 10 ±0 012	0 546 ±0 10	2 274 ±0 75	13 203 ±4 35	0 415 ±0 05	1 06 ±0 17	204 20 ±55 05	3 531 ±2 698	1 32 ±1 375	2 845 ±2 848	0 819 ±0 621
	Alexandria	0 074 ±0 003	0 588 ±0 028	0 68 ±0 127	25 91 ±1 103	0 193 ±0 004	0 739 ±0 123	33 195 ±5 31	2 866 ±0 075	0 511 ±0 016	1 473 ±0 066	1 21 ±0 102
Siganus rivulatus	Red Sea	0 063 ±0 005	0 587 ±0 054	0 60 ±0 04	5 555 ±0 125	0 493 ±0 053	0 479 ±0 035	32 05 ±0 039	1 864 ±0 162	0 20 ±0 018	1 512 ±0 043	0 607 ±0 009
	Suez Bay	0 051	0 81	0 97	7 93	0 101	0 473	35 96	1 386	0 131	0 81	0 634
	Port Said	0 05	0 13	1 60	11 76	0 64	1 91	768 12	0 798	0 394	1 178	0 711
	Alexandria	0 055	0 24	0 65	11 81	0 301	0 738	57 68	1 944	0 414	1 34	0 661
Rhabdosargus hafara	Suez Gulf	0 07	0 46	0 71	25 23	0 31	0 59	93 14	1 708	1 244	1 528	1 492
	Suez Bay	0 132	0 526	0 76	17 45	0 276	0 768	28 53	3 501	0 252	0 746	0 985

Table (6) Cont

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Mugil seheli	Suez Gulf	0 048	0 399	0 55	2 34	0 152	0 724	307 62	2 333	0 682	1 494	0 587
	Suez Bay	0 093 ±0 001	1 24 ±0 112	0 95 ±0 09	12 10 ±0 40	0 274 ±0 024	0 379 ±0 037	38 415 ±1 095	2 762 ±0 039	0 242 ±0 006	1 475 ±0 028	0 752 ±0 003
	Suez Canal	0 07	0 595 ±0 005	1 225 ±0 34	27 24 ±1 72	0 26 ±0 01	1 20 ±0 05	105 47 ±14 09	1 154 ±0 101	0 376 ±0 017	1 543 ±0 02	1 231 ±0 011
Mugil cephalus	Suez Canal	0 07 ±0 008	0 542 ±0 07	1 237 ±0 23	17 783 ±3 49	0 203 ±0 02	1 373 ±0 14	55 33 ±2 86	1 268 ±0 125	0 34 ±0 092	0 853 ±0 117	0 563 ±0 035
Mugil auratus	Port Said	0 03	0 25	3 02	7 14	0 71	2 00	1191 30	1 494	0 766	1 126	0 702
Nemipterus japonicus	Red Sea	0 134 ±0 015	1 116 ±0 262	0 646 ±0 13	10 698 ±1 166	0 461 ±0 049	0 583 ± 131	223 06 ±285 09	4 712 ±0 558	0 445 ±0 165	0 82 ±0 08	0 825 ±0 051
	Suez Gulf	0 103 ±0 02	0 67 ±0 10	0 816 ±0 12	9 679 ±0 90	0 60 ±0 06	1 672 ±0 11	48 877 ±7 79	2 034 ±0 585	0 619 ±0 06	1 524 ±0 115	0 956 ±0 131
Pomadysis stridens	Suez Gulf	0 07	0 48	1 13	16 29	0 23	3 13	83 86	3 26	0 641	1 165	1 38
	Suez Bay	0 051	0 428	0 72	6 36	0 182	0 571	60 35	2 525	0 17	0 875	0 765

Table (6) Cont

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Pagrus pagrus	Suez Gulf	0 12	0 77	1 23	12 72	0 25	0 63	64 74	0 843	0 68	1 943	1 157
	Port Said	0 168 ±0 02	0 634 ±0 16	1 964 ±0 44	14 994 ±3 57	0 378 ±0 01	0 654 ±0 06	88 30 ±13 29	3 469 ±0 556	1 062 ±0 409	2 086 ±0 548	1 048 ±0 203
	Alexandria	0 07 ±0 011	0 596 ±0 091	0 795 ±0 325	14 885 ±4 235	0 118 ±0 016	0 741 ±0 097	224 87 ±25 22	2 246 ±0 327	0 492 ±0 021	1 184 ±0 062	0 727 ±0 051
Upenaeus sp	Suez Gulf	0 10	0 51	1 45	21 42	0 27	1 52	117 96	2 504	0 73	1 273	1 302
	Port Said	0 06	0 34	0 79	6 80	0 29	0 74	140 19	1 153	0 356	1 126	0 678
Mullus barbatus	Alexandria	0 056	0 677	1 18	10 73	0 141	0 66	196 46	1 097	0 447	1 278	0 723
Sardinella gibbosa	Suez Gulf	0 10	0 87	1 29	33 51	0 27	2 24	115 50	3 182	0 569	1 347	1 165
	Suez Bay	0 101 ±0 02	0 762 ±0 39	0 79 ±0 20	33 92 ±7 03	0 81 ±0 13	2 031 ±0 44	81 229 ±32 74	1 939 ±0 66	0 746 ±0 054	2 585 ±0 222	1 657 ±0 257
Etrumeus teres	Suez Gulf	0 09	0 63	1 60	42 40	0 37	1 52	125 82	3 24	1 281	1 302	2 411
Scomber japonicus		0 194 ±0 04	0 436 ±0 03	0 982 ±0 19	49 10 ±6 45	0 38 ±0 04	1 28 ±0 25	215 04 ±62 72	5 306 ±0 712	0 884 ±0 125	1 267 ±0 189	0 78 ±0 135
Trachurus indicus		0 062	0 36	0 80	10 06	0 201	0 611	69 39	2 625	0 826	1 374	0 70

Teble (6) Cont

Species	Area	Trace metals (µg/g wet wt)							Major elements (mg/g wet wt)			
		Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Tilapia sp	Suez Canal	0 054 ±0 01	0 522 ±0 11	1 044 ±0 21	14 274 ±2 20	0 17 ±0 04	0 414 ±0 05	61 006 ±11 17	1 34 ±0 271	0 324 ±0 138	0 981 ±0 356	0 646 ±0 286
Trachinotus ovatus	Alexandria	0 046	0 27	0 33	1 99	0 164	0 726	42 49	2 254	0 713	1 473	0 84
Caranx cryzes		0 061 ±0 016	0 47 ±0 12	0 435 ±0 095	5 83 ±3 39	0 177 ±0 026	0 518 ±0 028	55 865 ±12 785	2 671 ±0 255	0 742 ±0 043	1 641 ±0 054	0 415 ±0 142
Diplodus sargus		0 071	0 48	0 51	9 40	0 195	0 699	58 85	2 836	0 535	1 43	0 457

In fact, it is difficult to explain specifically the differences in metal content of fish organs in the different sites complexity arises from many factors, some of which are belonging to the environmental conditions, while others are being judged in relation to the selected fish species and other biological aspects

Although metal salts have a great influence on the bioaccumulation of heavy metals, the metabolism of the metal in the organism has an important influence on the concentrations ultimately achieved, both factors are, of course, influenced by environmental parameters such as salinity, temperature, pH and so on (Bryan, 1980) Also, water ambient concentrations of metals may affect the accumulation rate of metals in the tissues of the organisms Accordingly, the variations of the metal contents in the fish caught from the different areas in the present study may be related to the variations in water conditions as well as the concentrations of metals in the water which are differed according to the source of pollution (types and amounts)

Bryan (1980) stated that, if an organism absorbs metals as a rate proportional to the environmental concentration there are at least three possible types of relation between the concentrations achieved by the tissues and those of the environment,

(1) The organism excretes the metal at a rate proportional to the body burden and therefore the concentration in the body is proportional to the environmental availability and usually remains fairly constant or trend to fall with increasing age

(2) The organism has limited powers of excretion and tends to store absorbed metals In this case the concentration in the organism may still be directly proportional to environmental availability but, unless it grows fast enough to dilute the metal, the level in the body tends to increase with age

(3) The organism is able to increase the efficiency of excretion in response to increased absorption and therefore the concentration in the body does not increase in proportional to environmental availability

Generally, the more highly evolved forms including fish and decapod crustaceans tend to be the best regulators and the essential metals such as zinc and copper are better regulated than the nonessential such as cadmium and specially mercury

In the present survey, the variations of the metal contents from species to another are mainly due to one of the points stated above

(2) Response of fish to metals in different areas:

According to the literature, heavy metal concentrations are extremely variable in various marine and freshwater organisms (Roberts, 1976, Forstner and Porsi, 1979), depending on the geochemical background and the level of pollution in the given area Also, the species variations in metals content may depend on the fish activity to uptake of metals from the environment, the feeding habit and mechanism and amount of lipids present in in each fish and its organs, which is usually vary from one organ to another

Ayling (1974) and Coughtrey and Martin (1977) suggested that different mechanisms exist for the uptake of copper, chromium, zinc, cadmium and lead within *Crassostrea gigas* (oyster) and *Helix aspersa* (pulmonate mollusc) These mechanisms may also vary with physiological and environmental factors (Bryan, 1973) or even with sexual state of the animal (Alexander and Young, 1976) Thus the observed variation in metal levels of the fish species, in the present study, may be related to one or more of the following factors

(1) The availability, of different metals to the animal (fish), varies in the different sites

(2) Habitat of the fish species and the availability of different metals to the fish varies with the type of the feeding habit and mechanism (carnivorous, omnivorous or herbivorous)

(3) The lipids content in the tissues of different fish species

(4) The animal involves different uptake and retention mechanisms for the same metal at different sites

One of our objectives, in the present study, is to discuss the aforementioned factors Discussion in the next parts depends on the previous works in addition to data collected from the field to get accurate explanation

<u>Part I</u>: The availability of metals to fish in the different sites.

Allen *et al* (1974) stated that, the ratio of metals in the fallout at different sites varies and also the chemical form of the metal changes hence the availability of metals may also change

The present data reveal certain variations in heavy metal concentrations in the tissues of the fish species harvested from the selected areas In all tested regions, except Port Said region, the order of metals accumulation in fish muscle was Fe > Zn > Ni > Cu > Pb > Co > Cd While in Port Said region, the order was Fe > Zn > Cu > Ni > Pb > Co > Cd The change in the order of copper in Port Said region may be resulted from the high contamination with copper in this area that can affect the marine organisms and lead to magnification of copper in their tissues

Regional variation in the bioaccumulation rate of heavy metals by the aquatic organisms were cited by various authors (Hobden, 1967, Preston *et al*, 1972, Coughtrey and Martin, 1977, Grimanis *et al*, 1980, Voutsinou, 1980, Hafez, 1982, Karbe *et al*, 1989, Barak and Mason, 1990, Emara *et al*, 1993 and El-Moselhy and El Samra, 1994)

The data obtained by Karbe *et al* (1989) show that there are differences among the various metals with respect to their patterns of regional distribution Also, concentrations are high at locations influenced directly by the known riverine and other landbased sources

Emara *et al* (1993) showed that, the accumulation of metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb) in fish was more pronounced in Red Sea species than in Mediterranean species In contrast, El-Moselhy and El Samra (1994) stated that, fish from Mediterranean infront of Port Said city gave higher values of metals than those collected from the Red Sea The difference between the two studies may be related to select more than one species, in the first study, for comparison which are varies in its habitat and feeding mechanisms, while in the other study, they compared the metal contents in the same species collected from the different sites

Part II: Feeding and habitat mechanisms.

To find the effect of feeding and habitat mechanisms, fish collected from the Gulf of Suez, three species of which are pelagic and filter feeding fish, one is pelagic and carnivorous, while, seven species are bottom and carnivorous fish

Metals content in the different organs of these different species are shown in Figs (1 - 3)

For all metals other than cadmium, gills showed their higher levels in pelagic and filter feeding fish than those recorded in carnivorous fish This result may be due to adsorption of metals on the outer surface of gill tissues during the filtration mechanism

In liver, copper, zinc cobalt and iron showed high values in the filter feeders, while other metals (cadmium, lead and nickel) were found in carnivorous fish

For muscle, only cadmium and nickel were present in carnivorous fish with high values, while the other metals recorded its highest levels in filter feeding fish

Cadmium was the only metal that showed its highest level in carnivorous fish for all tested organs, and this may indicate that cadmium can be magnified during the food chain and reaches its highest level in the top of the food chain

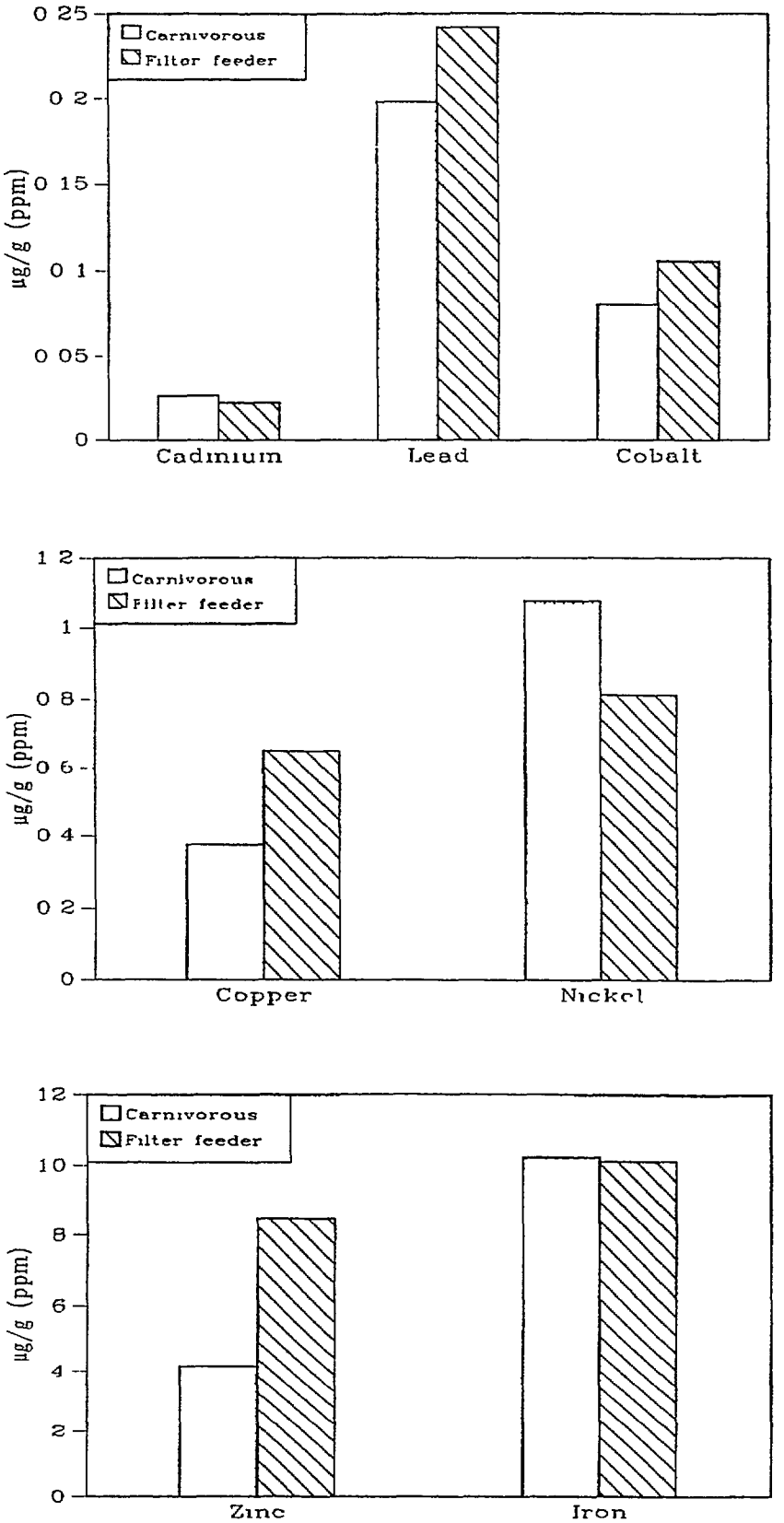


Fig (1) Metal variations in muscles of carnivorous and filter feeding fish from the Gulf of Suez

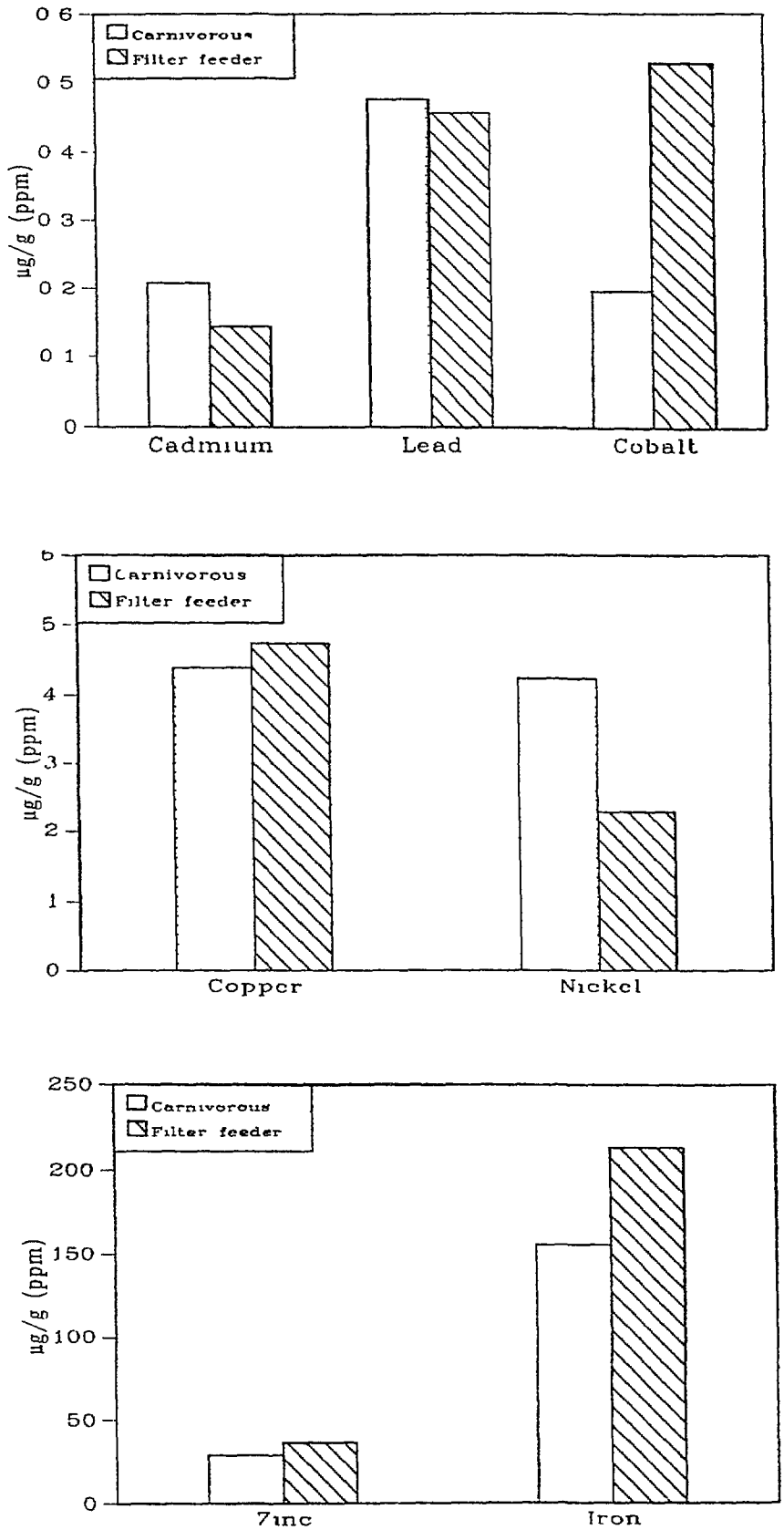


Fig (2) Metal variations in liver of carnivorous and filter feeding fish from the Gulf of Suez

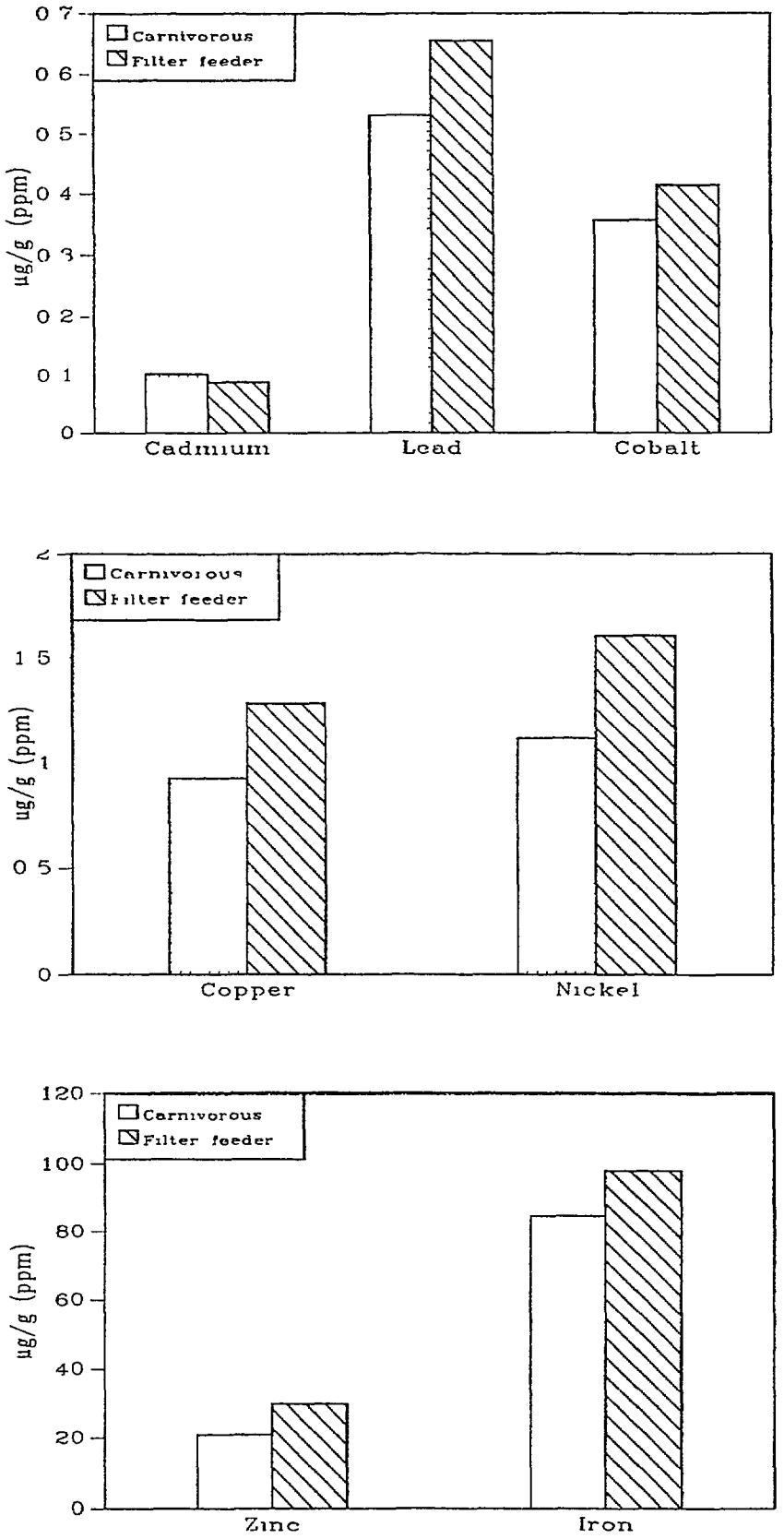


Fig (3) Metal variations in gills of carnivorous and filter feeding fish from the Gulf of Suez

Generally, the maximum values of most studied metals were found in pelagic and filter feeding fish This result can suggests that the carnivorous fish species tested in the present study tend to regulate metals although its food (fish, crustaceans and molluscs) not regulate metals, and have high concentrations of metals Hardisty *et al* (1974) stated that, flounder, *Platichthys flesus*, from Severn Estuary having a diet of *Macoma balthica* (non-regulator) contained higher levels of Zn than those having a diet of crustaceans and small fish tend to regulate Zn

Samples of *Mytilus galloprovincialis, Parapenaeus longirostis, Merluccius merluccius*, and *Mullus barbatus* collected in the Saronikos Gulf (Athens) and analysed for Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb and Zn showed no evidence of elevated pollution levels (Bernhard, 1982) However, it is interesting to note that the Cu, Cr, Fe, Mn and Zn concentration of *M merluccius*, which probably preys on *P longirostis*, are lower than in *P longirostis* If it is confirmed by a food chain analysis, it means that the concentration of these metals decreased in higher levels of the food chain

Part III· The lipids content in the tissues of different fish species.

The lipid contents can affect the accumulation rate of metals in the tissue Hoar and Randall (1969) reported that, most of metals are usually stored in fatty tissues this observation is in accordance with the observations given by various authors (Pentreath, 1973, Bryan, 1973, Andereotis and Papadopoulou, 1980, El-Nady, 1981, Hafez, 1982 and El-Moselhy, 1993) Liver which is fatty tissue showed highest accumulation rate of most metals studied than other organs According to the literature, amount of lipid in the fish tissues affects the distribution of metals in the different organs of the same individual, from individual to other and from species to other, there are, of course, other factors which are important in the accumulation rate of the metals in fish Benemariya *et al* (1991) showed that, correlation between trace element levels in the fish and fish lipid were not found

The distribution of heavy metals within the tissues is vary from organ to other according to the target organ of the metal In the present study, the highest concentration of cadmium, copper, zinc, nickel and iron was observed in the liver which is fatty tissue Gills showed the highest concentration of cobalt While the lead was fluctuated between liver and gills tissues

Abdel-Salam (1981) and Salanki *et al* (1982) found that the liver had highest copper than other organs The former author observed also high amounts of zinc and lead in gonads Bendell-Young *et al*

(1986) recorded that, liver can accumulate cadmium with a level higher than those found in other organs

Bradley and Morris (1986) stated that, muscle tissue was a poor indicator of increased metal availability, while liver tissues was a good indicator for Cu, and kidney tissue was best for Ni In this context, Miller *et al* (1992) suggested that liver and kidney are better indicators of chronic Cu and Zn exposure than muscle

El-Nabawi *et al* (1987) showed that the liver had concentrations of Cd, Pb, Cu and Zn higher than in muscle tissue of investigated fish collected from Abu Qir Bay, Lake Idku and Lake Mariut Fujise *et al* (1988) discernibled that some metals showed organ - and metal specific accumulations, and recorded high concentration of lead and zinc in hard tissues of Dall's Porpoise as skin and bone

Hernandez *et al* (1990) reported that an important accumulation of metals was found in digestive tract, liver, and particularly in kidney, as well as in gills for lead and chromium

El-Moselhy (1993) observed that the highest concentration of cadmium and lead was found in bone tissues, while the highest copper was presented in liver, and zinc was recorded in gonads

Al-Mohanna (1994) stated that all the heavy metals were found to be accumulation more in liver and kidney, least concentrations of different metals were found in muscle tissue

Abdelmoneim *et al* (1994 b) showed that, in fish, the essential heavy metals Zn and Cu were accumulated in soft tissues as liver while the non- essential Pb and Cd were more accumulated in hard tissues (bone and gills)

Part IV: Uptake and retention mechanisms for the metal at different sites

A case study

Here, discussion will be focused on the response of a same species collected from different sites Statistical analysis was carried out to give accurate data *Saurida sp* was collected from three areas, Alexandria, and Port Said regions (Mediterranean) and Suez region (Gulf of Suez) Table (7) shows the range and mean (n = 32) length (cm) and weight (g) of the fish from each of the three regions The correlation coefficient (r) between length and weight is calculated This correlation is positive and highly significant for all regions (it is 0 97322 for Alexandria fish, 0 96431 for Port Said fish and 0 95735 for Suez fish) Consequently, it is expected either length or weight will give paralell relation when it is plotted against the concentration of metals In the present study, length was used to give an idea about the relationships between fish growth and its metals concentration in muscle (Figs 4 - 9)

1- Metal - length relationships:

Alexandria region

In fish from Alexandria (Table 8), each of Cd, Zn and Fe shows a negative correlation with the fish length While for the other heavy metals (Pb, Cu, Co and Ni) the correlation is positive But these

Table (7) Range, and mean of length and weight and their correlation coefficient (r) of *Saurida sp* collected from different sites (no of samples = 32)

Region		Alexandria	Port Said	Suez Gulf
Length (cm)	range	16 1 - 26 0	16 6 - 28 6	15 0 - 28 7
	mean	21 33	20 12	21 86
Weight (g)	range	26 43 - 139 00	29 30 - 157 00	19 10 - 159 20
	mean	76 28	57 26	70 48
r		0 97322	0 96431	0 95735

correlation (whether they are negative or positive) are insignificant (-0 5 < r < 0 5) On the other hand each of the major metals Ca, Mg and Na shows a negative correlation while K shows a positive correlation with fish length Surprisingly, calcium is the only metal that gave a significant correlation (r=-0 766) with length for Alexandria fish

Port Said region

Cadmium, cobalt and iron in fish from Port Said gave a negative correlation with the fish length, while other heavy metals (Pb, Cu, Zn and Ni) gave a positive correlation, but all these correlations like Alexandria region were insignificant Each of the major elements Ca and Na showed a negative correlation, while each of Mg and K gave a positive correlation In this region, only potassium has significant correlation with the fish length (r = 0 589)

Suez region

In fish from the Gulf of Suez, the correlation between each of Cd, Pb, Co, Ni and fish length is positive and insignificant This relation is inverse and insignificant for Cu (r = - 0 395) While, Zn and Fe gave a negative and significant correlation with fish length (r = - 0 682 and - 0 804, respectively) For the major element, K length relation was positive and marginally significant (r = 0 494), while for the other major metals, the correlation were negative and insignificant

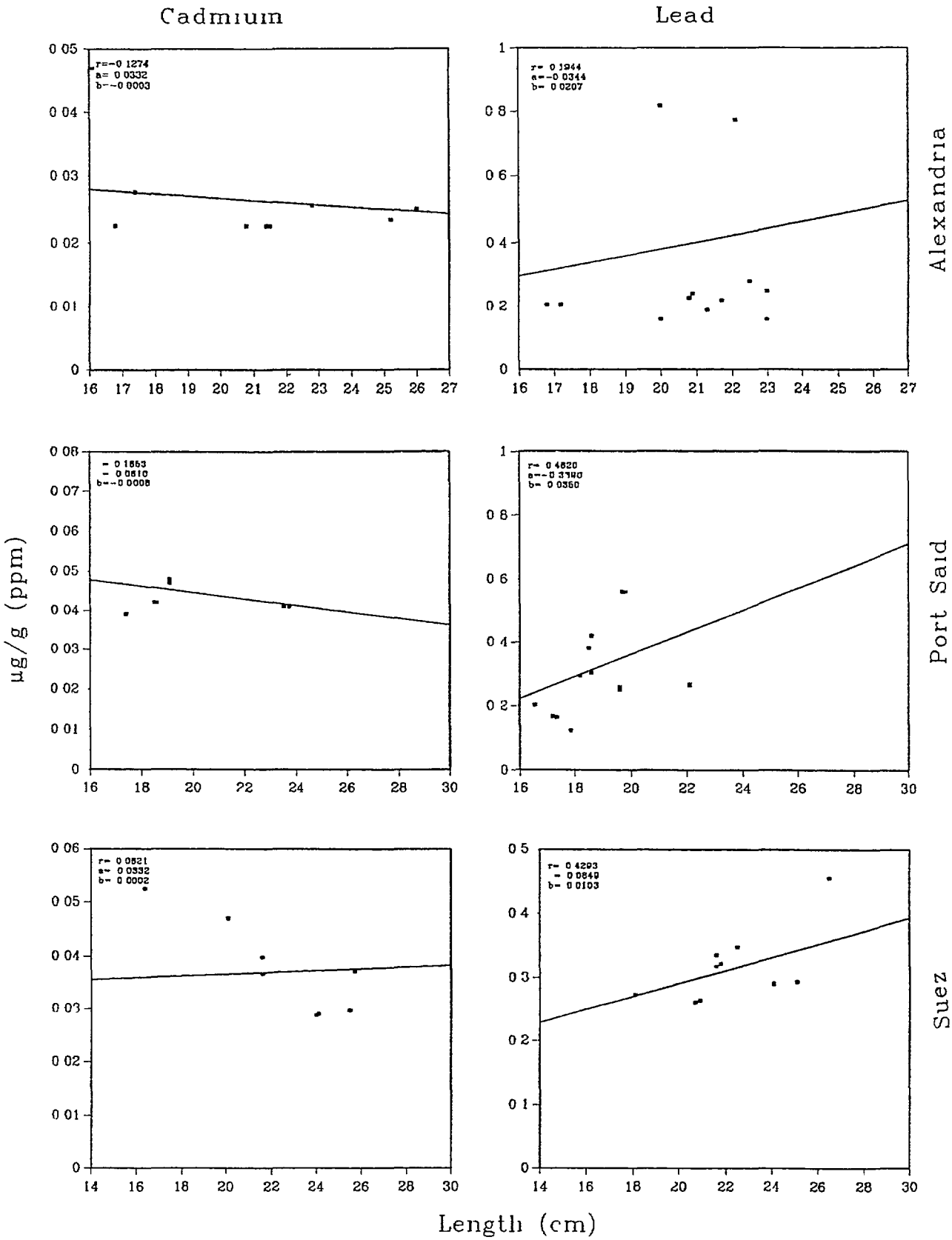


Fig (4) Relationships between length and metals (Cd, Pb) in muscles of fish, *Saurida sp* from different regions of Egyptian waters

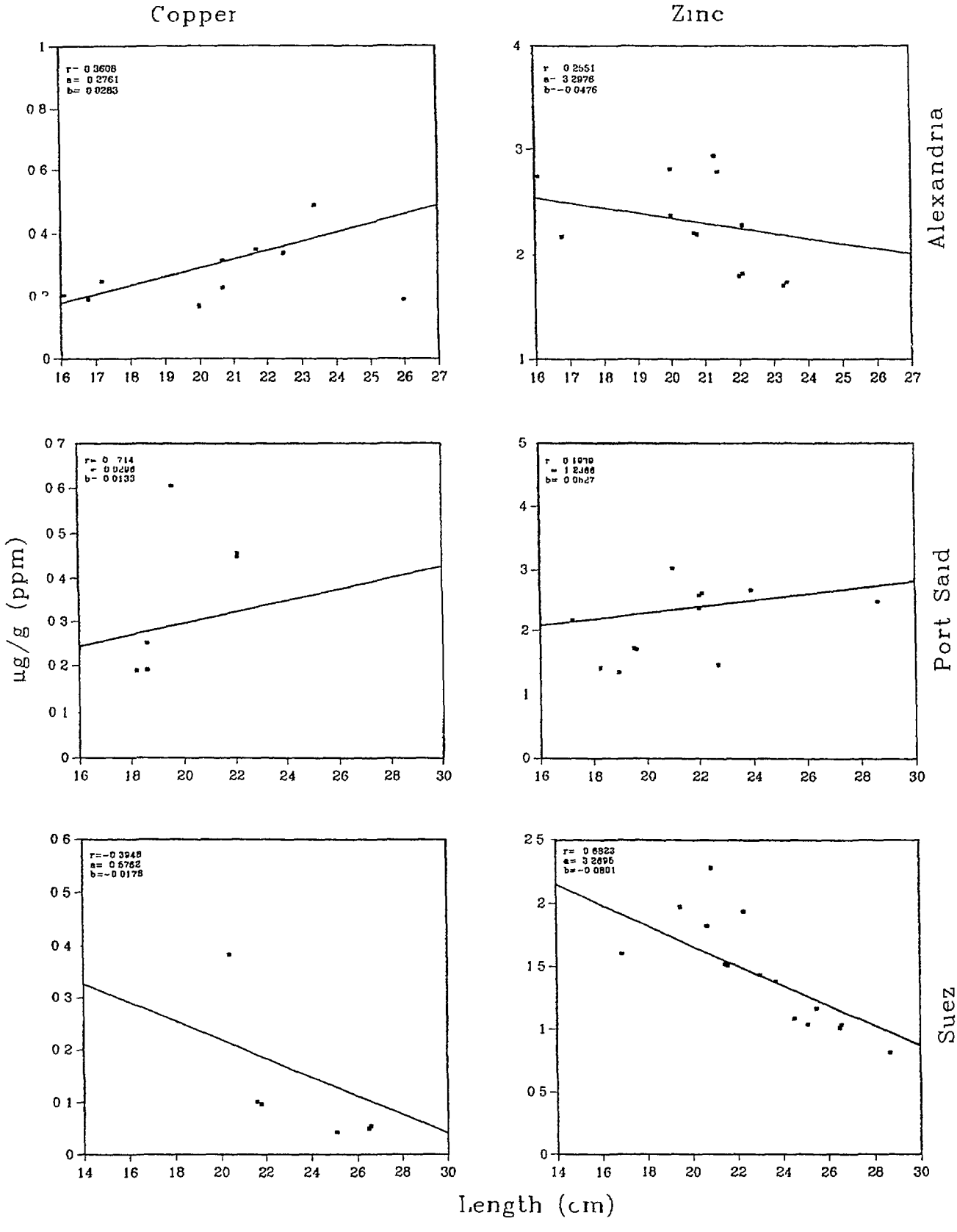


Fig (5) Relationships between length and metals (Cu, Zn) in muscles of fish *Saurida sp*, from different regions of Egyptian waters

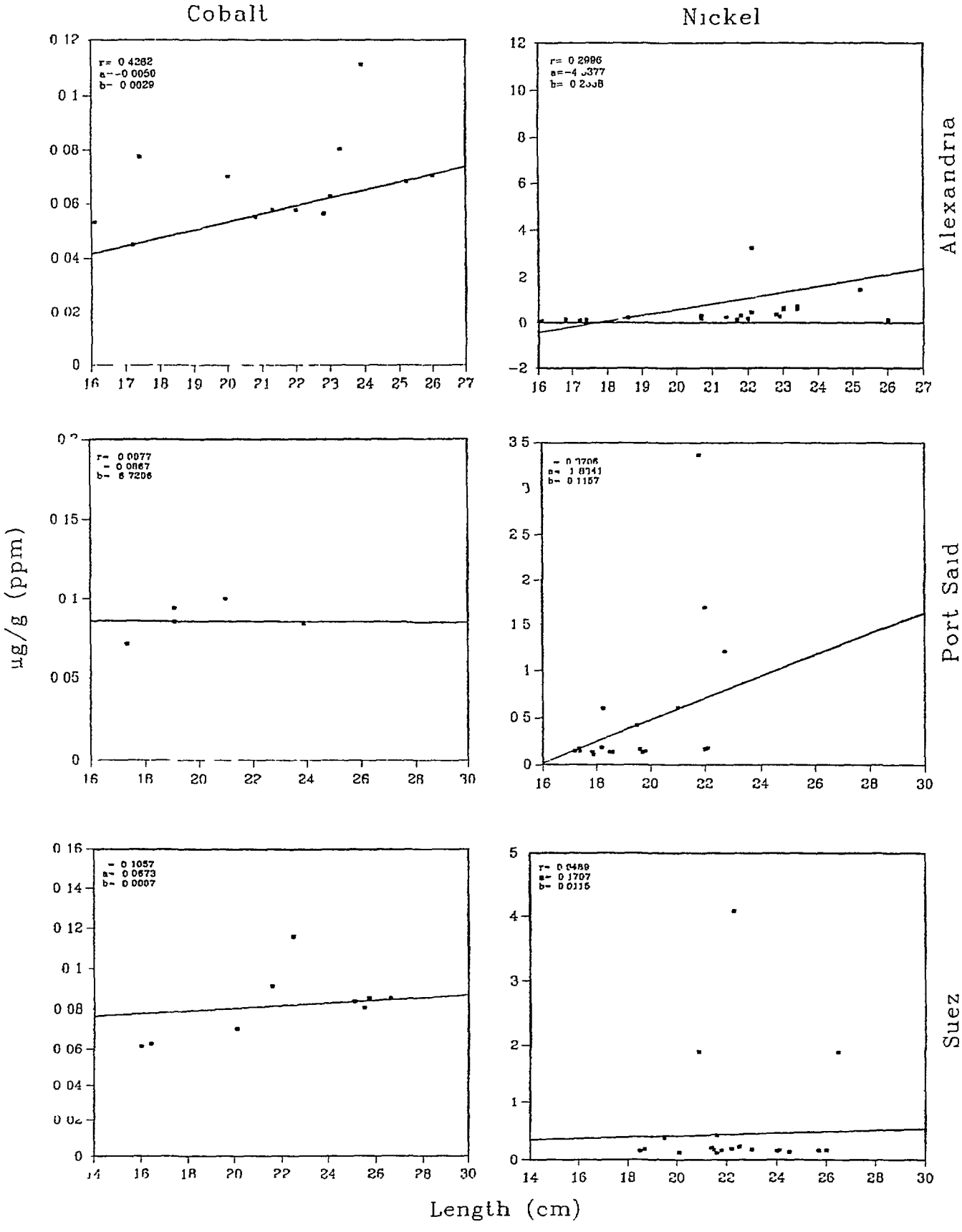


Fig (6) Relationships between length and metals (Co, Ni) in muscles of fish, *Saurida sp*, from different regions of Egyptian waters

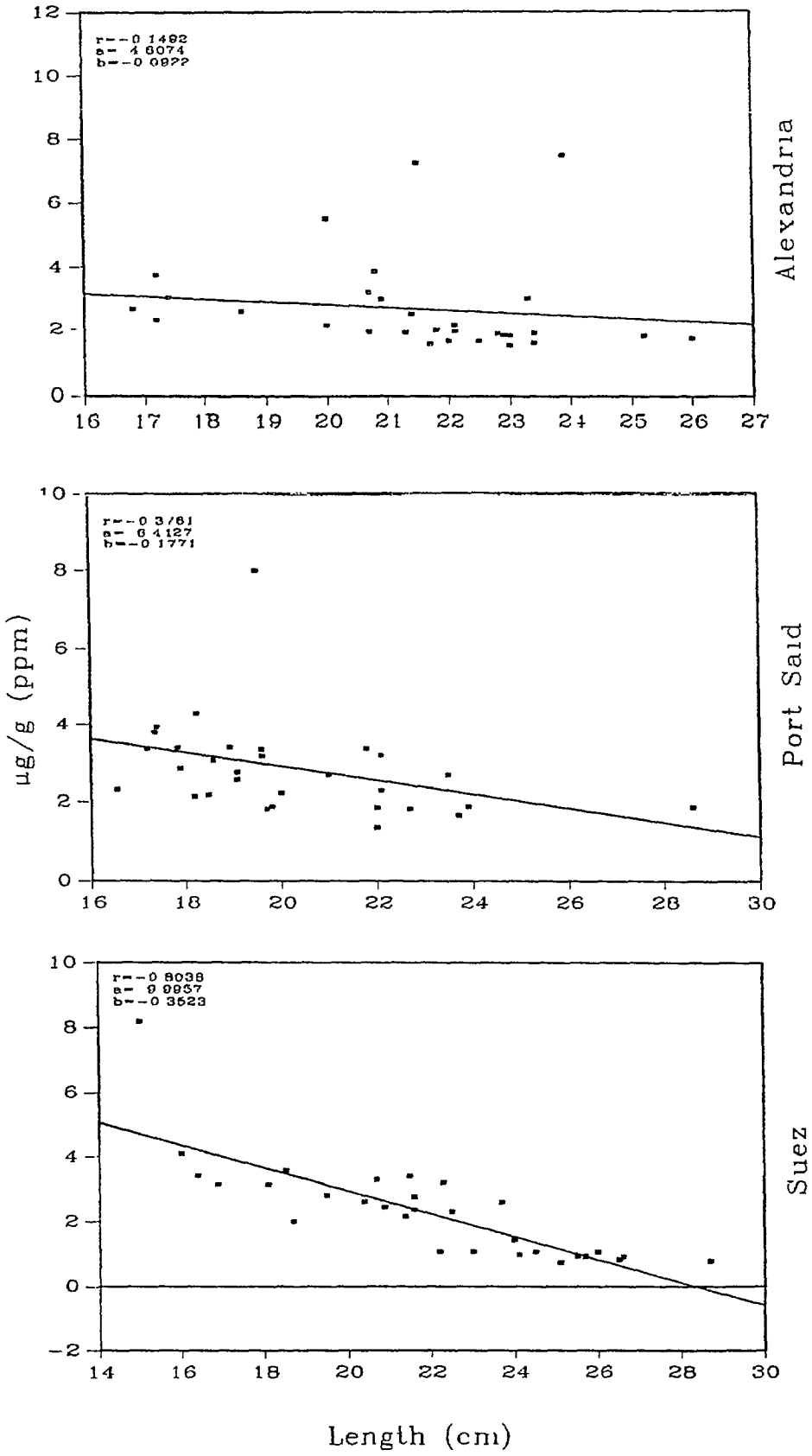


Fig (7) Relationships between length and metals (Fe) in muscles of fish, *Saurida sp*, from different regions of Egyptian waters

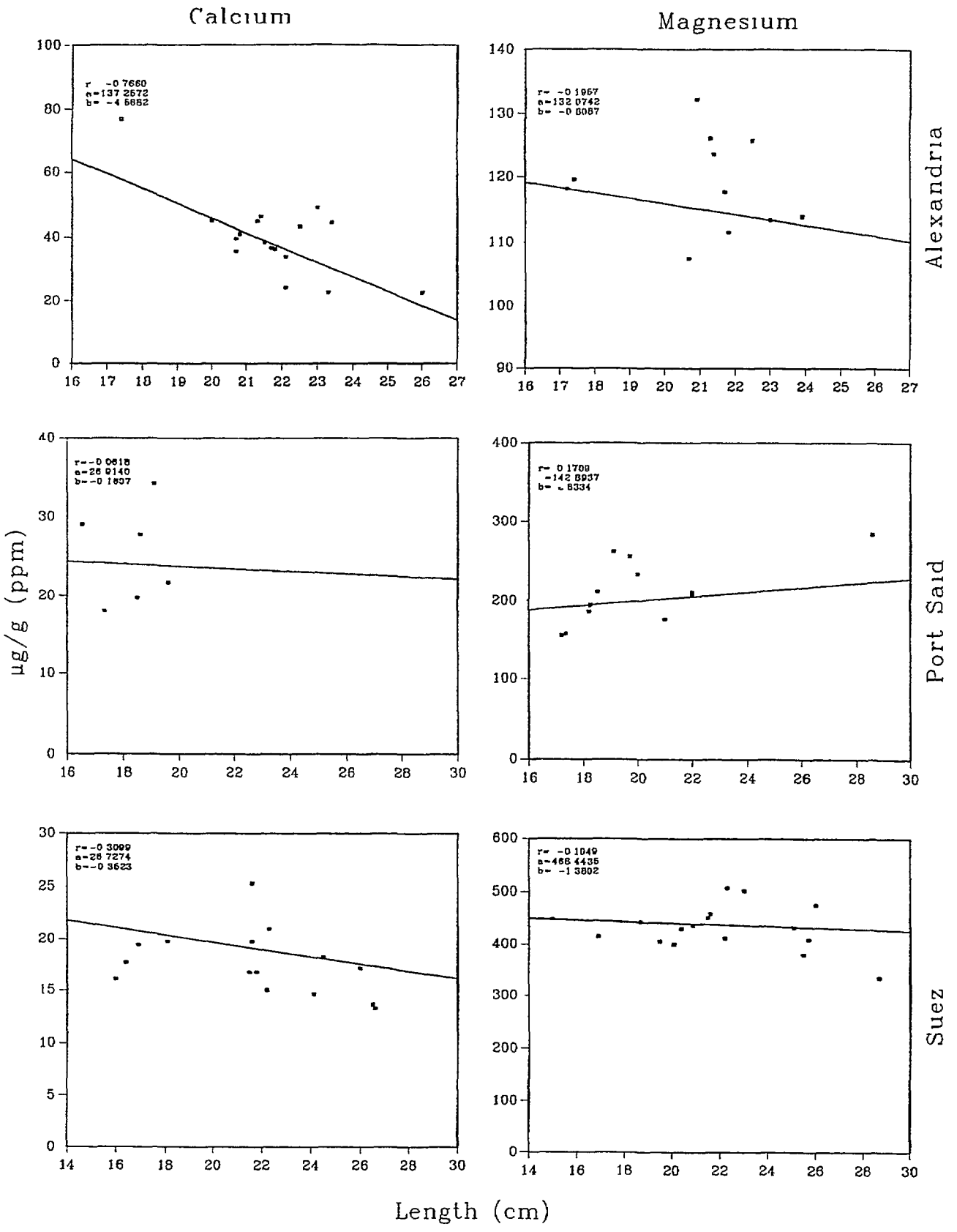


Fig (8) Relationships between length and metals (Ca, Mg) in muscles of fish, *Saurida sp*, from different regions of Egyptian waters

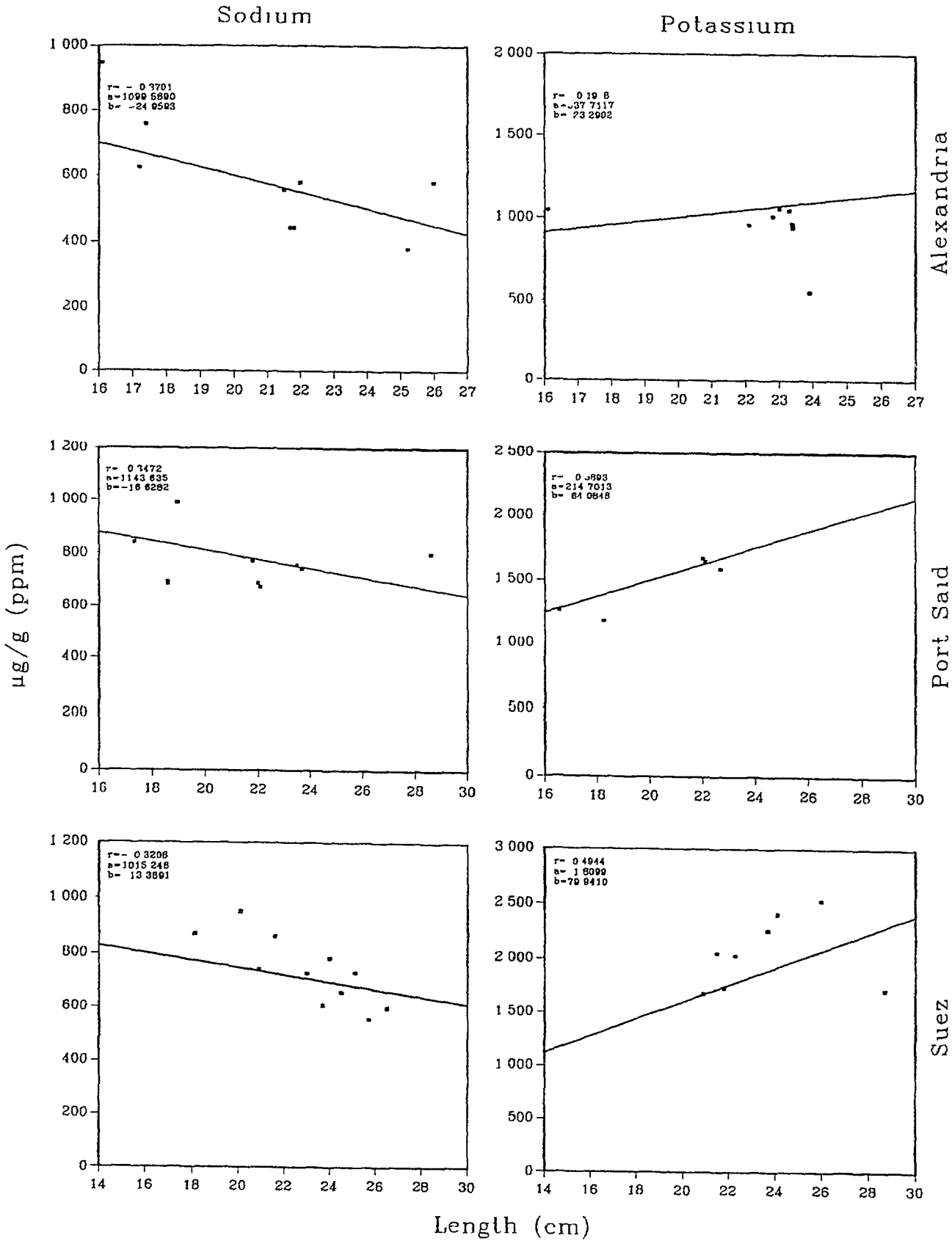


Fig (9) Relationships between length and metals (Na, K) in muscles of fish, *Saurida sp*, from different regions of Egyptian waters

Generally, most metals in muscle of fish, *Saurida sp* , recorded non- significant correlation with fish length whether positive or negative, except few, such as calcium in fish from Alexandria, potassium in fish from Port Said, and zinc and iron in fish from Suez In this context, Beveridge *et al* (1985) showed that, there was no significant difference between large and small fish in the levels of metals in the tissues examined (skin, muscle, bone and liver) Liver and flesh of eels, *Anguilla anguilla*, and roach, *Rutilus rutilus*, were examined to measure mercury, cadmium and lead (Barak and Mason, 1990), they found that, there were fewer significant relationships with fish length and the concentrations of cadmium and lead

Kalal *et al* (1990) recorded that, the heavy metal concentrations in the muscle of rainbow trout showed little increase with increasing body weight, and they concluded that the waters under investigation were safe for farming of edible fish

El-Moselhy (1993) studied four fish species from the Gulf of Suez, the concentration of copper increased apparently with the weight and length of all tested fish, but the correlation for other metals (Cd, Pb and Zn) were tended to be inversely proportional with the weight and length

Law and Singh (1991) showed a significant correlation between heavy metals content (Cu, Zn, Pb and Hg) in the edible tissues of three Malaysian fish species and body weight of fish

McFarlane and Franzin (1980) demonstrated a consistent positive correlation between copper in pike liver and fish age

In muscle and liver of three species of shark from the Bahia Blanca estuary, Argentina, metal concentrations (Hg, Cd and Zn) showed an increasing patterns proportionally to the total length of the sharks (Marcovecchio *et al* , 1991)

Khalaf *et al* (1986) reported that, the relationships of metals (Cd, Cu, Mn, Pb and Zn) with age and fish weight were generally insignificant However in case of small fish, the metal concentration decrease with increasing weight and the large fish showed some increasing trend

Hornung and Ramelow (1987) studied the relationships between metal concentrations (Cd, Cr, Cu and Zn) and length for *Mullus barbatus* collected from eastern Mediterranean, and showed that there was no significant correlation between metals and length of fish

Haynex *et al* (1995) recorded that the tissue weight of the bivalve, *Donax deltoides*, was negatively and insignificant correlated with metal concentrations (Cd, Cu, Hg, Mo, Ni, Se and Zn)

Boyden (1974) suggested that the relationship of metal content to body weight of a wide range of molluscs was governed by physiological rather than environmental factors While Coughtrey and Martin (1977) stated that the rate of uptake of metal with increasing body weight might be useful in the comparison of polluted and non polluted sites

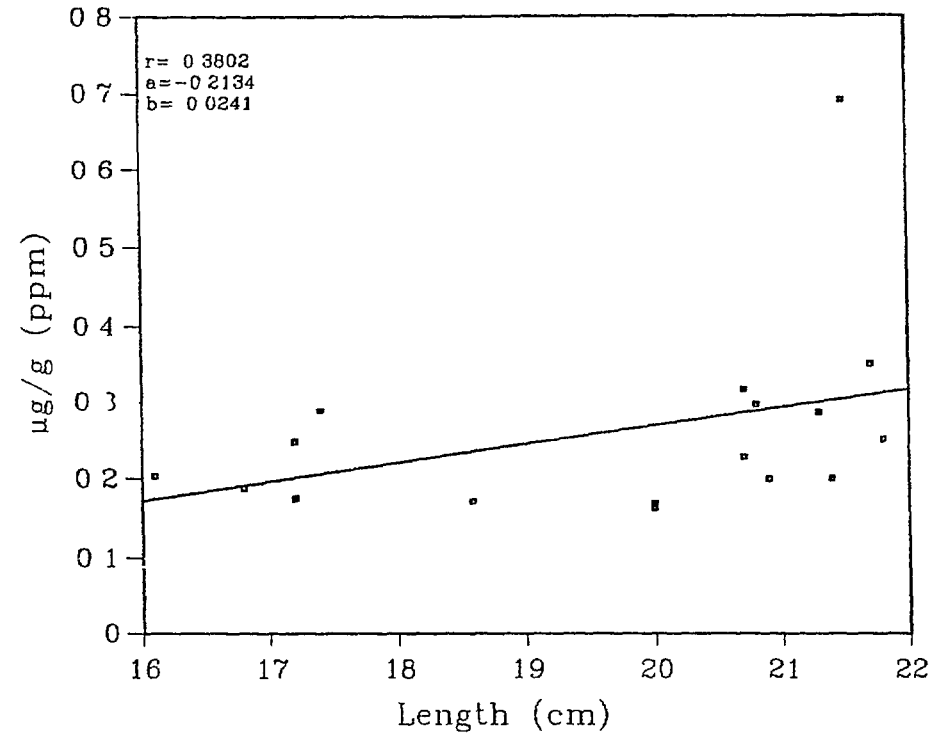
2- Copper - length relationships:

In the present study, relationship between copper and fish length showed a particular case in the muscle of fish, *Saurida sp* , collected from the three tested regions (Figs , 10 - 12)

In the small fish (length < 22 0 cm), copper showed a positive relationships with length, and the correlation coefficient for Alexandria, Port Said and Suez fish were 0 3802, 0 7137 and 0 8711, respectively (insignificant for Alexandria and significant for Port Said and Suez) While for large fish (length ≥ 22 0 cm), the relations were inversely and the correlation coefficient were -0 1415, -0 5450 and -0 5490 (insignificant for Alexandria and significant for Port Said and Suez)

Copper is an essential element for animal life Its involvement in various physiological mechanisms (growth, haemoglobin formation, enzymatic activities and other metabolic processes) is clear Therefore, copper in the small fish, which are in development stage, may present in the tissues with large amounts than that in the large one Underwood (1956) recorded that the whole body content of copper in new-born animals was greater than that in the adult

In this context, Fouda (1987) showed that the content of copper and zinc was decreased in muscle, skin and bone compered with the increase of fish age Tacon and De Silva, 1983 discussed that the mineral requirement of small fish, particularly zinc and copper, is higher than that of adult fish in view of the high metabolic activity and growth in small fish



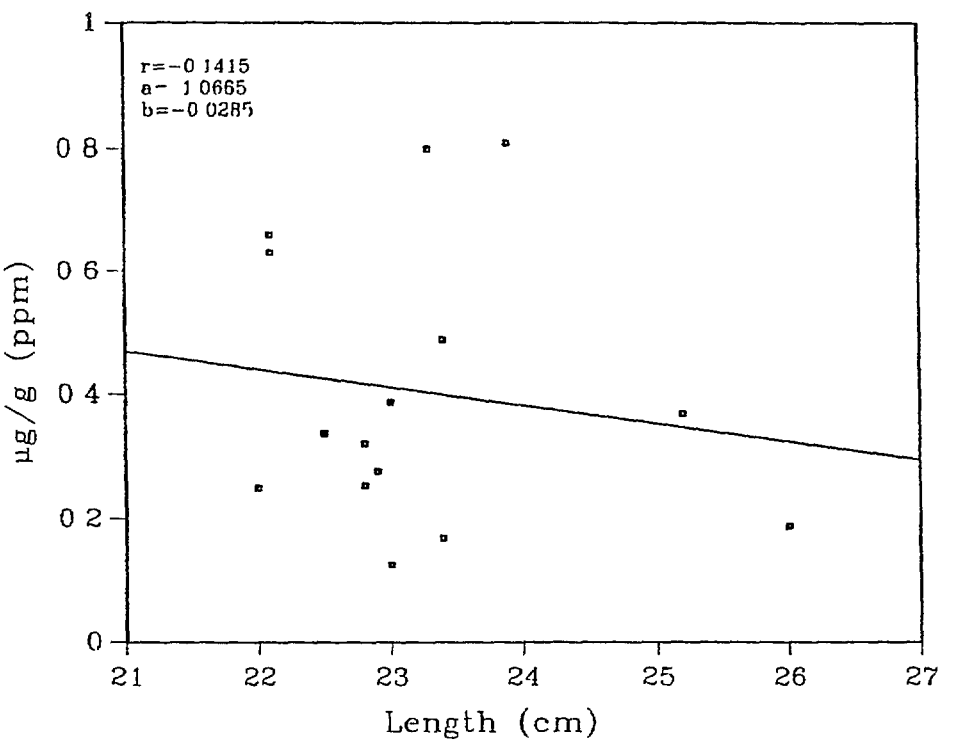
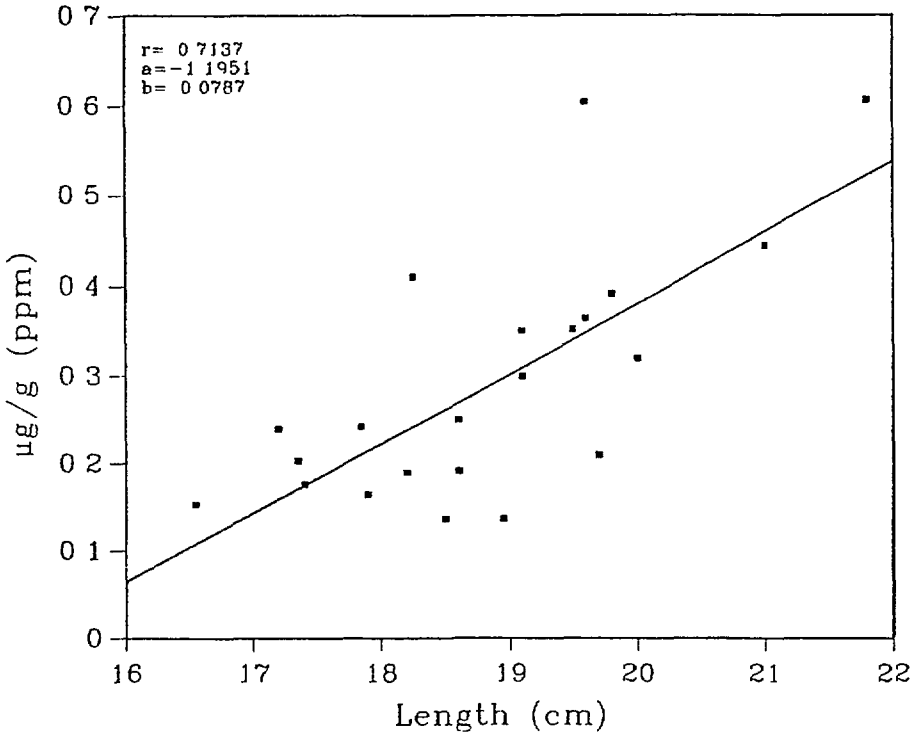


Fig (10) Relatioship between copper and two length groups of *Saurida sp* from Mediterranean water at Alexandria



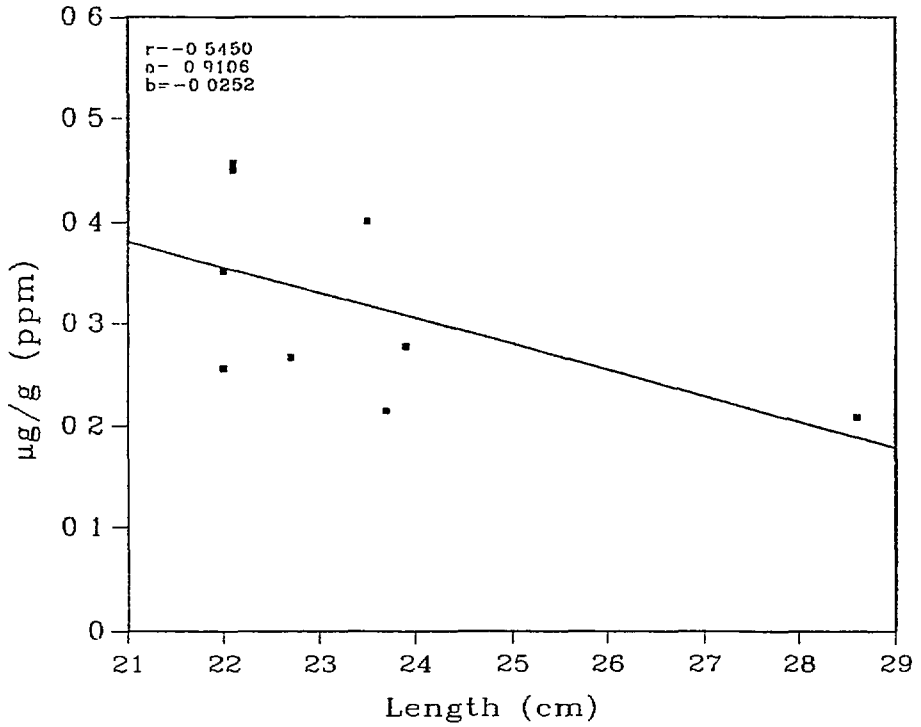


Fig (11) Relatioship between copper and two length groups of *Saurida sp* from Mediterranean water at Port Said

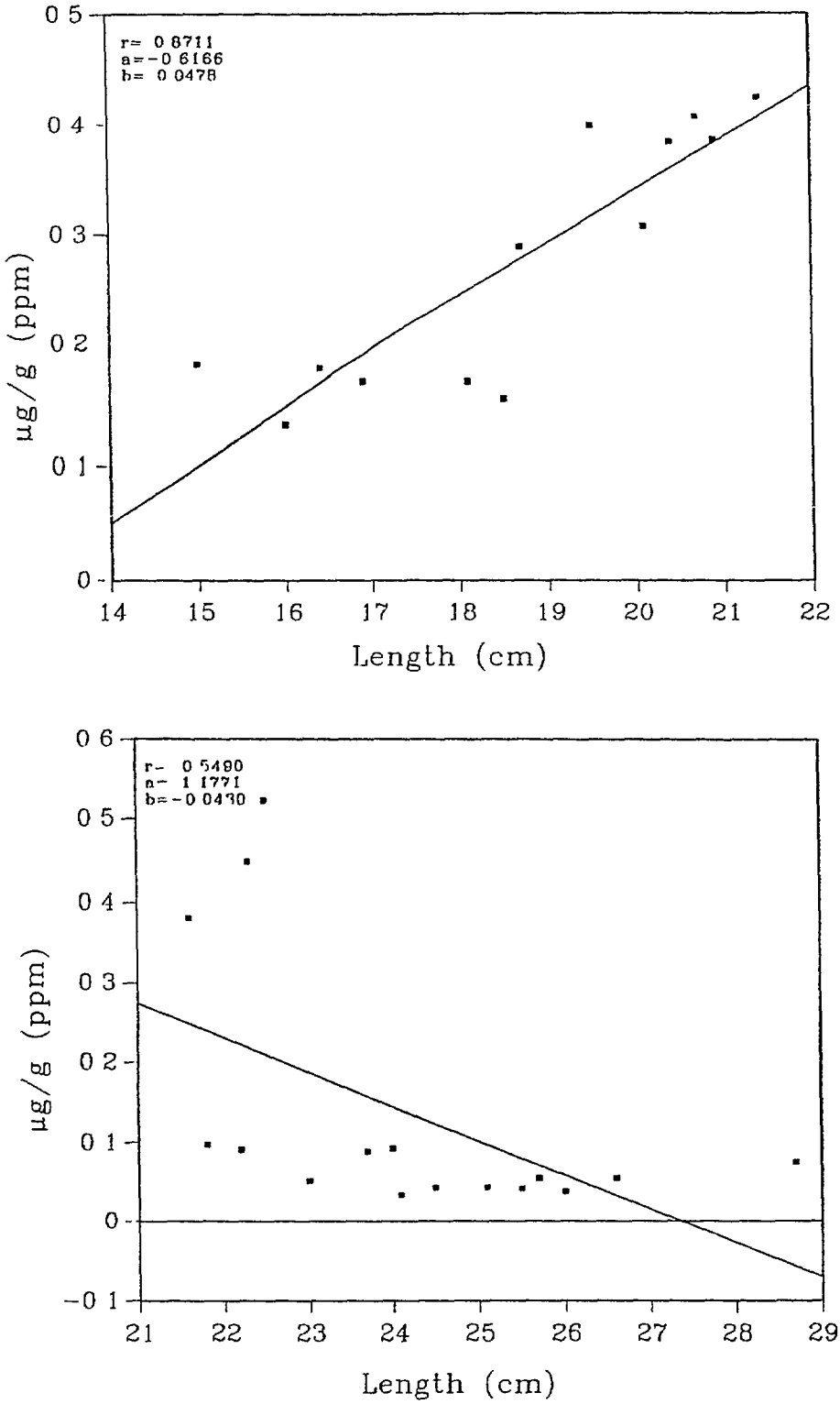


Fig (12) Relatioship between copper and two length groups of *Saurida sp* from Suez Gulf water at Suez

This inverse relationship of copper with the fish length was also reported by many authors (Cross *et al*, 1973, Boyden, 1974, Marks *et al*, 1980, Honda *et al*, 1983 and 1987, Anil and Wagh, 1988, Wagemann *et al*, 1990, Abdelmoneim and El-Deek, 1992, Emara *et al*, 1993)

3- Metals interrelationships:

Tables (8 - 10) show the correlation matrix of metal versus metal in the fish, *Saurida sp*, collected from Alexandria, Port Said and Gulf of Suez, and the significant relationships are illustrated in Figs (13-18)

The following remarks are obviously noticed

1- Fish from Port Said region had a poor significant correlation between metals, and this indicate that, the accumulation of metals by the marine organisms from the Port Said waters is affected by various and complicated factors, such as wind and current regime (ENODC, personal communication), variation in salinity during different months, impact of different pollution sources and so on

2- Lead did not record any significant correlation with other metals in all studied regions

3- Most of significant correlation were observed for essential and major elements, perhaps due to their common existence in mineral deposits

Table (8) Correlation matrix total length vs metal, metal vs metal in the muscle of *Saurida sp* collected from Alexandria

	Cadmium	Lead	Copper	Zinc	Cobalt	Nickel	Iron	Calcium	Magnesium	Sodium	Potassium	Length
Cadmium	1 000											
Lead	-0 142	1 000										
Copper	-0 392	0 178	1 000									
Zinc	0 208	-0 030	-0 522	1 000								
Cobalt	0 041	-0 218	0 423	0 024	1 000							
Nickel	-0 264	0 039	0 678	0 363	0 682	1 000						
Iron	-0 318	0 055	0 432	-0 264	0 202	0 587	1 000					
Calcium	0 309	-0 444	-0 348	0 332	-0 137	-0 230	0 137	1 000				
Magnesium	0 457	-0 455	-0 417	0 521	0 067	-0 223	-0 182	0 494	1 000			
Sodium	0 514	-0 150	-0 173	0 373	0 026	-0 173	0 035	0 568	0 661	1 000		
Potassium	0 081	0 262	-0 294	0 623	0 222	-0 276	-0 480	-0 195	0 078	0 064	1 000	
Length	-0 127	0 194	0 361	0 255	0 428	0 300	-0 149	-0 766	-0 195	-0 390	0 196	1 000

- 0 5 > r > 0 5 is significant

Table (9) Correlation matrix total length vs metal, metal vs metal in the muscle of *Saurida sp* collected from Port Said

	Cadmium	Lead	Copper	Zinc	Cobalt	Nickel	Iron	Calcium	Magnesium	Sodium	Potassium	Length
Cadmium	1 000											
Lead	-0 493	1 000										
Copper	0 242	0 049	1 000									
Zinc	-0 058	0 271	0 233	1 000								
Cobalt	0 524	-0 249	0 300	-0 189	1 000							
Nickel	0 124	0 023	0 369	0 306	0 049	1 000						
Iron	0 201	-0 348	0 137	-0 240	0 039	-0 096	1 000					
Calcium	-0 309	0 410	-0 357	0 024	-0 279	-0 361	0 028	1 000				
Magnesium	-0 332	0 125	-0 158	0 186	-0 203	-0 052	-0 301	0 310	1 000			
Sodium	0 146	-0 397	0 148	-0 326	0 285	-0 096	0 533	0 050	0 127	1 000		
Potassium	0 008	0 375	0 106	0 090	0 013	0 231	-0 463	-0 028	0 00001	-0 493	1 000	
Length	-0 165	0 462	0 271	0 194	-0 008	0 371	-0 376	-0 062	0 171	-0 347	0 589	1 000

- 0 5 > r > 0 5 is significant

Table (10) Correlation matrix total length vs metal, metal vs metal in the muscle of *Saurida sp* collected from the Gulf of Suez

	Cadmium	Lead	Copper	Zinc	Cobalt	Nickel	Iron	Calcium	Magnesium	Sodium	Potassium	Length
Cadmium	1 000											
Lead	0 247	1 000										
Copper	0 189	-0 092	1 000									
Zinc	0 131	-0 231	0 632	1 000								
Cobalt	0 289	0 212	0 537	0 180	1 000							
Nickel	0 254	0 336	0 341	0 243	0 563	1 000						
Iron	-0 001	-0 301	0 345	0 622	0 056	0 120	1 000					
Calcium	0 250	-0 181	0 632	0 460	0 389	0 080	0 396	1 000				
Magnesium	0 528	0 271	0 439	0 416	0 431	0 279	0 191	0 529	1 000			
Sodium	0 285	-0 010	0 655	0 480	0 288	0 196	0 228	0 506	0 562	1 000		
Potassium	0 109	0 406	-0 137	-0 182	0 143	0 157	-0 498	-0 317	0 340	0 037	1 000	
Length	0 062	0 429	-0 395	0 682	0 106	0 049	-0 804	-0 310	-0 105	-0 321	0 494	1 000

- 0 5 > r > 0 5 is significant

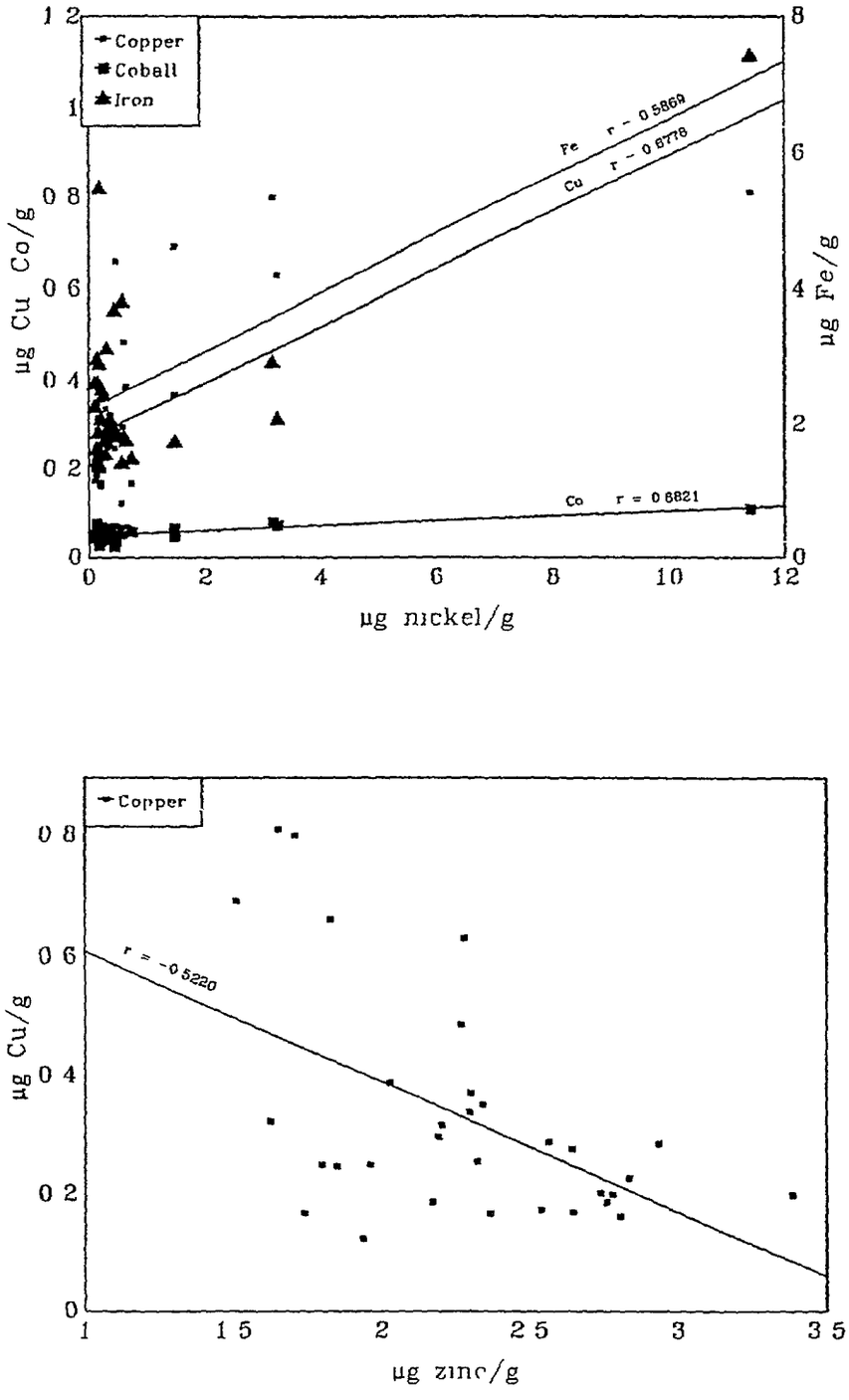
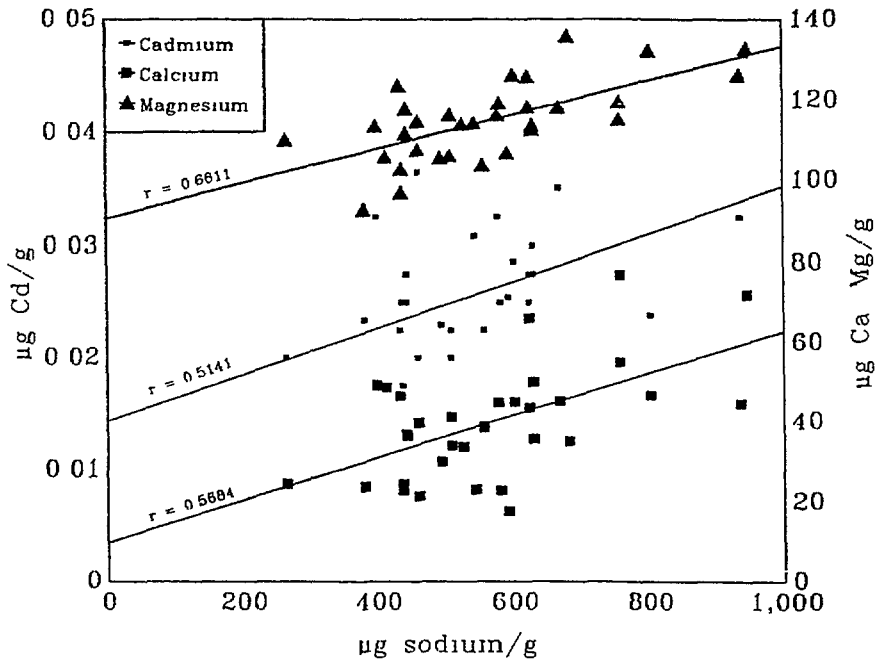


Fig (13) Relationships between metals in the muscles of *Saurida sp* from Alexandria region



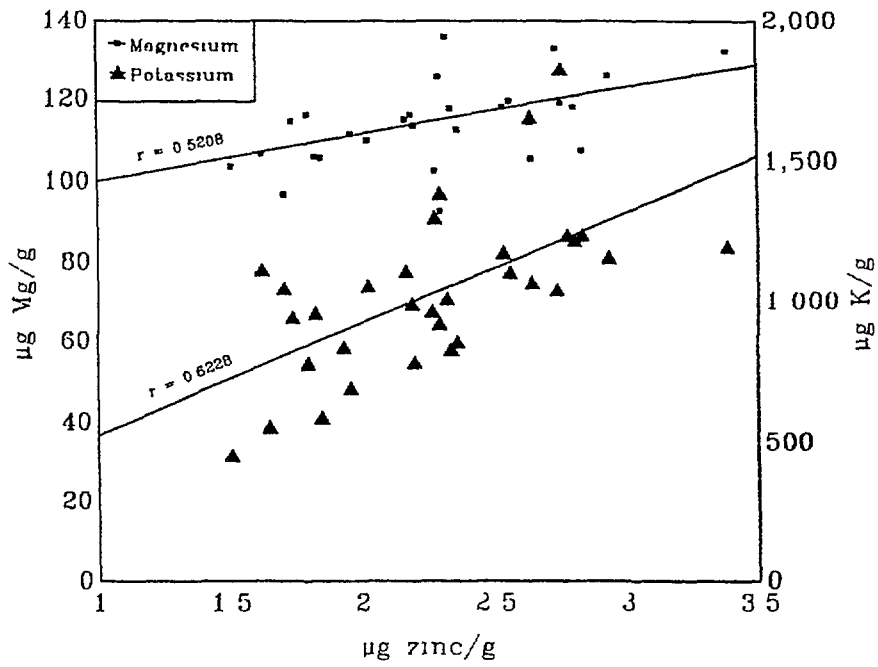
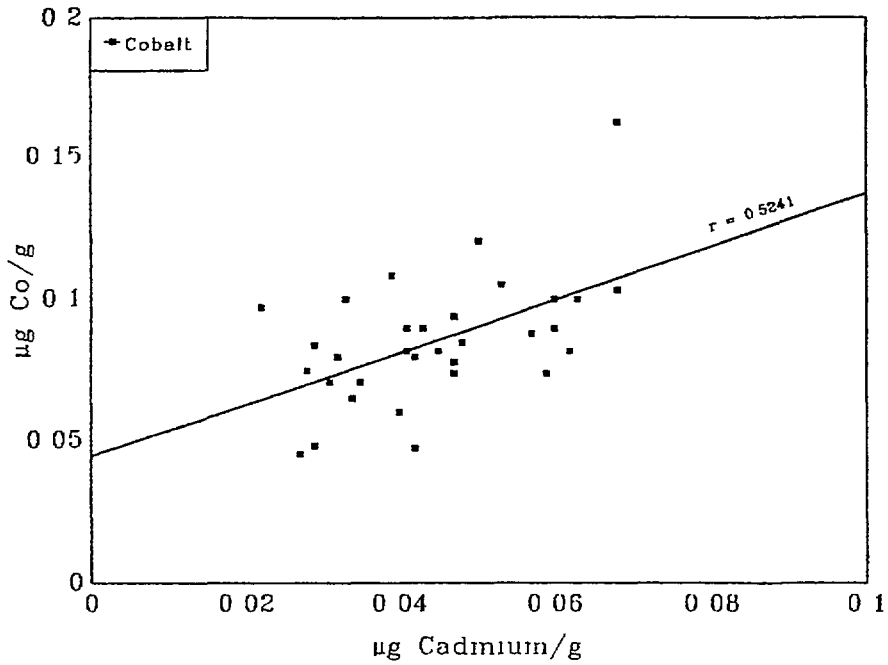


Fig (14) Relationships between metals in the muscles of *Saurida sp* from Alexandria region



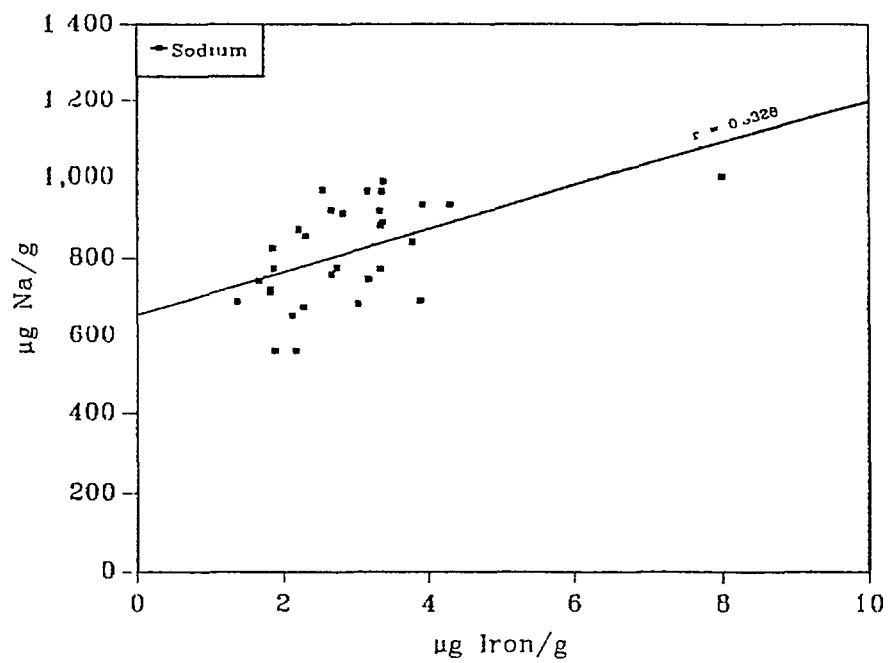


Fig (15) Relationships between metals in the muscles of *Saurida sp* from Port Said region

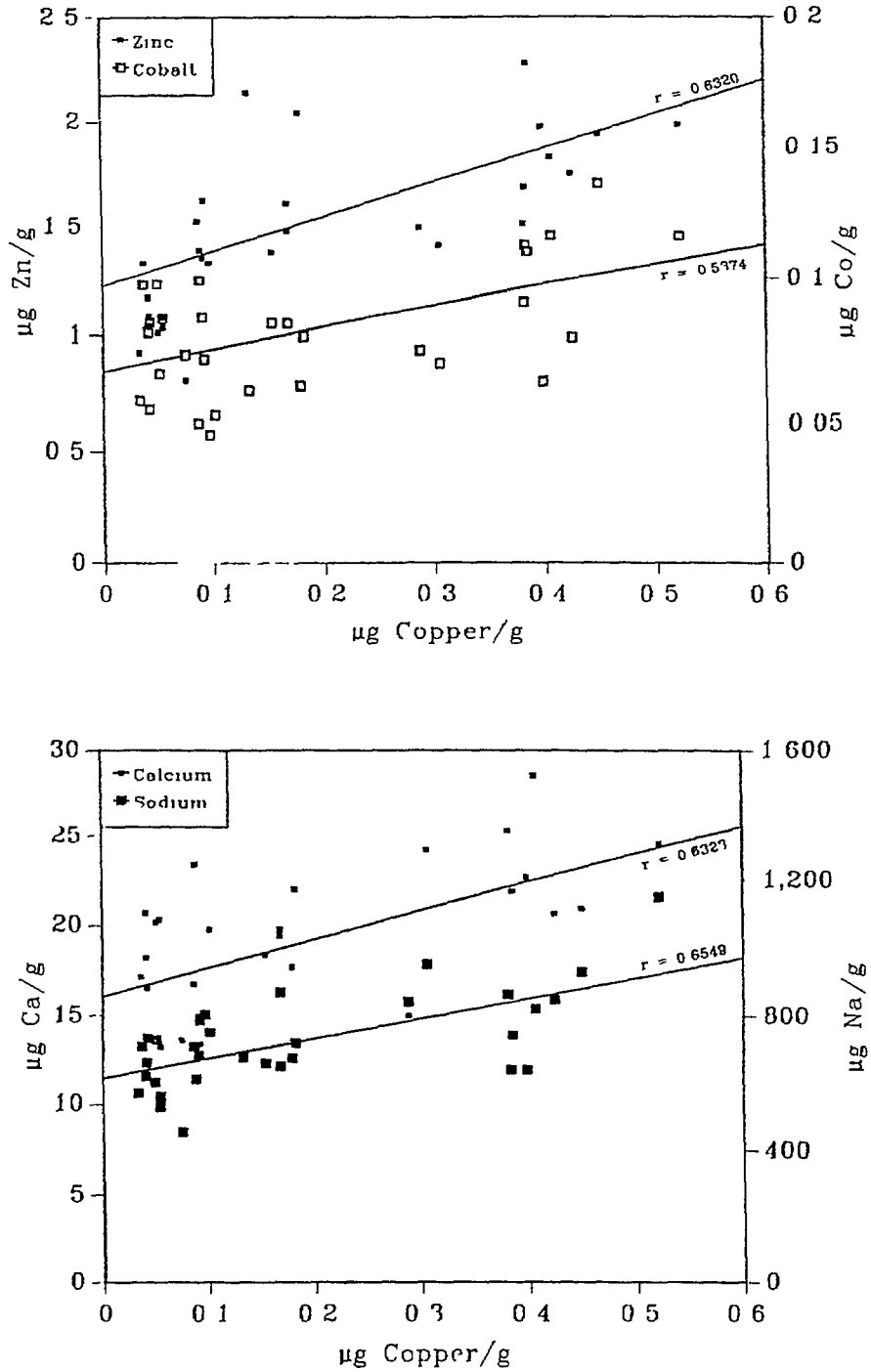
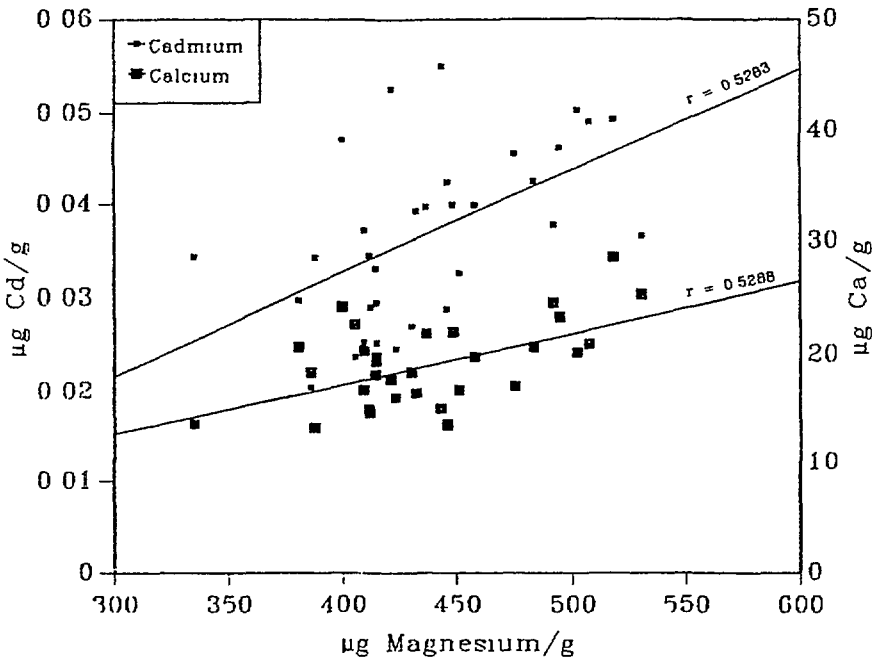


Fig (16) Relationships between metals in the muscles of *Saurida sp* from the Gulf of Suez



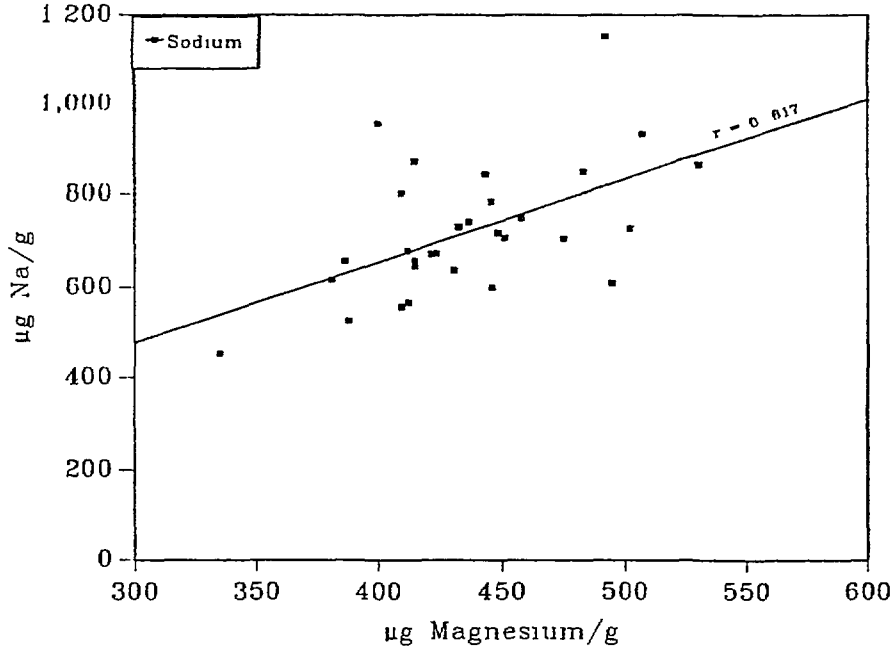


Fig (17) Relationships between metals in the muscles of *Saurida sp* from the Gulf of Suez

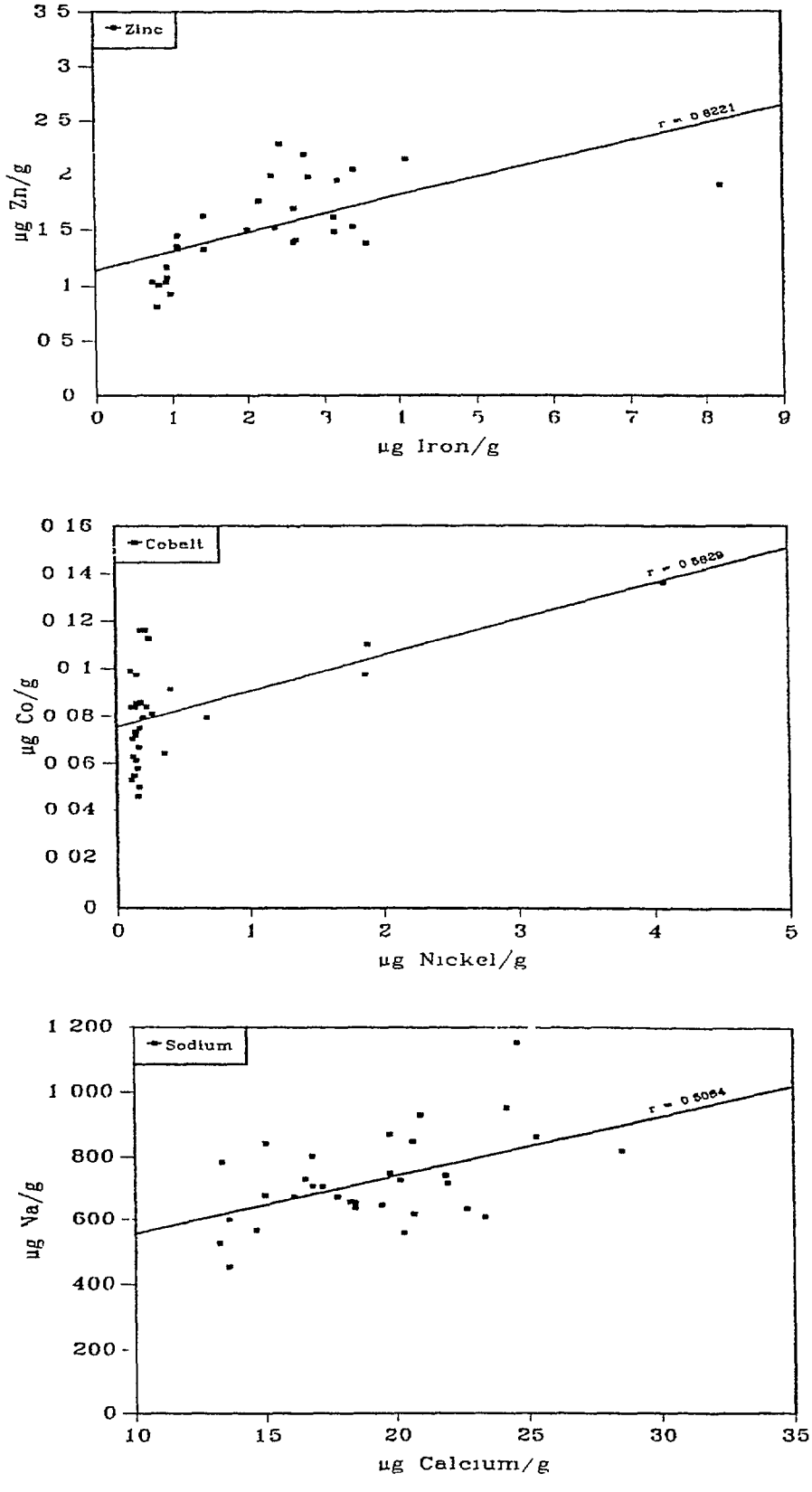


Fig (18) Relationships between metals in the muscles of *Saurida sp* from the Gulf of Suez

4- Calcium and magnesium showed the same patterns when correlated with other metals and length of fish, and this indicates that the fish have similar response to these two elements, also the metabolic reaction of calcium and magnesium has the same affinity

Holwerda (1991) reported that, cadmium and copper inhibit each other, when *Anodonta cygnea* was exposed to a concentrations of cadmium and copper in their aquarium The Cd-accumulation factor (AF) for whole animal was reduced by 90 % in the presence of Cu and Cu-AF was reduced by 50 % in the presence of Cd In the present study, the relationship of cadmium and copper in the fish from Alexandria was coincided with the result of Holwerda, where the correlation coefficient was negative (- 0 392)

Peterson *et al* (1989) observed that copper and zinc were consistently positively correlated for all tested fish species, in this context, one of the copper or zinc was increased in the presence of the other in the muscle of *Mytilus edulis* (Elliott *et al* , 1986) Similar result was obtained in *Saurida sp* from Port Said and Gulf of Suez (r = 0 233 and 0 632, respectively), while the fish from Alexandria showed a negative correlation between Cu and Zn (r = - 0 522)

Tariq *et al* (1991) estimated the correlation coefficient between major cations and heavy metals in fish from the Arabian Sea They reported a significant correlation ($r \geq 0\ 468$) between the concentrations of trace metals and major cations Also, stronger correlation ($r \geq 0\ 900$) were observed to exist between calcium and/or

magnesium and Cd, Fe, Hg, Mn and Pb in *Loligo duvauceli*, for Cr, Mn, Ni and Pb in *sardinella longiceps* and for Cd alone in *Lapturacanthus savala*

Haynex *et al* (1995) investigated the inter-element correlation in bivalve, *Donax deltoides*, and recorded a significant correlation of zinc with mercury, nickel and selenium, selenium with copper and mercury, and nickel with copper In this context, Honda *et al* (1987) reported a positive and significant correlation for copper with zinc, nickel with lead, cobalt with lead and nickel, cadmium with zinc and copper, and mercury with zinc, copper and cadmium, in southern minke whales *Balaenoptera acutorostrata*

Huggett *et al* (1973) showed that, while there was no relationship of zinc concentration and body weight in the eastern oyster (*Crassostrea virginica*) the relationship of copper and zinc concentrations could be used to indicate unnatural inputs of these metals into the environment

4- Level of metals in the fish *Saurida sp.* and its concentration factors:

Table (11) shows the concentrations of the seven heavy metals (Cd, Pb, Cu, Zn, Co, Ni and Fe) and that of four major elements (Ca, Mg, Na an K) in the fish muscle of *Saurida sp* collected from Alexandria, Port said and the Gulf of Suez waters

The maximum levels of cadmium (0 044 ppm), Zinc (2 296 ppm), cobalt (0 085 ppm), iron (2 879 ppm) and sodium (811 94 ppm) were observed in the fish from Port Said waters While, Pb, Cu, Ni and Ca were recorded its highest level (0 408, 0 328, 0 919 and 39 826 ppm, respectively) in the fish from Alexandria waters Magnesium and potassium were elevated in the fish from the Gulf of Suez (438 24 and 1749 27 ppm, respectively)

To determine the concentration factors (CF) of the trace metals (Cd, Pb, Cu, Zn, Co, Ni and Fe) in fish from all tested regions, the levels of these metals in water at different areas were collected from the literature and tabulated (Table, 12) Data for Cd, Pb, Cu and Zn were enough presented to compare the CF in all regions

Table (13) shows the concentration factors of metals in fish, *Saurida sp* , from Alexandria, Port Said and Gulf of Suez It can be noticed that, the concentration factors of Cd, Pb, Cu and Zn were found to be higher in Port Said than those of the others (Alexandria and Gulf of Suez), this result indicate that the fish from Port Said have the ability

Table (11) Range, mean and standard error (S E) of metals level (ppm) in muscle of *Saurida sp* collected from different sites (Egypt) (no of samples = 32)

Metal	Region	Alexandria	Port Said	Suez Gulf
Cd	range	0 015 - 0 0469	0 022 - 0 068	0 0205 - 0 055
	mean	0 0261	0 0444	0 0369
	S E	0 0011	0 0023	0 0016
Pb	range	0 159 - 0 909	0 123 - 0 924	0 103 - 0 455
	mean	0 4075	0 3651	0 3095
	S E	0 0456	0 0343	0 0143
Cu	range	0 125 - 0 810	0 136 - 0 606	0 0335 - 0 522
	mean	0 3278	0 2969	0 1865
	S E	0 0336	0 0222	0 0269
Zn	range	1 509 - 3 386	1 316 - 4 456	0 810 - 2 279
	mean	2 2817	2 2962	1 5195
	S E	0 0798	0 123	0 070
Co	range	0 025 - 0 111	0 045 - 0 162	0 046 - 0 136
	mean	0 057	0 0853	0 0818
	S E	0 0029	0 004	0 0038
Ni	range	0 089 - 11 430	0 057 - 3 365	0 11 - 4 083
	mean	0 9186	0 493	0 4221
	S E	0 3651	0 1414	0 1403
Fe	range	1 442 - 7 440	1 369 - 7 991	0 742 - 8 199
	mean	2 6408	2 8793	2 2936
	S E	0 2642	0 2133	0 2615
Ca	range	17 71 - 76 79	12 17 - 37 92	13 24 - 28 54
	mean	39 826	23 682	19 025
	S E	2 55	1 176	0 679
Mg	range	92 64 - 135 89	124 29 - 284 31	334 77 - 530 54
	mean	114 826	199 895	438 274
	S E	1 766	7 509	7 847
Na	range	265 79 - 947 37	260 0 - 1001 5	451 27 - 1151 71
	mean	567 254	811 936	722 571
	S E	27 35	21 755	24 906
K	range	545 10 - 1822 92	994 9 - 1943 7	597 1 - 2835 8
	mean	1034 45	1503 939	1749 271
	S E	50 849	49 255	96 469

Table (12) Concentration (µg/L) of the dissolved heavy metals in the water of each of the different sites (Egypt)

Location	Cadmium	Lead	Copper	Zinc	Cobalt	Nickel	Iron	Reference
Alexandria	0 17	0 60	3 78	21 90	---	---	74 00	Aboul Dahab, 1985
	2 08 - 2 14	0 48 - 0 61	3 39 - 3 72	---	---	---	---	Shriadah and Emara, 1991
	---	---	---	162 4-178 0	0 05 - 0 07	0 47 - 0 55	24 8 - 26 0	Emara and Shriadah, 1991
	0 81 - 0 97	2 67 - 3 47	3 03 - 4 42	27 58-37 57	---	---	---	Abdelmoneim et al , 1994 b
	2 14	0 56	2 90	140 4	0 07	0 61	25 70	Emara et al , 1995
Port Said	0 15 - 0 93	0 36 - 3 51	0 23 - 3 82	1 78 - 17 57	---	---	---	Abdelmoneim and Fattouh, 1994
Gulf of Suez	---	1 00	1 60 - 9 60	1 62 - 29 22	---	---	11 32-2132 1	Abdel-Salam, 1981
	0 17 - 0 29	1 79 - 1 85	8 55 - 10 67	9 09 - 29 50	---	---	---	El-Moselhy, 1993

Table (13) Concentration factors of metals in *Saurida sp* collected from different sites

Metal	Alexandria	Port Said	Suez Gulf
Cadmium	12 2 - 153 5	47 7 - 296 0	127 2 - 217 1
Lead	117 4 - 727 7	104 0 - 1014 2	167 3 - 309 5
Copper	74 2 - 113 0	75 7 - 1290 9	17 5 - 116 6
Zinc	16 3 - 104 2	130 7 - 1290 0	51 5 - 938 0
Cobalt	814 3 - 5700 0	---	---
Nickel	1505 9	---	---
Iron	35 7 - 661 9	---	1 1 - 202 6

to concentrate the trace metals in its tissues much more than those of Alexandria and Gulf of Suez

5- One Way Anova analysis:

One Way Anova analysis for the metals in the muscle of fish, *Saurida sp*, collected from the three regions in the present study (Alexandria, Port Said and Gulf of Suez) was used to estimate the probability and difference in the metal content of the different areas (Table 14)

Cadmium, calcium, magnesium and sodium in the muscle of fish recorded high significant differences between all tested regions In contrast, lead, nickel and iron showed insignificant differences Copper and zinc showed insignificant differences between fish from Alexandria and Port Said only, while cobalt and potassium recorded insignificant differences between Port Said and Gulf of Suez fish These analysis indicate that there is a difference between the concentration of some elements in the tissues of the fish from the three areas while the other are similar, however, this similarity may observed for two areas only such as Cu and Zn in fish from Alexandria and Port Said

The present case study explain properly the response of fish in different sites "the animal involves different uptake and retention mechanisms for the same metal at different sites" Briefly the conclusion could operate in one of two reasons 1) the different populations of the same species at the three regions may have different

Table (14) Propability of metals in the muscles of *Saurida sp* at different sites using One Way Anova analysis

Area	Propability (P <)										
	Cd	Pb	Cu	Zn	Co	Ni	Fe	Ca	Mg	Na	K
Alexandria & Port Said	0 001	0 5	0 5	>0 5	0 001	0 5	0 5	0 001	0 001	0 001	0 001
Alexandria & Suez Gulf	0 001	0 05	0 01	0 001	0 001	0 5	0 5	0 001	0 001	0 001	0 001
Port Said & Suez Gulf	0 01	0 5	0 01	0 001	>0 5	>0 5	0 1	0 01	0 001	0 01	0 05
Alexandria Port Said & Suez Gulf	0 001	0 5	0 01	0 001	0 001	0 5	0 5	0 001	0 001	0 001	0 001

P < 0 001 Very highly significant
P < 0 01 Highly significant
P < 0 05 Significant
P < 0 1 & 0 5 Insignificant

abilities to accumulate metals, 2) the uptake of one metal affects the uptake of other metals

Individual variation for uptake and accumulation of metals from the environment can be expected in the same population, therefore, the different populations should have certain different abilities to accumulate metals

The second alternative has been extensively studied with the molluscs (e g Romeril, 1971, Coombs, 1972 and 1974. Coughtrey, 1975, Frazier, 1975, Martin and Felgal, 1975, Howard, 1975, Coughtrey and Martin, 1977, Elliott *et al* , 1986 and Holwerda, 1991), and is also suggested by the present correlation analysis of the data for the *Saurida sp* Significant correlation (0 5 < r < - 0 5) exist between most of the metals at Alexandria and Gulf of Suez, while at Port Said some were between cadmium cobalt and iron sodium Literature showed that, Cd uptake was significantly reduced by the presence of zinc (Bryan and Hummerstone, 1973, Jackim *et al* , 1977, Ray *et al* , 1979 and 1980 b) In juvenile minnows (*Phoxinus phoxinus*), Zn-induced increase in Cd turnover rate in the fish (Glynn *et al* , 1992) Effect of copper and lead on Cd bioaccumulation by herring eggs have been studied (Westernhagen *et al* , 1979), at 2 exposure concentrations, Cd contents of eggs were enhanced by lead and decreased by copper whereas, at an intermediate concentration, both copper and lead inhibited Cd accumulation Cadmium and copper inhibit each other, when *Anodonta cygnea* was exposed to a concentrations of cadmium and copper in their aquarium (Holwerda, 1991) In bivalve, *Donacilla cornea*, large increases in calcium concentrations were observed

following exposure to Cu and Cd (Regoli *et al*, 1991) The toxicity of cadmium was reduced in water with high calcium concentration (Gill and Epple,1992) Wicklund and Runn (1988) showed that ^{109}Cd uptake in the gills decreased with increasing Ca levels

(3) Sea food safety in Egypt

The risk to man can be estimated by comparing the metal intake from an observed consumption rate of seafood with the Provisional Tolerable Weekly Intake (PTWI) For a few trace metals these PTWIs have been published (Bebbington *et al*, 1997 and Bernhard, 1982) The following PTWI values are available

Provisional tolerable weekly intake in mg per 70 kg man

Cd	0 3
Pb	2 8
Cu	245 0

Table (15) shows the percentage of the present metal concentrations in fish muscle to that of PTWI The obtained result demonstrate that the concentrations of trace metals (Cd, Cu and Pb) in the muscle of fish species from different regions along the Egyptian coast would be much lower than the PTWI values and accordingly there is no risk from the human consumption of these fish The same results were recorded by Emara *et al* (1993) with the exception of lead in *Mugil* and *Epinephelus* species from the Mediterranean which showed a 80 and 76 % to that of PTWI

For liver, the percentage of the cadmium concentrations to that of PTWI was varied between 6 33 % in *Mullus barbatus* from

Table (15) Mean concentrations of trace metals Cd, Pb and Cu in muscles of fish species from different regions and their percentage to that of Provisional Tolerable Weekly Intake (PTWI)

Species	Location	Mean concentration mg / kg			% of the present concentration to that of PTWI		
		Cd	Pb	Cu	Cd	Pb	Cu
Saurida undosquamis	Red Sea	0 023	0 172	0 566	7 67	6 14	0 23
	Gulf of Suez	0 013	0 133	0 129	4 33	4 75	0 05
	Port Said	0 052	0 182	1 019	17 33	6 50	0 42
	Alexandria	0 027	0 50	0 614	9 0	17 86	0 25
Siganus rivulatus	Red Sea	0 039	0 226	0 245	12 33	8 07	0 10
	Suez Bay	0 026	0 255	0 333	8 67	9 11	0 14
	Port Said	0 02	0 06	0 69	6 67	2 14	0 28
	Alexandria	0 026	0 566	0 743	8 67	20 21	0 30
Rhabdosargus hafaira	Gulf of Suez	0 024	0 216	0 342	8 0	7 71	0 14
	Suez Bay	0 03	0 217	0 247	10 0	7 75	0 10
Mugil seheli	Gulf of Suez	0 023	0 194	0 38	7 67	6 93	0 16
	Suez Bay	0 033	0 268	0 418	11 0	9 57	0 17
	Suez Canal	0 02	0 186	0 738	6 67	6 64	0 30
Mugil cephalus	Suez Canal	0 03	0 188	0 61	10 0	6 71	0 25
Mugil auratus	Port Said	0 02	0 09	1 36	6 67	3 21	0 56
Nemipterus japonicus	Red Sea	0 022	0 336	0 288	7 33	12 0	0 12
	Gulf of Suez	0 03	0 169	0 228	10 0	6 04	0 09
Pomadysis stridens	Gulf of Suez	0 02	0 124	0 568	6 67	4 43	0 23
	Suez Bay	0 033	0 304	0 44	11 0	10 86	0 18
Pagrus pagrus	Gulf of Suez	0 028	0 27	0 404	9 33	9 64	0 16
	Port Said	0 09	0 192	1 116	30 0	6 86	0 46
	Alexandria	0 035	0 191	0 272	11 67	6 82	0 11
Upenaeus sp	Gulf of Suez	0 032	0 226	0 542	10 67	8 07	0 22
	Port Said	0 044	0 17	0 906	14 67	6 07	0 37
Mullus barbatus	Alexandria	0 027	0 272	0 366	9 0	9 71	0 15
Sardinella gibbosa	Gulf of Suez	0 023	0 144	0 406	7 67	5 14	0 17
	Suez Bay	0 016	0 059	0 549	5 33	2 11	0 22

Table (15) Cont

Species	Location	Mean concentration mg / kg			% of the present concentration to that of PTWI		
		Cd	Pb	Cu	Cd	Pb	Cu
Etrumeus teres	Gulf of Suez	0 022	0 156	0 87	7 33	5 57	0 36
Scomber japonicus	Gulf of Suez	0 024	0 126	0 484	8 0	4 50	0 20
Trachurus indicus	Gulf of Suez	0 028	0 61	0 782	9 33	21 79	0 32
Tilapia sp	Suez Canal	0 034	0 234	0 618	11 33	8 36	0 25
Trachinotus ovatus	Alexandria	0 028	0 404	0 964	9 33	14 43	0 39
Caranx cryzs	Alexandria	0 028	0 48	0 752	9 33	17 14	0 31
Diplodus sargus	Alexandria	0 031	0 356	0 892	10 33	12 71	0 36

Alexandria and 386 67 % in *Scomber japonicus* from the Gulf of Suez Lead showed a percentage of 2 14 - 66 11 %, while copper gave a range of 0 53 - 33 13 to that of PTWI hence, liver, which is a detoxification organ, can accumulate metals much higher than the values of Provisional tolerable weekly intake (PTWI) and consequently cause a serious effect to human when take this organ in their daily diet

By comparing the level of metals of the fish muscle in the present study with the other works in the Egyptian waters (Table 16), it can be noticed that

1- Cadmium and lead in fish samples of the present survey show the lowest concentrations than that recorded in the other studies

2- Copper, zinc and iron in the present survey are going within the levels of the Egyptian fish

3- No available data for cobalt and nickel to give an ideal comparison, the levels of cobalt and nickel recorded by Emara *et al* (1993) were slightly lower than those recorded in the present study

The wet-weight concentrations of the four metals (Cd, Pb, Cu and Zn) found in the muscle of fish, *Mullus barbatus*, collected from the Egyptian waters (Alexandria region) in this study are compared with results of other workers along the Mediterranean coast in Table (17) Generally, our values are within the range seen in other regions of the Mediterranean, and may thus provide valid information about the current state of the Egyptian regions (Mediterranean and Red Sea)

Table (16) Comparison of metals (ppm wet weight) in fish muscles of the present study to those found in other Egyptian literature

Location	Cadmium	Lead	Copper	Zinc	Cobalt	Nickel	Iron	Reference
Red Sea	---	0 612-7 142	0 563-20 11	2 48 - 17 69	---	---	---	Abdel-Salam, 1981
Mediterranean	0 30 - 0 339	2 83 - 3 76	0 372	5 36 - 6 97	---	---	---	Abbas et al , 1988
Gulf of Suez	0 39 - 0 51	0 64 - 1 14	0 34 - 0 45	4 81 - 6 87	---	---	19 25 - 20 14	Abdelmoneim and El-Deek, 1992
Red Sea	0 13 - 0 21	0 26 - 1 24	0 25 - 0 95	3 16 - 3 60	0 02 - 0 08	0 16 - 0 18	16 2 - 42 3	Emara et al , 1993
Mediterranean	---	0 67 - 2 67	0 23 - 0 48	---	0 03 - 0 05	---	39 0 - 78 2	Emara et al , 1993
Gulf of Suez	0 12 - 0 24	0 54 - 0 93	0 41 - 0 59	7 04 - 22 10	---	---	---	El-Moselhy, 1993
Ismailia	---	3 62 - 4 60	---	13 04 - 13 47	---	---	31 48 - 37 31	El-Dekk et al , 1994 b
Port Said	---	2 58	---	11 21	---	---	22 52	El-Deek et al , 1994 b
Gulf of Suez	0 26 - 0 55	3 36 - 3 96	0 51 - 1 01	4 34 - 10 22	---	---	8 11 - 16 30	Abdelmoneim et al , 1994 c
Suez Bay	0 012 - 0 12	N D - 0 74	0 31 - 1 55	4 73 - 9 65	---	---	---	Abdel-Azim, 1996
Gulf of Suez	N D - 0 077	N D - 0 921	0 39 - 3 303	3 33 - 37 87	---	---	---	Yousif, 1996
Red Sea	0 022-0 039	0 172-0 336	0 245-0 566	2 13 - 4 43	0 053-0 108	0 251-0 952	3 353-10 726	present study
Gulf of Suez	0 013-0 032	0 124 - 0 61	0 129 - 0 87	1 921-13 512	0 035-0 127	0 317-2 468	3 008-47 46	,,,
Suez Canal	0 02 - 0 034	0 186-0 234	0 61 - 0 738	3 182-8 212	0 06 - 0 065	0 342-1 966	5 262-17 934	,,,
Port Said	0 02 - 0 09	0 06 - 0 192	0 69 - 1 36	2 798 - 5 58	0 064 - 0 14	0 30 - 0 557	5 557-9 529	,,,
Alexandria	0 026-0 035	0 191-0 566	0 272-0 964	2 708-5 932	0 037-0 082	0 306-2 261	3 762-15 872	,,,

Table (17) Comparison of metals concentrations (µg/g wet weight) in fish, *Mullus barbatus*, in the present study to those found in other Mediterranean regions

Region	Cd	Pb	Cu	Zn	Reference
Israel	0 2 - 0 7	---	3 3 - 6 4	14 9 - 25 5	Roth and Hornung, 1977
Turkey	0 03	---	0 48	4 5	Balkas et al , 1978
Italy	<0 005 - 0 08	---	---	---	Bolognari et al , 1978
Greece	---	---	0 30 - 0 51	3 6 - 6 9	Grimanis et al , 1980
Greece	0 02 - 0 22	---	0 16 - 1 48	2 1 - 7 7	Voutsinou-Taliadouri, 1982
Greece	0 034 - 0 07	---	---	---	Vasilikiotis et al , 1982
Egypt	0 009 - 0 013	---	0 32 - 0 65	---	Emara, 1982
Italy	< 0 08	---	0 33 - 1 3	2 4 - 9 5	Capelli et al , 1983
Yugoslavia	---	---	0 43 - 0 78	3 42 - 5 45	Vukadin et al , 1984
Turkey	0 05 - 0 13	1 18 - 1 9	0 48 - 0 95	3 74 - 5 98	Uysal and Tuncer, 1984
Spain	0 001 - 0 023	0 01 - 0 54	---	---	de Leon et al , 1984
Israel	0 007 - 0 114	---	0 005 - 0 19	1 8 - 10 9	Hornung and Ramelow 1987
Turkey	0 09 - 0 21	1 34 - 2 21	---	2 36 - 3 2	Kucuksezgin and Balci 1994
Egypt	0 013 - 0 09	0 06 - 0 61	0 129 - 1 36	1 921 - 13 512	Present study

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Chapter IV

Results and Discussion

II- Bioassay

II- Bioassay

1- Toxicity tests of metals (cadmium and copper)

The toxicity tests are necessary in water pollution evaluation because chemical and physical tests alone are not sufficient to assess potential effects on aquatic biota (Tarzwell, 1958 and 1971)

Many acute lethality studies have been conducted on the effects of metals on marine and freshwater invertebrates and fish (Sprague, 1967) Such information is generally used in two ways firstly, to compare the sensitivities of different species and potencies of chemicals using LC_{50} values, and secondly to drive "safe" environmental concentrations using LC_{50} values and application factors in the absence of chronic toxicity information on the tested species (Ahsanullah *et al* , 1981) Most acute studies have been conducted for 96 h as recommended by Portmann (1972), NAS/NAE (1973) and APHA (1989) However, the lethal threshold concentration of a toxicant may be a more appropriate quantity to characterize toxicity, since it represents a common point to lethal physiological response (Wuhrmann, 1952, Sprague, 1967 and Brown, 1973) The lethal threshold concentration, therefore, severs as a better concentration from which relative sensitivities of different species to a toxicant can be determine than LC_{50} values based on an arbitrary time (Sprague, 1967) Some investigators (Eisler, 1971, Thorp and Lake, 1974) have also suggested that for certain toxicants, 96 h tests are too short to determine acutely toxic effect adequately

Determination of the median lethal concentration (LC_{50}) of the cadmium and copper for the juveniles of fish, *Mugil seheli*, at 96 h is the aim of the present section It is an important step to predict the levels of cadmium and copper to be used in the uptake experimental study of the accumulation and depuration rates of these metals in the tissues of adult fish

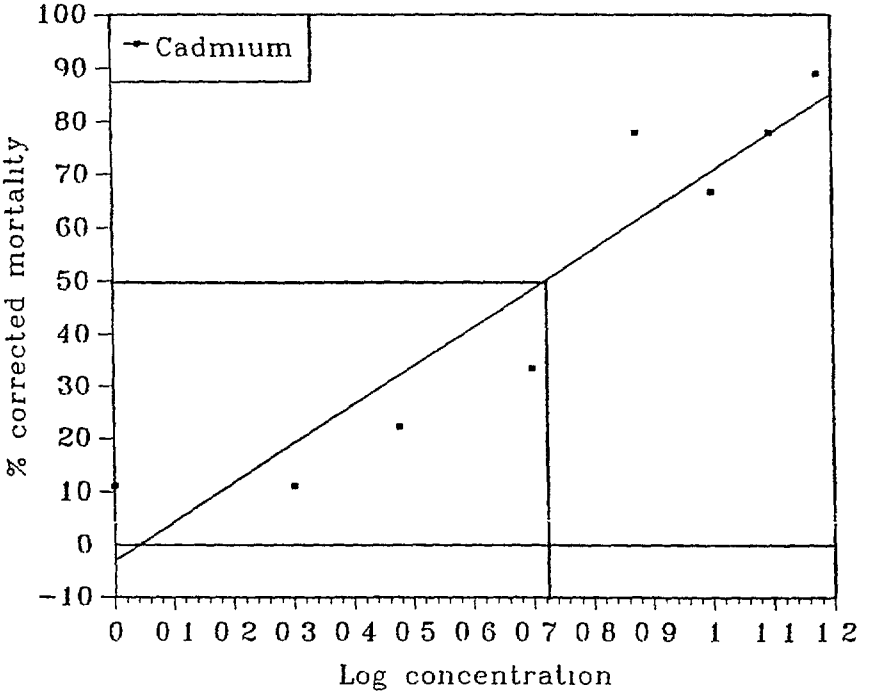
Acute toxicity tests of cadmium and copper to *Mugil seheli* are shown in Fig (19)

The experiments were conducted during February and March, 1994 The conditions of the experiments were as follow temperature ranged from 19 5 to 21 5 °C, pH ranged from 8 22 to 8 31, salinity ranged from 40 90 to 41 03 ‰ and dissolved oxygen varied from 4 38 to 4 97 mg O_2 / l

Juveniles of *Mugil seheli* are collected from the Dersa Pond in the Suez Canal, sorted for size from 1 8 to 3 4 cm in total length and from 0 1 to 0 45 g in total weight

In the present study, 96 h-LC_{50} values of Cd and Cu (used as cadmium and copper sulphate) were 5 27 and 1 64 ppm, respectively This indicate that the ionic form of Cu is more toxic than the ionic form of Cd to *Mugil seheli*, and the juveniles are more sensitive to copper toxicity than those of cadmium

This finding agrees with toxicity information reported for other fish by Denton and Burdon-Jones (1986 b), Cui-Keduo *et al* (1987) and Wu-Yulin *et al* (1990) The same result was obtained for



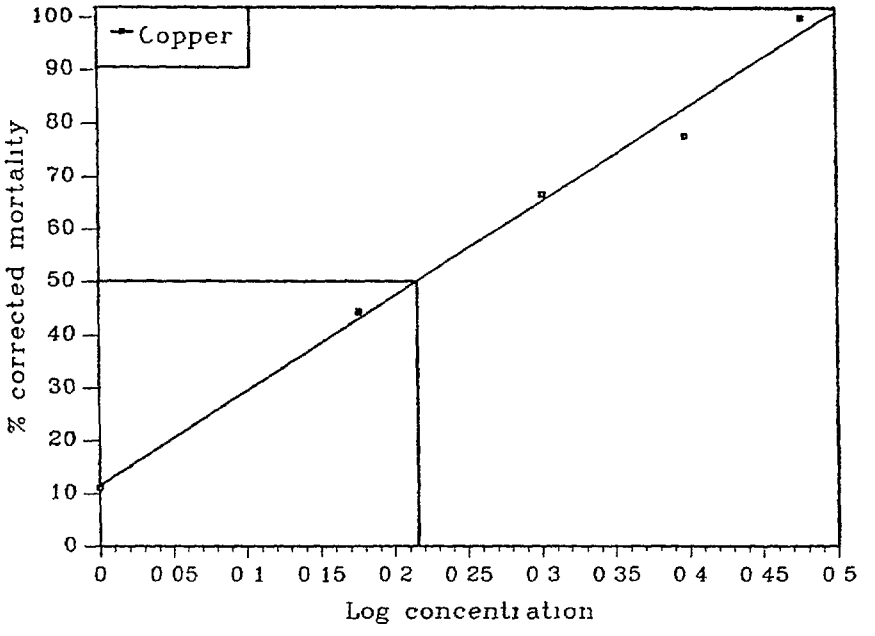


Fig (19) Toxicity of Cadmium and copper (96 h-LC_{50}) to the juveniles of *Mugil seheli*

crustaceans by Bryan (1971), MacInnes (1973), Ahsanullah and Arnott (1978), Arnott and Ahsanullah (1979), Ahsanullah *et al* (1981) and de Nicola Giudica (1989)

In contrast, Hamilton and Buhl (1990) stated that the cadmium was more toxic to fry of Chinook salmon than of the copper, this result may be due to the sensitivity of the organisms to the individual metal which is differ from species to other

Spehar (1976) reported that the 96 h LC_{50} of Cd for flagfish, *Jordanella floridae*, was 2 5 mg / l Hamed (1992) found that the 72 h LC_{50} of Cd for *Mugil seheli* was 4 87 mg/l, while in the present, study it was 5 27 mg/l The LC_{50} values of Cd and Cu for oyster, *Crassostrea virginica*, were 3 80 and 0 103 ppm, respectively (MacInnes, 1973) The 96 h LC_{50} values of copper was 1 83 ppm for fish *Etroplus maculaus* reported by Gaikwad (1989) The variation in the LC_{50} values for the same metal may be due to, species type, chemical structure of metal compound, and the conditions of the experiment

Taylor (1981) reported LC_{50} values of about 0 3 to 50 mg Cd/l While 96 h LC_{50} of Cu ranged from 0 2 to 3 mg/l for various marine fish and crustaceans (Bryan, 1976) Ward (1984) stated that the Cu was highly toxic to marine fishes and crustaceans, ignoring metal-metal and metal-environment interactions, and its water concentration does not exceed 0 01 mg / l in the highly contaminated areas

Shi and Yu (1986) described the influence of various concentrations of Cd and Cu ions on the fertilization and development of the early embryo of the thick shell mussel (*Mytilus coruscus*) The

results obtained showed that when the concentration of Cd^{+2} was below 2 ppm, no obvious influence occurs, but in the case of Cu^{+2}, the concentration of only 20 ppb had a serious influence on the incubation of fertilized eggs

Pagenkopf (1986) studied the toxicity of copper, cadmium, lead and zinc to fishes He derived at least four general conclusions from the analysis of literature

(1) some chemical species of metal are more toxic than other

(2) an increase in water hardness tends to reduce the metal toxicity,

(3) some metals are more toxic than others, and

(4) naturally occurring materials often reduce the concentrations of toxic species

These parameters are not the only ones affecting toxicity, but they can be utilized to rationalize many observed metal toxicity results

From the results stated above, we can conclude that, although copper is essential metal for various physiological processes, it shows a toxic effect to marine organisms higher than those of cadmium which is known as toxic metal and not required for physiological reactions at any concentration This result should be impelled us to make a focusing on the copper and other essential elements that can produce a hazardous influences on the marine organisms, and in general on the marine life and environment

2- Accumulation and depuration of metals

Metals of biological concern may be divided into three groups

(1) light metals (sodium, potassium, calcium, etc) normally transported as mobile cations in aqueous solutions,

(2) transitional metals (e g iron, copper, zinc, cobalt, and manganese) which are essential in low concentrations but may be toxic in high concentrations,

(3) heavy metals or metalloids (e g mercury, cadmium, lead, selenium, tin, and arsenic) which are generally not required for metabolic activity and are toxic to the cell at quite low concentrations

Absorption of heavy metals from solution is dependent on active transport system in some micro-organisms and sea urchin larvae, but generally in plant and animals it is by passive diffusion across gradients created by adsorption at the surface, and by binding by constituents of the surface cells, body fluids, etc An alternative and important pathway for animals is when metals are adsorbed onto or present in food, and by the collection of particulate or colloidal metal by a food-collecting mechanism such as gills in marine organisms There is considerable variation in the extent to which plants and animals can regulate the concentrations of metals in the body Plants and bivalve molluscs are poor regulators of heavy metals Decapod crustaceans and fish are generally able to regulate essential metals such as zinc and copper, but nonessential such as mercury and cadmium are less well regulated

The present experiments were designed to follow the accumulation pattern of cadmium and copper in different organs of *Mugil seheli* during 84 days (12 weeks) when exposed to two concentrations of each metal in their aquarium, and to evaluate the ability of fish to excrete the metals from its body by transferring the fish to natural (nonpolluted) water

A- Cadmium

Cadmium was first isolated and identified by F Strohmeyer in 1817 from the zinc ore smithsonite ($Zn\ CO_3$), it is among the rarer trace elements and is seldom found in pure minerals (GESAMP, 1985) It is usually associated with zinc ores, particularly zinc blende (Zn S), where its concentration may range from 0 1 to 5 0 % or higher (Chizhikov, 1966) Industrial use of cadmium was minor until about 50 years ago But now it is a very important metal with many applications The main use is electroplanting or galvanizing because of its noncorrosive properties It is also used as a colour pigment for paints and plastics, and cathode material for nickel-cadmium batteries

Marine geochemistry of Cd has been discussed by Eaton (1976) and Boyle *et al* (1976) It is well established that, although concentration of Cd in surface water may be less than 10 ng / l, it increases to a maximum of about 125 ng / l at about 1000 m depth and then decreases slightly at lower depths (Knauer and Martin, 1973, Bender and Gagner, 1976, Boyle *et al*, 1976, Martin *et al*, 1976,

Bruland *et al*, 1978, and Raspor, 1980) Nriagu (1980) estimated that atmospheric input of Cd to the oceans is 2 4 x 10^9 g Cd / yr, while the annual input via stream runoff is 7 5 x 10^9 g, and that most of the net gain of Cd to the oceans is due to human activities

Cadmium is a ubiquitous nonessential (toxic) element that possesses high toxicity and is easily accumulated from the environment by aquatic organisms It has been demonstrated that body burdens are influenced by season and sex (Watling and Watling, 1976, Orren *et al*, 1980), age (Cossa *et al*, 1979), temperature and salinity (Phillips, 1976), complexing agents (George and Coombs, 1977) and starvation (Jansen and Scholz, 1979)

Cadmium uptake from water can take place either by passive diffusion through body surface or from water passing through the gills and subsequently through the body (Ray, 1984 and del Ramo *et al*, 1993)

Cadmium bioaccumulation by marine organisms has been the subject of considerable interest in recent years because of serious concern and high levels of Cd may have detrimental effects on the marine organism and may create problems in relation to their suitability as food for humans

Accumulation of cadmium

The concentration of cadmium in the liver, gills, blood and muscle at each sampling time for the 0 (control), 0 5 and 2 0 mg / l groups are shown in Tables (18 - 21), and illustrated as a folds to the initial concentration in Figs (20 - 21)

The accumulation patterns of liver show that the two groups (0 5 and 2 0 mg / l) are approximately similar in the rate of accumulation during the first 7 days But from the day 14, the accumulation rate is differ to be much higher in the group of 2 0 mg Cd / l, and show a fast increase to reach 318 folds over the initial concentration at the end of exposure period (84 days) While the low water ambient concentration of cadmium (0 5 mg / l) shows more or less constant pattern "plateau" (41 - 62 folds over the initial concentration) until the end of exposure period

In gills, as shown in Fig , cadmium is accumulated most rapidly during the first day showed 6 and 11 folds over the initial concentration for 0 5 and 2 0 mg /l groups, and its maximum values are recorded at the day 14 (12 and 23 folds, respectively) After that, levels of cadmium in gills are fluctuated and decreased slightly until the end of exposure period

For blood, the concentrations of cadmium are fluctuated near the levels of control during all time of the experiment

No response is recorded in muscle for 0 5 mg / l group during the experimental time While in 2 0 mg / l group, slightly increase in Cd

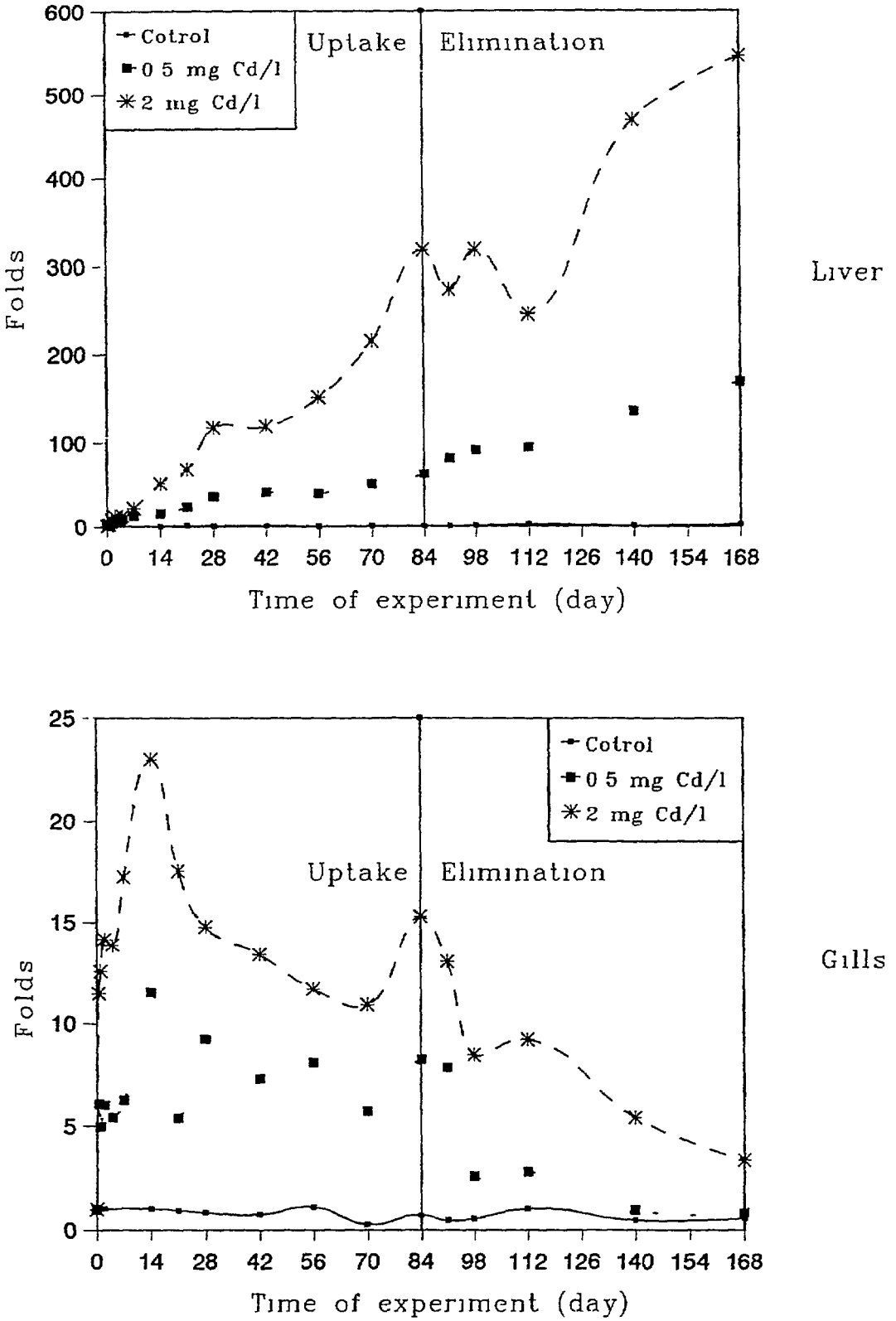
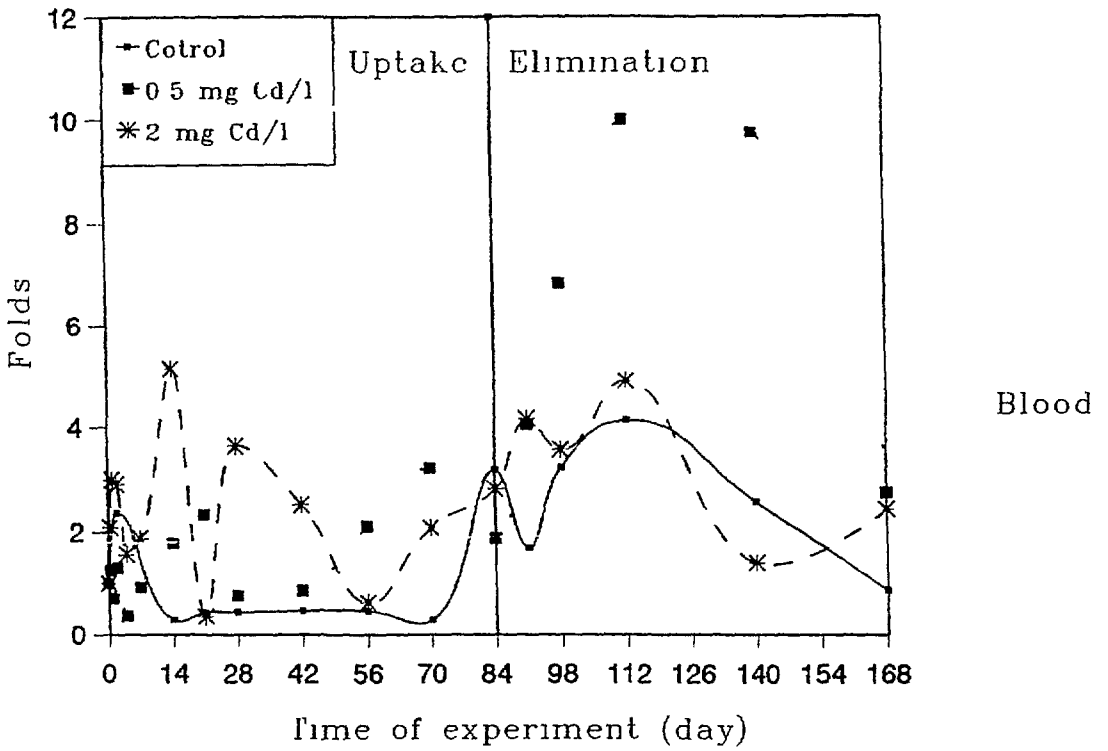


Fig (20) Accumulation and depuration patterns of cadmium in liver and gills of *Mugil seheli*



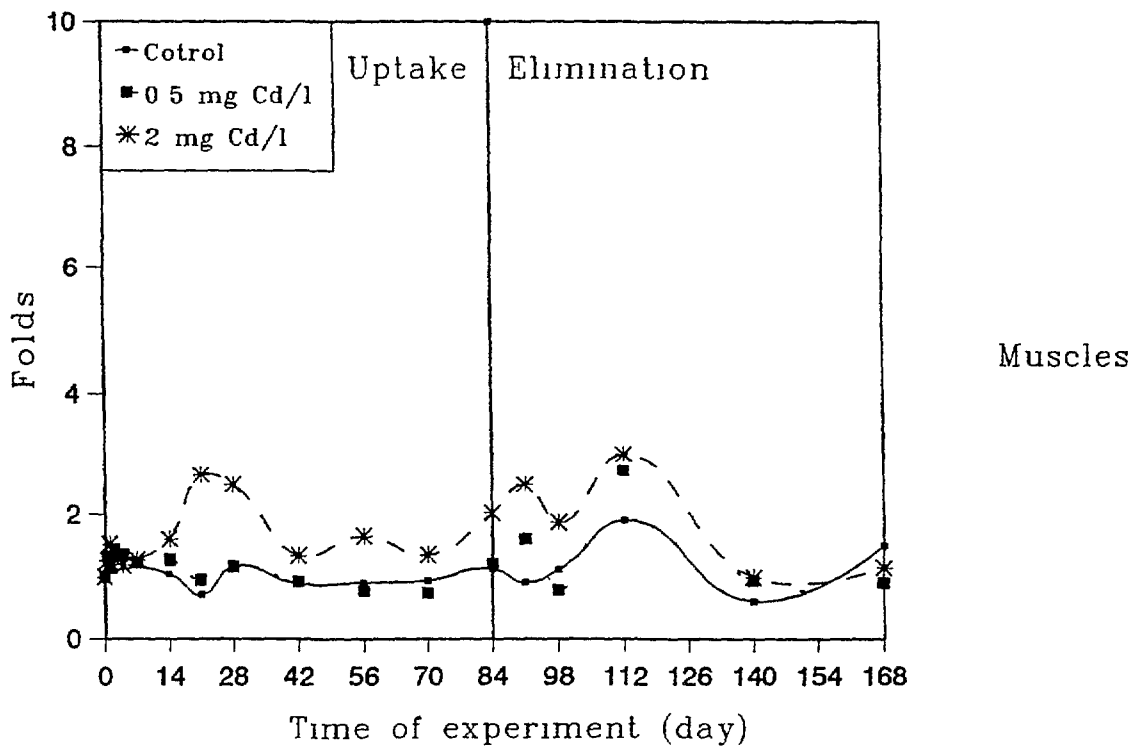


Fig (21) Accumulation and depuration patterns of cadmium in blood and muscles of *Mugil seheli*

reach up to 2 folds over the initial concentration and fluctuated until the end of experiment

The data obtained by the accumulation of cadmium showed that there are different variations in the ability of organs to accumulate the metal, and the concentration of cadmium in the fish tissues can be influenced by the ambient concentration in their water

Adult rainbow trout, *Salmo gairdneri*, were exposed to two ambient concentrations of Cd in their aquarium for 178 days (Giles, 1988) Cadmium accumulated most rapidly in gill tissue which became saturated at levels 100 fold higher than controls within 24 and 52 days in the high and low metal exposures, respectively Liver cadmium increased 250 to 400 fold over the test period but accumulation exhibited a plateau between 52 and 129 d following by a rapid rise by 178 d Kidney cadmium increased consistently through the test period to levels approximately 50 to 100 fold higher than control values Cadmium in the gut and skin increased 10 and 5 fold, respectively, while no increase was recorded in white muscle

Carp, *Cyprinus carpio*, were exposed to a serious concentrations of cadmium for a period of 120 days (Ikeda *et al* , 1986) Cd levels in tissues showed higher values as exposure days elapsed in higher Cd concentrations, and the concentrations of Cd were in the order Kidney > hepatopancreas > gills

Rainbow trout, *Oncorhynchus mykiss*, were fed on a commercial food enriched with Cd for 32 days the body burden of fish fed Cd-enriched diet increased from about 0 05 to 0 39 µg / g wet weight,

reflected by elevation in the Cd content in gills, liver, blood plasma, kidney, skin, mucus, and whole gut Muscle Cd content did not alter (Handy, 1992)

The accumulation of cadmium from external environmental solution was measured in channel catfish (*Ictalurus punctatus*) with the aid of ^{109}Cd (Bentley, 1991) In chronic 7 days experiments, fasted catfish were found to accumulate the toxic metal in their liver and kidney from external media with Cd concentrations as low as 10^{-9} M (about 0 1 µg / l) Concentrations were greater in the kidney than the liver Detectable amounts of Cd (< 0 03 µg / g net wt) were not found in muscle in this time at external concentration of Cd < 10^{-5} M (< 1 0 mg / l)

Cadmium bioaccumulation from solution by plaice *Pleuronectes platessa* and thornback ray *raja clavata* was found to be extremely low for both species (Pentreath, 1977)

Brooks and Rumsby (1967) found that the concentration factors for Cd in oyster *Ostrea sinuata* decreased steadily with increase in exposure concentration and the concentrations of Cd in the tissues decrease in the order gill > heart > visceral mass > mantle > white muscle > striated muscle *Crassostrea virginica* (Shuster and Pringle, 1969 and Eisler *et al* , 1972) exposed to Cd rapidly accumulated high levels of the metal in soft tissues

Crassostrea gigas and *Ostrea edulis* collected from a clean environment and transplanted for a period of 5 months in polluted water containing an average of 5 7 µg Cd / l accumulated 15 and 17

times, respectively, the concentrations of Cd in control samples (Boyden, 1975) *Crassostrea virginica* (Zaroogian and Cheer, 1976 and Zaroogian, 1980) was exposed to 5, 10 and 15 µg Cd / l seawater for 40 weeks at ambient temperature and salinity, had as much as 89, 176 and 292 µg Cd / g (dry wt), respectively, in the whole-body soft tissues without reaching equilibrium The Cd concentration in the soft tissues was linearly related to the exposure concentration and had a curvilinear relationship with time of exposure

In *Saccostrea commercialis* (Ward, 1982) exposed to several concentrations of Cd (nominally 0, 10, 25, 50 and 150 µg / l) in flowing seawater, the gill tissues always had the highest concentration of Cd at any sampling time, generally in the order gill > viscera $\simeq$ mantle > muscle in all experiments other than in the control group where the viscera consistently had the highest Cd concentration, suggesting that the gill was the critical organ for Cd uptake in this species

Greig (1979) exposed quahaugs, surf clams and oysters to 19 and 20 µg Cd/l seawater for 43 days At the end of 10 µg / l experiment, the Cd concentrations in quahaugs, clams, and oysters were 2, 2, and 4 times the concentration in control animals The corresponding values for exposure at 20 µg Cd / l were 2, 4, and 8 times, respectively

George and Coombs (1977) reported an initial lag period in uptake of Cd in mussel *Mytilus edulis*, but a subsequent linear relationship with time and exposure concentration Similar results were obtained by Jackim *et al* (1977) for 3 filter-feeding (*Mytilus edulis*,

Mulinia lateralis, and *Mya arenaria*), and 1 deposit-feeding bivalve (*Nucula proxima*) and by other workers (Jansen and Scholz, 1979, Gutierrez-Galindo, 1980 and Scholz, 1980) for *Mytilus edulis*

The scallops *Aquipecten irradians* and *Argopecten irradians* were also observed to Cd accumulate rapidly when exposed to spiked water (Eisler *et al* , 1972 and Carmichael and Fowler, 1981)

Whole-body Cd concentration in shrimp *Penaeus duorarum*, *Palaemonetes vulgaris*, and *Palaemonetes pugio*, exposed to a range of 75-1000 µg Cd / l were in all case directly proportional to the concentration in exposure solution and to time of exposure (Nimmo *et al* , 1977 and Engel and Fowler, 1979) A similar relationship has also been observed for *Palaemon elegans* (White and Rainbow, 1982)

The burrowing marine shrimp *Callianassa australiensis* collected from an uncontaminated area in Western Port, Victoria, Australia, and then exposed to cadmium-contaminated water and sediment for 8 weeks The concentrations ranged from 0 5 to 63 µg Cd/l for water and 0 5 to 63 µg Cd / g for sediment the shrimp accumulated cadmium from water at a rate commensurate with increases in the concentration of cadmium in water and the duration of the experiment (Ahsanullah *et al* , 1984)

Regoli *et al* (1991) exposed sandy-bottom bivalve, *Donacilla cornea*, from unpolluted shore in northern Sardinia, to 200 µg Cd / l The bivalves were found to accumulate the metal, and Cd concentration progressively increased through the period of exposure

Marine prosobranch, *Littorina littorea*, were exposed to two ambient concentrations and for various exposure times (Marigomez and Ireland, 1989) Linear accumulation appeared to occur in the whole soft body at the cadmium concentrations and times of exposure There was also a general linear trend in the accumulation of cadmium in the various organs (gills, kidney, digestive gland / gonad complex and remaining tissues)

Depuration (excretion) of cadmium

Concentrations of cadmium in liver during the depuration period show unexpected patterns (Fig 20) being increased continuously with the same manner of exposure and reach to 169 and 545 folds over the initial concentration for 0 5 and 2 0 mg / l groups, respectively, at the end of experiment (168 days)

To explain this unexpected result, it is worth to know that the accumulated cadmium is stored in different tissues Borchardt (1983) discussed that, cadmium can be shifted from one organ to another according to the different cadmium affinities At the same time a part of the cadmium is released, while another is transferred into fixed bonds Hence the organisms has to be regarded as a multi-compartment system Therefore the measured elimination curve represents the sum of an unknown number of elimination processes

If we consider the detoxification function of liver, hence, the blood may carry accumulated Cd from different organs (Cd in blood increased for 28 days of depuration period, see Fig , 22) and then leave

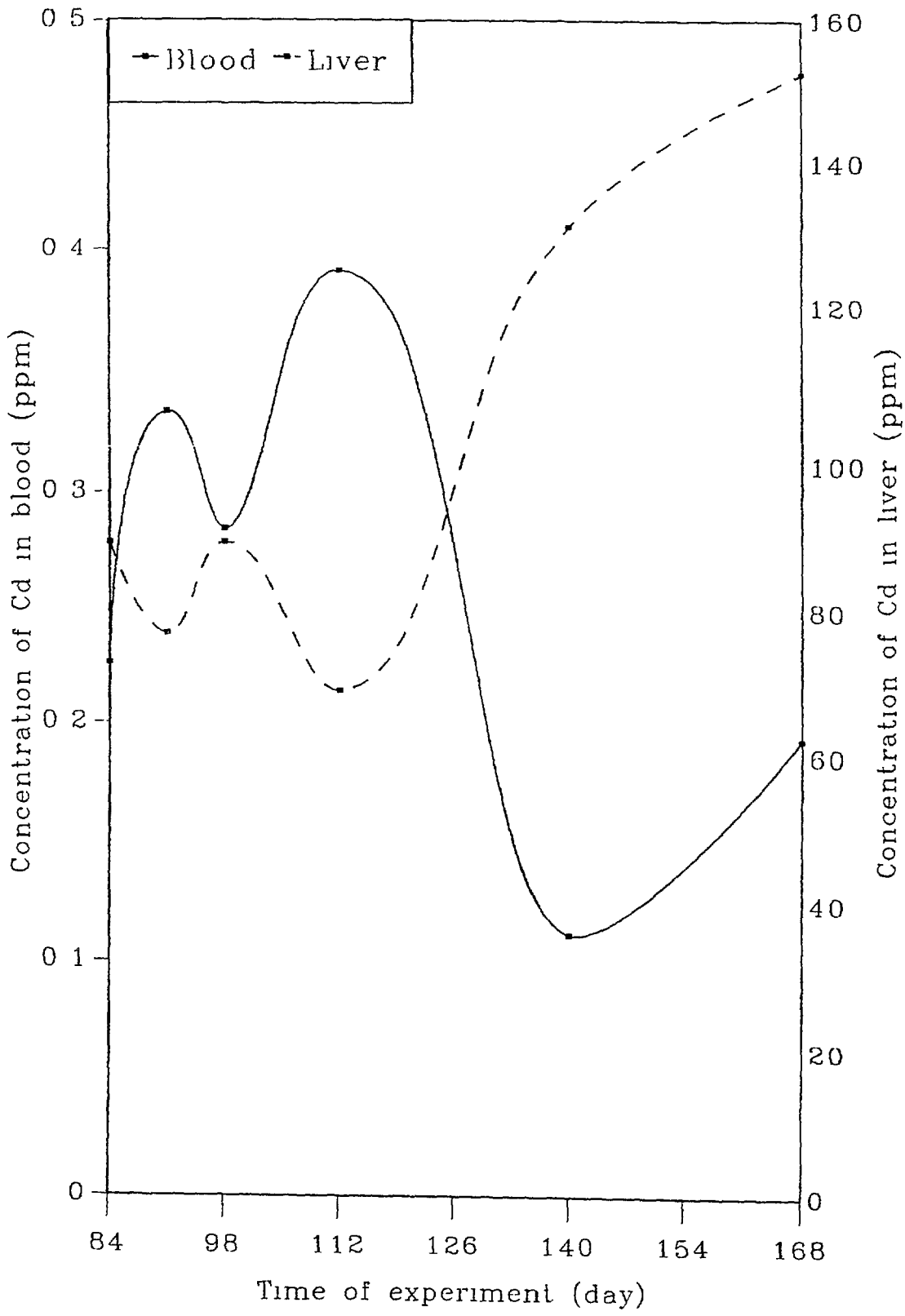


Fig (22) Depuration patterns of cadmium (2 0 mg/l group) in liver and blood of *Mugil seheli*

its load into liver (Cd content of blood began to decrease at 112 day of experiment) then storing of Cd start inside the liver

In gills, the concentrations of cadmium are normally decreased to reach the control level at the end of the experiment for 0 5 mg / l group, while in 2 0 mg / l group, the level of cadmium is 3 folds over the initial concentration

The patterns of blood and muscle during the depuration period are similar to that recorded for exposure period

There is very little, if any, excretion of Cd by marine organisms The biological half-life is usually quit long (Ray, 1984) Excretion of cadmium by mussels *Mytilus galloprovincialis* (Majori and Petranio, 1973 b) and *Mytilus edulis* (George and coombs, 1977) was reported to be very slow Greig and Wenzloff (1978) and Zaroogian (1979) did not observe any lowering in concentration of Cd when contaminated oyster *Crassostrea virginica* were held in unpolluted waters for 40 weeks However, Mowdy (1981) showed that oysters exposed in the laboratory eliminated Cd when transferred to uncontaminated estuarine environment and suggested that the elimination rate depended upon salinity and temperature

Conflicting results have also been presented for crabs For example, there was no decreased in Cd content in *Callinectes ssapidus* (Hutcheson, 1974) but *Carcinus maenas* (Wright, 1977 and Jennings and Rainbow, 1979) excreted than 50 % Cd in about 10 days Ueda *et al* (1976) reported 30 % Cd loss from polycheate *Nereis japonicus* within 7 days but no subsequent significant loss In contrast, no Cd

excretion from *Nereis virens* was observed (Ray *et al* , 1980 a) over a period of 75 days, regardless of the initial Cd concentrations in the worms

Eisler (1974) reported that in mummichogs *Fundulus heteroclitus* there was a 50 % Cd loss within 2 - 3 days and over 90 % by 180 days but biological half-life ($T_{1/2}$) for Cd in plaic *Pleuronectes platesssa* and thornback ray *raja clavata* was 150 - 200 days and 76 - 147 days, respectively (Pentreath, 1977)

After 15 days in clean seawater, the loss of cadmium was not statistically significant in bivalve, *Donacilla cornea* (Regoli *et al*, 1991) Zorba *et al* (1992) reported a significant depuration of Cd in clam *Circenita callipyga* during a period of 60 days Norey *et al* (1990 a) observed that the distribution of cadmium with three major cadmium-sequestering organs (liver, kidney and gills) of the rainbow trout (*Salmo gairdneri*) and stone loach (*Noemacheilus barbatulus*) did not change significantly during the period of their maintenance in cadmium free water

When the prawn, *Macrobrachium rosenbergi*, were transferred to clean freshwater after 32 days of exposure to cadmium, the accumulated metal markedly decreased over a 20 days period (Liao-IChiu *et al*, 1990) No loss of cadmium occurred in the hard clam, *Mercenaria mercenaria*, even after 64 days depuration (Robinson and Ryan, 1986) Most organs of rainbow trout, *Oncorhynchus mykiss*, remained contaminated with Cd after 12 days depuration (Handy, 1992)

B- Copper

Copper is widely distributed in nature and is an essential element It was first identified in biological materials by Bucholtz (1816) and Meissner (1817) who found it in plant Its presence in animals was demonstrated by Sarzeau (1830), who found ox blood to contain 700 µg / litre

Although copper is highly toxic to fish, its compounds are used in fish culture and fisheries as algicides and in the prevention and therapy of some fish diseases The maximum admissible copper concentration in water for the protection of fish is in the range of 0 001 to 0 01 mg / l, depending on the physical and chemical properties of water and on the species of the fish (FAO, 1993)

The natural input of copper to the marine environment from erosion of mineralized rocks is estimated to be 325000 t / yr Inputs from human activities are localized and vary widely in their nature About 7 5 million t / yr of copper is produced for use in electrical equipment, in alloys, as a chemical catalyst, in antifouling paint for ships'hulls, as an algicide, and a wood preservative Several of these uses inevitable result in copper being transferred to the environment (Clark, 1993) Dissolved copper in the sea is in the form of Cu CO3, Cu^{+2}, and $CuOH^{+}$, but copper is one of the metals readily removed from solution by adsorption to particles and it is estimated that 83 percent of copper in the sea is in this form

Copper is an essential element for animals and highest concentrations are usually found in the liver Despite the existence of a number of detoxifying and storage systems for copper, it is the most toxic metal, after mercury and silver, to a wide spectrum of marine life

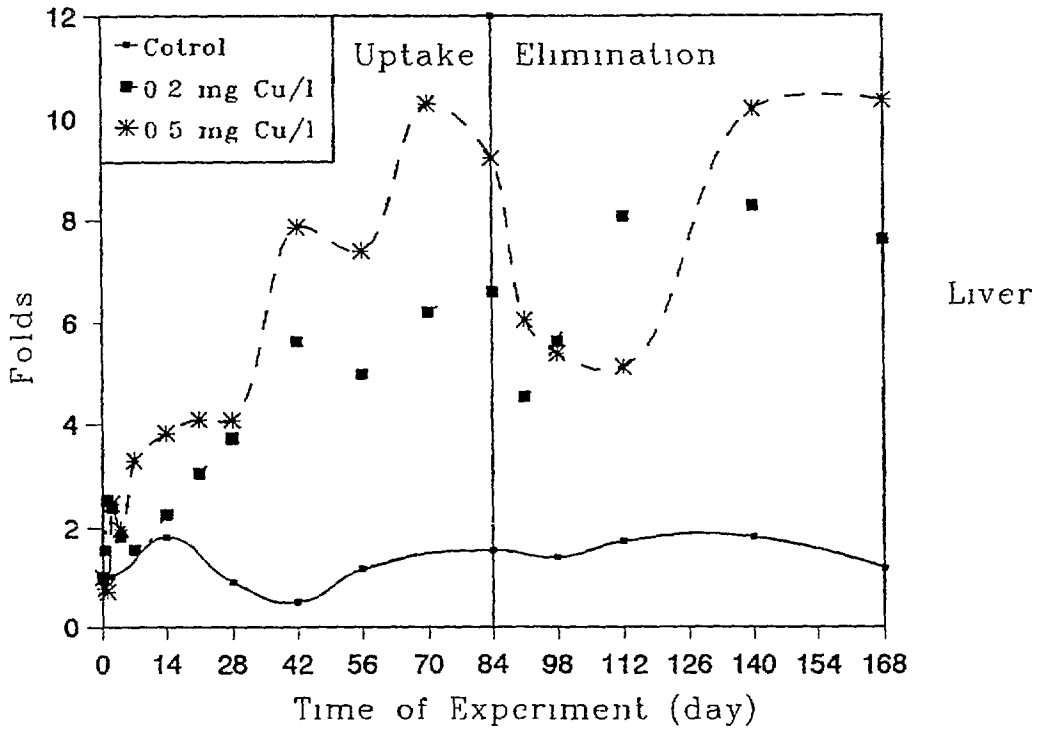
Experimental studies on the accumulation and excretion of copper by marine organisms are very few when compared with cadmium

Accumulation of copper

The concentrations of copper in liver, gills, blood and muscle at each sampling time for the 0 (control), 0 2 and 0 5 mg / l groups are shown in Tables (18 - 21), and illustrated as a folds to the initial concentration in Figs (23 - 24)

Copper concentrations in liver during the first 28 days of the experiment show no significant differences between individuals exposed to 0 2 and 0 5 mg /l, after this time, the differences are observed between the two groups and the levels of Cu reach to 6 and 9 folds over the initial concentration, respectively

For gills, at the first 6 hours, Cu level showed its highest values and recorded about 4 and 10 folds over the initial concentration for 0 2 and 0 5 mg / l groups, respectively, then, as for cadmium, decrease and fluctuate until the end of exposure period which reach up to 2 folds for the two groups



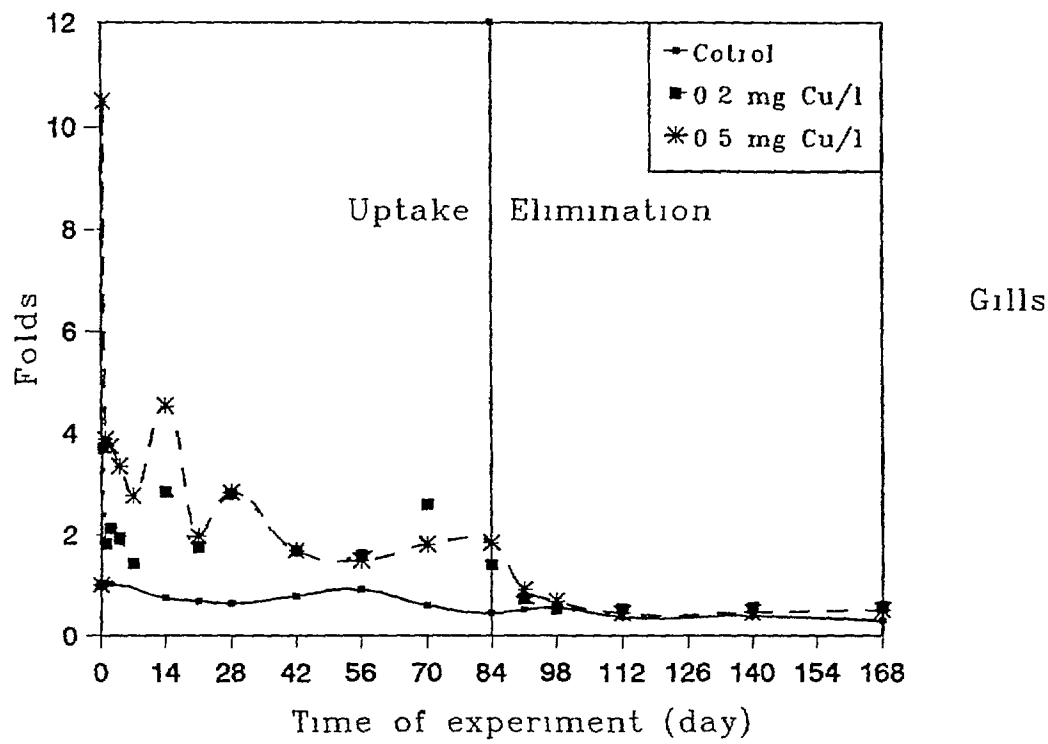
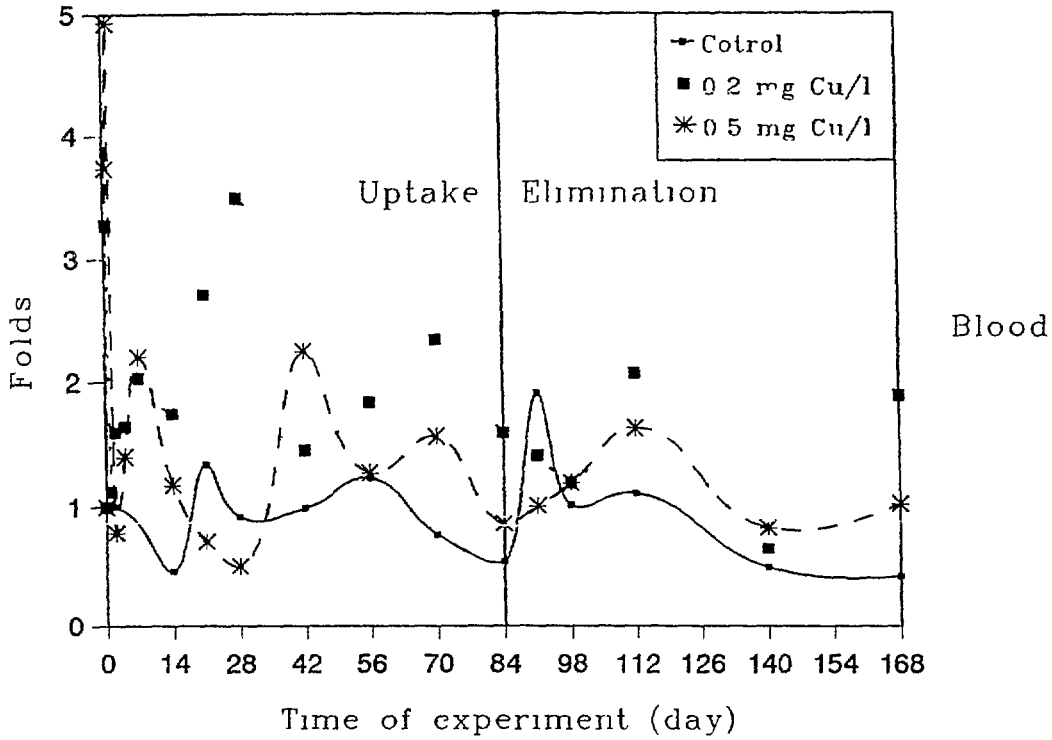


Fig (23) Accumulation and depuration patterns of copper in liver and gills of *Mugil seheli*



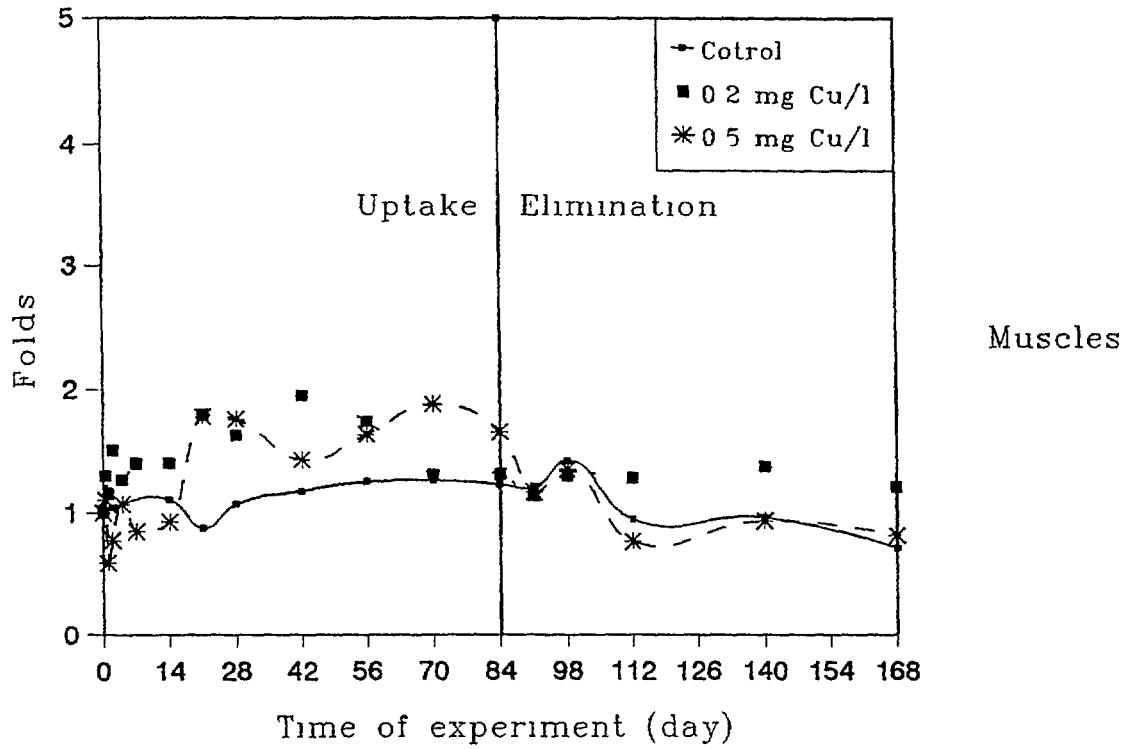


Fig (24) Accumulation and depuration patterns of copper in blood and muscles of *Mugil scheli*

In blood, copper is fluctuated around the control level during all time of experiments, and shows its highest values in the beginning of exposure period

No response is recorded in muscle for 0 2 and 0 5 mg / l groups during the time of experiment, and the levels of copper are fluctuate near the levels of control group

Laboratory experiments revealed that copper was strongly accumulated by sandy bottom bivalve, *Donacilla cornea* (Regoli *et al* , 1991), with maximum body concentration at 25 °C At this temperature the body concentrations for 150 µg / l of Cu in seawater were significantly higher than those for 100 µg / l No significant differences in Cu accumulation were observed at 18 °C between individuals exposed to 150 and 300 µg / l

Clam, *Circenita callipyga* were exposed to copper in their aquarium for 36 days, and it showed a progressively increase of copper in their tissues (Zorba *et al* , 1992)

Liao-IChiu *et al* (1990) studied the accumulation of copper in young prawn, *Macrobrachium rosenbergii*, and stated that the accumulation rates varied with the concentration of copper

Rainbow trout, *Oncorhynchus mykiss*, were fed on a commercial feed enriched with Cu for 32 days (Handy, 1992) The body burden of animals fed Cu-enriched diet increased from about 1 2 to 1 5 µg / g wet weight, with the gill, whole gut, blood plasma, skin, and mucus

contaminated after 32 days, no changes in the liver and muscle occurred

Depuration (excretion) of copper

During the depuration period, copper is slightly decreased in liver (Fig , 23) for the two groups and then begin increasing to reach up to 8 and 10 folds over the initial concentration for 0 2 and 0 5 mg / l, respectively

In gills, after 7 days of depuration period, copper decrease suddenly and its values are similar to those found in control during the remaining time of depuration period

The patterns of blood and muscle during the depuration period are similar to that recorded for exposure period

Zorba *et al* (1992) observed a significant elimination of Cu in clam, *Circenita callipyga*, during a depuration period of 60 days in clean seawater

When the prawn *Macrobrachium rosenbergii* were transferred to clean water after 32 days of exposure to copper, the accumulated copper markedly decreased over a 20 days period (Liao-IChiu *et al* , 1990)

Rainbow trout were fed on Cu-enriched diet for 32 days and allowed to recover on normal food for 12 days (Handy, 1992), all

organs, except the gill and kidney, returned to control values after 12 days depuration

From the above results, we can noticed the following remarks -

(1) Gills tissue accumulate metals (Cd and Cu) most rapidly, and this suggests a role for gill in direct contact of metals from the water Also, adsorbed metals on the surface of gills can smoothly be released to the water by the movement of fish, therefore, the concentration of metals in gills appears to be fluctuated during all times of exposure period

(2) Liver records the highest rate of accumulation rather than the other organs This may be attributed to the detoxification function of the liver, thus it has the ability to store any stranger and toxic substances from the blood stream of animals

(3) Blood has a fluctuated patterns in the level of metals during all times of experiments This is in agreement with the function of liver and kidney which can get off the toxic substances from the blood

(4) No response is observed in muscles with except of Cd in group of 2 0 mg / l which record 2 folds over the initial concentration This result may be related to that the muscle of fish, have an age of 2 - 3 years and reared in water contains about 0 3 ppb

cadmium and 1 6 ppb copper, and thus, reached to the saturation levels before the beginning of experiments

(5) Accumulation rate of cadmium and copper in gills and liver was higher for the high water ambient concentrations (2 0 ppm Cd and 0 5 ppm Cu), this observation is in agreement with different previous studies

(6) Gills showed a normal patterns during the depuration period which reach to the control levels (except Cd in group 2 0 mg / l), and this result support the suggestion in the first remark, that adsorbed metals can easily be released from the surface of gills while, in case of Cd in groups 2 0 mg / l, the metal may be diffused to the cells of gills and bond to a protein fractions

(7) Liver records unexpected results during the depuration period of the cadmium groups, which increased continuously until the end of experiments While in copper groups, levels of Cu were decreased slightly during the first month of depuration, then increased again and reach to level higher than recorded at the end of exposure period This may indicate that the liver can accumulate the metals carried by the blood from other internal organs according to its ability to accumulate more and more toxicants from the animal body

(8) During the exposure period, accumulation rate of cadmium was higher than those of copper with the same water ambient concentration (0 5 mg / l) After 84 days of exposure, cadmium level in liver was 62 folds over the initial concentration, while for

copper was 10 folds only This result suggests that cadmium which is toxic and nonessential element is easily accumulated from the water more than copper which is essential element

(9) By estimation of concentration factors (CF) for cadmium and copper in liver of fish during all times of experiments (Table 22) It can be noticed that, the concentration factors decreased with increasing metals concentration in the water but increased as the duration of the experiment was increased Concentration factors of cadmium and copper for the control group (water ambient concentration was about of 0 2 µg Cd / l and 8 0 µg Cu / l) were much higher than other experimental tanks The same results for CF of cadmium were recorded by Brooks and Rumsby (1967), Ward (1982) and Ahsanullah *et al* (1984)

Table (18) Accumulation rate of cadmium and copper in the liver of *Mugil seheli* during all time of experiments

Time (day)	Cadmium			Copper		
	Control	0 5 mg/l	2 mg/l	Control	0 2 mg/l	0 5 mg/l
Exposure period						
0	0 280 ± 0 029	0 280 ± 0 029	0 280 ± 0 029	15 210 ± 2 658	15 210 ± 2 658	15 210 ± 2 658
0 25		0 508 ± 0 027	0 715 ± 0 030		23 544 ± 3 572	11 813 ± 3 566
1		1 258 ± 0 153	2 189 ± 0 153		38 677 ± 6 219	10 880 ± 2 795
2	0 283 ± 0 061	1 596 ± 0 184	3 274 ± 0 793	15 505 ± 2 390	36 680 ± 1 965	37 625 ± 7 622
4		2 320 ± 0 309	3 537 ± 0 339		27 814 ± 3 078	30 127 ± 2 715
7		3 648 ± 0 757	6 116 ± 0 439		23 759	50 232 ± 6 613
14	0 468 ± 0 052	4 332 ± 0 361	14 298 ± 2 272	27 630 ± 4 510	34 440	58 141 ± 9 606
21	0 212 ± 0 036	6 500 ± 1 178	19 046 ± 2 231		46 372 ± 0 875	62 210 ± 5 099
28	0 203 ± 0 039	9 848 ± 3 703	32 968 ± 5 299	13 701 ± 3 891	56 590 ± 13 510	62 032 ± 6 665
42	0 200 ± 0 024	11 352 ± 0 249	33 365 ± 4 905	7 675 ± 1 744	85 700 ± 2 580	119 678 ± 8 184
56	0 233 ± 0 031	11 023 ± 2 688	42 550 ± 1 770	17 710 ± 3 428	75 870 ± 21 650	112 477 ± 17 975
70	0 208 ± 0 042	14 113 ± 6 671	60 245 ± 4 395		94 298 ± 15 230	156 461 ± 22 792
84	0 175 ± 0 045	17 449 ± 4 691	89 170 ± 26 11	23 530 ± 5 418	100 270 ± 25 110	140 067 ± 2 420
Depuration period						
7	0 240 ± 0 042	22 840 ± 8 480	76 628 ± 0 830		68 944 ± 6 032	92 003 ± 31 427
14	0 367 ± 0 066	25 580 ± 6 321	89 322 ± 8 072	21 411 ± 3 090	85 679 ± 7 896	82 028 ± 13 047
28	0 732 ± 0 211	26 357 ± 5 914	68 616 ± 1 267	26 277 ± 5 139	122 709 ± 60 292	77 922 ± 10 913
56	0 392 ± 0 109	38 210 ± 9 025	131 355 ± 7 193	27 574 ± 9 232	125 938 ± 13 375	154 926 ± 17 784
84	0 733 ± 0 159	47 400 ± 13 51	152 703 ± 14 377	18 027 ± 4 214	115 781 ± 7 390	157 520 ± 20 860

Table (19) Accumulation rate of cadmium and copper in the gills of *Mugil seheli* during all time of experiments

Time (day)	Cadmium			Copper		
	Control	0 5 mg/l	2 mg/l	Control	0 2 mg/l	0 5 mg/l
Exposure period						
0	0 220 ± 0 034	0 220 ± 0 034	0 220 ± 0 034	1 490 ± 0 262	1 490 ± 0 262	1 490 ± 0 262
0 25		1 333 ± 0 162	2 526 ± 0 402		5 522 ± 0 813	15 636 ± 5 428
1		1 091 ± 0 120	2 766 ± 0 624		2 715 ± 0 176	5 797 ±1 068
2	0 226 ± 0 067	1 320 ± 0 290	3 114 ± 0 418	1 524 ± 0 260	3 168 ± 0 712	5 588 ± 2 042
4		1 192 ± 0 268	3 050 ± 0 437		2 875 ± 0 234	4 996 ± 0 377
7		1 374 ± 0 266	3 791 ± 1 120		2 129 ± 0 651	4 126 ± 1 700
14	0 228 ± 0 034	2 539 ± 1 373	5 064 ± 0 861	1 095 ± 0 196	4 240 ± 2 377	6 775 ± 2 148
21	0 209 ± 0 044	1 185 ± 0 236	3 856 ± 1 425	1 010 ± 0 176	2 621 ± 0 607	2 941 ± 0 531
28	0 185 ± 0 031	2 030 ± 0 317	3 248 ± 0 334	0 938 ± 0 171	4 182 ± 0 348	4 223 ± 1 300
42	0 165 ± 0 036	1 603 ± 0 395	2 948 ± 1 450	1 161 ± 0 096	2 513 ± 1 015	2 521 ± 0 233
56	0 245 ± 0 127	1 777 ± 0 294	2 575 ± 0 057	1 345 ± 0 288	2 375 ± 0 530	2 228 ± 0 779
70	0 062 ± 0 020	1 256 ± 0 451	2 403 ± 0 496	0 881 ± 0 332	3 863 ± 1 107	2 699 ± 0 553
84	0 158 ± 0 087	1 807 ± 0 810	3 363 ± 0 576	0 659 ± 0 131	2 096 ± 0 437	2 748 ± 0 590
Depuration period						
7	0 101 ± 0 012	1 720 ± 0 230	2 873 ± 0 856	0 762 ± 0 023	1 076 ± 0 134	1 355 ± 0 185
14	0 120 ± 0 007	0 568 ± 0 047	1 861 ± 0 125	0 816 ± 0 061	0 788 ± 0 025	1 002 ± 0 161
28	0 228 ± 0 045	0 615 ± 0 167	2 026 ± 0 608	0 542	0 784 ± 0 200	0 650 ± 0 239
56	0 105 ± 0 012	0 215 ± 0 083	1 191 ± 0 053	0 573 ± 0 041	0 807 ± 0 235	0 677 ± 0 114
84	0 127 ± 0 018	0 180 ± 0 075	0 738 ± 0 033	0 435 ± 0 033	0 835 ± 0 146	0 745 ± 0 065

Table (20) Accumulation rate of cadmium and copper in the blood of *Mugil seheli* during all time of experiments

Time (day)	Cadmium			Copper		
	Control	0 5 mg/l	2 mg/l	Control	0 2 mg/l	0 5 mg/l
Exposure period						
0	0 080 ± 0 018	0 080 ± 0 018	0 080 ± 0 018	0 470 ± 0 116	0 470 ± 0 116	0 470 ± 0 116
0 25		0 100 ± 0 015	0 167 ± 0 043		1 538 ± 0 324	1 753 ± 0 595
1		0 056 ± 0 011	0 240 ± 0 042		0 530 ± 0 050	2 318 ± 0 495
2	0 189 ± 0 026	0 104 ± 0 015	0 233 ± 0 094	0 473 ± 0 091	0 753 ± 0 132	0 364 ± 0 189
4		0 029 ± 0 008	0 125 ± 0 043		0 773 ± 0 151	0 662 ± 0 167
7		0 074 ± 0 012	0 150 ± 0 058		0 955 ± 0 233	1 037 ± 0 160
14	0 023 ± 0 008	0 142 ± 0 045	0 411 ± 0 114	0 213 ± 0 042	0 821 ± 0 210	0 555 ± 0 055
21	0 034 ± 0 007	0 187 ± 0 074	0 028 ± 0 006	0 633 ± 0 110	1 275 ± 0 288	0 333 ± 0 108
28	0 035 ± 0 009	0 060 ± 0 011	0 291 ± 0 085	0 433 ± 0 046	1 640 ± 0 760	0 233 ± 0 024
42	0 037 ± 0 010	0 068 ± 0 018	0 202 ± 0 002	0 467 ± 0 075	0 686 ± 0 135	1 058 ± 0 025
56	0 037 ± 0 012	0 168 ± 0 113	0 050 ± 0 016	0 583 ± 0 104	0 864 ± 0 232	0 601 ± 0 101
70	0 023 ± 0 005	0 257 ± 0 108	0 166 ± 0 134	0 361 ± 0 049	1 102 ± 0 249	0 737 ± 0 004
84	0 225 ± 0 093	0 150 ± 0 056	0 226 ± 0 071	0 253 ± 0 042	0 750 ± 0 110	0 405 ± 0 064
Depuration period						
7	0 135 ± 0 033	0 324 ± 0 077	0 333 ± 0 105	0 899 ± 0 187	0 667 ± 0 135	0 474 ± 0 093
14	0 258 ± 0 045	0 547 ± 0 101	0 285 ± 0 080	0 478 ± 0 115	0 564 ± 0 112	0 563 ± 0 131
28	0 330 ± 0 032	0 800 ± 0 095	0 391 ± 0 121	0 524 ± 0 047	0 972 ± 0 186	0 767 ± 0 224
56	0 206 ± 0 025	0 780 ± 0 080	0 112 ± 0 031	0 229 ± 0 044	0 304 ± 0 081	0 388 ± 0 035
84	0 069 ± 0 011	0 220 ± 0 006	0 195 ± 0 073	0 193 ± 0 031	0 889 ± 0 245	0 482 ± 0 066

Table (21) Accumulation rate of cadmium and copper in the muscle of *Mugil seheli* during all time of experiments

Time (day)	Cadmium			Copper		
	Control	0 5 mg/l	2 mg/l	Control	0 2 mg/l	0 5 mg/l
Exposure period						
0	0 060 ± 0 013	0 060 ± 0 013	0 060 ± 0 013	0 320 ± 0 042	0 320 ± 0 042	0 320 ± 0 042
0 25		0 080 ± 0 019	0 076 ± 0 018		0 413 ± 0 067	0 353 ± 0 057
1		0 071 ± 0 023	0 091 ± 0 014		0 369 ± 0 046	0 192 ± 0 026
2	0 066 ± 0 027	0 087 ± 0 011	0 078 ± 0 014	0 333 ± 0 015	0 480 ± 0 041	0 250 ± 0 034
4		0 082 ± 0 016	0 072 ± 0 005		0 403 ± 0 050	0 341 ± 0 028
7		0 074 ± 0 013	0 076 ± 0 014		0 445 ± 0 055	0 273 ± 0 053
14	0 063 ± 0 027	0 077 ± 0 023	0 096 ± 0 022	0 354 ± 0 051	0 446 ± 0 067	0 297 ± 0 040
21	0 043 ± 0 012	0 057 ± 0 018	0 159 ± 0 109	0 281 ± 0 044	0 573 ± 0 044	0 568 ± 0 058
28	0 070 ± 0 017	0 070 ± 0 009	0 149 ± 0 082	0 341 ± 0 028	0 519 ± 0 091	0 561 ± 0 075
42	0 054 ± 0 014	0 056 ± 0 008	0 081 ± 0 021	0 375 ± 0 085	0 624 ± 0 096	0 455 ± 0 081
56	0 055 ± 0 008	0 047 ± 0 016	0 099 ± 0 012	0 398 ± 0 066	0 555 ± 0 115	0 521 ± 0 076
70	0 057 ± 0 017	0 045 ± 0 003	0 081 ± 0 009	0 402 ± 0 060	0 417 ± 0 082	0 602 ± 0 143
84	0 068 ± 0 014	0 073 ± 0 036	0 121 ± 0 010	0 392 ± 0 039	0 418 ± 0 051	0 528 ± 0 096
Depuration period						
7	0 055 ± 0 018	0 096 ± 0 025	0 149 ± 0 066	0 386 ± 0 094	0 363 ± 0 141	0 372 ± 0 119
14	0 067 ± 0 017	0 048 ± 0 002	0 112 ± 0 011	0 453 ± 0 023	0 414 ± 0 062	0 430 ± 0 100
28	0 114 ± 0 003	0 163 ± 0 017	0 179 ± 0 008	0 304 ± 0 054	0 408 ± 0 045	0 247 ± 0 017
56	0 037 ± 0 012	0 056 ± 0 002	0 060 ± 0 019	0 309 ± 0 073	0 437 ± 0 017	0 300 ± 0 092
84	0 090 ± 0 008	0 055 ± 0 012	0 069 ± 0 031	0 230 ± 0 114	0 386 ± 0 086	0 263 ± 0 055

Table (22) Concentration factors of cadmium and copper for liver of *Mugil seheli* during all time of experiments

Time (day)	Cadmium			Copper		
	Control (0 2 µg/l)	0 5 mg/l	2 mg/l	Control (8 µg/l)	0 2 mg/l	0 5 mg/l
Exposure period						
1		2 5	1 1		193	22
2	1415	3 2	1 6	1938	183	75
4		4 6	1 8		139	60
7		7 3	3 1		119	100
14	2340	8 7	7 1	3454	172	116
21	1060	13 0	9 5		232	124
28	1015	19 7	16 5	1713	283	124
42	1000	22 7	16 7	959	429	239
56	1165	22 0	21 3	2214	379	225
70	1040	28 2	30 1		471	313
84	875	34 9	44 6	2941	501	280
Depuration period						
7	1200	45 7	38 3		345	184
14	1835	51 2	44 7	2676	428	164
28	3660	52 7	34 3	3285	614	156
56	1960	76 4	65 7	3447	630	310
84	3665	94 8	76 4	2253	579	315

14/a

Chapter V

Summary

Summary

Heavy metals considered as one of the most insidious and dangerous category of pollutants in the sea which enter the aquatic environment from both natural and anthropogenic sources Metal contamination of aquatic environment may lead to deleterious effects from localized inputs which may be acutely or chronically toxic to aquatic life within the effected area Most published data on the effects of metals on aquatic organisms, however, report adverse effects at concentrations higher than usually found in the environment Metals are often accumulated in the tissues of organs which have taken them up, and this leads to an amplification of the concentration of them in animals higher up to food chain Not only do heavy metals constitute a direct threat to public health, they are a broad contaminants and its control is extremely difficult

This work aimed to study the variation of metals in the tissues of commercial fish collected from different sites along the Egyptian coast, and their response to pollution in the sites To manage the problem of metals accumulation in fish, depuration patterns were studied in a long-term experiments

The results obtained from the study can summarize in the following

I- Field research

1- Level of metals in fish.

a) Muscle

The highest values of cadmium (0 09 ppm), copper (1 36 ppm), Mg (0 465 ppt), K (4 995 ppt) and Na (2 891 ppt) were found in fish collected from Port Said region While, Pb (0 61 ppm), Zn (13 512 ppm), Co (0 189 ppm), Ni (2 468 ppm), Fe (47 46 ppm) and Ca (196 ppt) were in fish from the Gulf of Suez

b) Liver.

The highest values of Cd (1 16 ppm), Pb (1 851 ppm), Co (1 11 ppm), Ni (19 76 ppm) and major elements, Ca, Mg, K and Na (1 875, 0 731, 9 633 and 2 603 ppt) were found in fish from the Gulf of Suez Cu showed its highest level (81 17 ppm) in fish *Mugil auratus* collected from Port Said *Siganus rivulatus* from Alexandria region and Red Sea had an elevated amount of zinc (102 90 ppm) and iron (573 59 ppm), respectively

c) Gills

The highest values of Cd (0 194 ppm), Pb (1 24 ppm), Zn (49 1 ppm), Co (0 81 ppm), Ni (3 13 ppm), Ca (0 194 ppt) and K (2 411 ppt) were found in fish from the Gulf of Suez On the other hand, Cu (3 02 ppm), Fe (1191 30 ppm), Mg (1 32 ppt) and Na (2 845 ppt) were in fish from Mediterranean infront of Port Said

2- Response of fish to metals in different areas:

a) The availability of metals to fish in different sites

In all tested regions, except Port Said region, the order of metals in fish muscle was Fe > Zn > Ni > Cu > Pb > Co > Cd While in Port Said region, the order was Fe > Zn > Cu > Ni > Pb > Co > Cd

b) Feeding and habitat mechanisms.

For all metals other than cadmium, gills showed their higher levels in pelagic and filter feeding fish than those recorded in carnivorous fish Cu, Zn, Co and Fe (in liver) showed high values in the filter feeders, while other metals (Cd, Pb and Ni) were found in carnivorous fish For muscle, Pb, Cu, Zn, Co and Fe were presented in filter feeding fish with high values Cd was the only metal that showed its highest level in carnivorous fish for all different organs

c) The lipids content in the tissues of different fish species

Liver which is fatty tissue showed higher accumulation rate of most metals studied than other organs

d) Uptake and retention mechanisms for the metals at different sites *A case study*

Fish, *Saurida sp* , was collected from Alexandria, Port Said and Gulf of Suez to give some statistical analysis of the obtained data

i- Metal - length relationships

Most metals in the muscle of fish, *Saurida sp*, recorded insignificant correlation with fish length whether positive or negative, except few, such as, calcium (r = - 0 766) in fish from Alexandria, potassium (r = 0 589) in fish from Port Said, and zinc (r = - 0 682) and iron (r = - 0 804) in fish from Suez

ii- Copper - length relationships·

In the small fish (length < 22 0 cm), Cu showed a positive relationships with length (r = 0 3802, 0 7137 and 0 8711 for Alexandria, Port Said and Suez fish, respectively) While in large fish (length ≥ 22 0 cm), the relations were inversely with correlation coefficients (r) of - 0 1415, - 0 5450 and - 0 5490 for Alexandria, Port Said and Suez fish, respectively

iii- Metals interrelationships.

Fish from Port Said region had a poor significant correlation between the studied metals Lead did not record any significant correlation with the other metals in all studied regions Most of significant correlation were observed for essential and major elements Calcium and magnesium showed more or less same patterns during study the correlation with the other metals and with length of the fish

iv- Level of metals in *Saurida sp* and its concentration factors:

The maximum levels of Cd (0 044 ppm), Zn (2 296 ppm), Co (0 085 ppm), Fe (2 879 ppm) and Na (811 94 ppm) were observed in

the fish from Port Said waters While Pb, Cu, Ni and Ca were recorded its highest level (0 408, 0 328, 0 919 and 39 826 ppm, respectively) in the fish from Alexandria waters Mg and K were elevated in the fish from the Gulf of Suez (438 24 and 1749 27 ppm, respectively) Concentration factors of metals, Cd, Pb, Cu and Zn in fish were found to be higher in Port Said than those of the others (Alexandria and the Gulf of Suez)

v- One Way Anova analysis.

One Way Anova analysis was used to estimate probability and difference in the metals content of fish muscle from the different areas Cd, Ca, Mg and Na in the fish muscle recorded high significant differences between all tested regions In contrast, Pb, Ni and Fe showed insignificant differences Cu and Zn showed insignificant differences between fish from Alexandria and Port Said only, while Co and K recorded insignificant differences between Port Said and the Gulf of Suez fish

3- Sea food safety in Egypt:

The percentage of the present metal concentrations in fish muscle to that of PTWI (Provisional tolerable weekly intake in mg per 70 kg man) was calculated, and the obtained data demonstrate that the concentrations of trace metals (Cd, Pb and Cu) would be much lower than the PTWI values and accordingly there is no risk from the human consumption of these fish

By comparing the metal levels in the fish muscle of our study with the Egyptian fish, it can be noticed that, Cd and Pb show the lowest concentrations than that recorded in the other studies, Cu, Zn and Fe are going within the levels of the Egyptian fish

Also, *Mullus barbatus* which collected from Alexandria region was selected to compare our levels of Cd, Pb, Cu and Zn with results of other workers along the Mediterranean coast It can noticed that, our metal levels lies in the range recorded in the other Mediterranean regions

II- Bioassay:

1- Toxicity of cadmium and copper:

Juveniles of *Mugil seheli* were collected from the Dersa Pond in the Suez Canal to estimate the mortality effects of cadmium and copper, they sorted for size from 1 8 to 3 4 cm in total length and from o 1 to 0 45 g in total weight Copper showed a toxic effect to the fish juveniles (LC_{50}, 1 64 ppm) higher than those of cadmium (LC_{50}, 5 27 ppm)

2- Accumulation and depuration of cadmium and copper:

i) Cadmium.

<u>Liver</u> After about 14 day of exposure period, Cd showed a fast increase to reach 318 folds over the initial concentration at the end of exposure period (84 days) in the group of 2 0 mg Cd / l, while the low water ambient concentration of cadmium (0 5 mg / l) showed more or

less constant pattern (41 - 62 folds) until the end of exposure period During the depuration period, liver showed unexpected patterns being increased continuously with the same manner of exposure and reached to 169 and 545 folds over the initial concentration for 0 5 and 2 0 mg / l groups, respectively, at the end of experiments (168 days)

Gills Cadmium was accumulated most rapidly during the first day and its maximum values were recorded at the day 14 (12 and 23 folds for 0 5 and 2 0 mg / l groups, respectively) During the depuration period, the concentrations of Cd were normally decreased to reach the control level for 0 5 mg / l group, and 3 folds over the initial concentration for 2 0 mg / l group

Blood. The concentrations of Cd were fluctuated near the level of control during all time of the experiment

Muscle No response was recorded in muscle for 0 5 mg / l group during the experimental time While in 2 0 mg / l group, slight increase in Cd occurs and reaches up to 2 folds over the initial concentration and fluctuated until the end of experiment

ii) Copper.

Liver During the exposure period, the concentration of copper in liver reached to 6 and 9 folds over the initial concentration for 0 2 and 0 5 mg Cu / l groups, respectively, and then showed more or less constant pattern during the depuration period which reached to 8 and 10 folds for the two groups

Gills At the first 6 hours, Cu level showed its highest values and recorded about 4 and 10 folds for 0 2 and 0 5 mg / l groups, then decreased and fluctuated until the end of exposure period After 7 days of depuration period, Cu decreased and reached to control level for the two groups

Blood Copper was fluctuated around the control level during all time of experiments

Muscle: No response was recorded in muscle for the two groups during all time of experiments, and its levels were fluctuated near the background level of control group

From the results of the experimental work, it can be concluded that the muscles of fish, the edible part which are slightly or even not affected by the metals (Cd and Cu in the present study) contamination in their aquarium Other organs including liver (organ for detoxification) and gills (direct contact with water surface) that accumulate high amount of metals, and reach to levels more than the safe concentration Therefore, the level of metals in fish organs caught from highly polluted areas must be taken into consideration by those people responsible for human being health It is, thus, of urgent need to prevent risks caused by sea food contains high level of metals in its organs The first step is to initiate a regular and well planned national programme to follow the metals level in the Egyptian marine environment Also, preventing using the polluted organs as a food for other consumable animals (in animal farming)

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Chapter VI

References

References

Abbas, M M , Beltagy, A I Naguib, M M and Naguib, Kh M , 1988. Levels of contamination by heavy metals in some fish families from Egypt Paper presented at 102 nd A O A C , Annual International Meeting, Aug 29 - Sept , 1988, Arlington, VA, USA

Abdel-Azim, H., 1996: Lead dynamics in Suez Bay M Sc Thesis, Fac Sci , Helwan University

Abdelmoneim M A and El-Deek, M S , 1992: Lethrinus Family A model of edible Red Sea fish with low heavy metals accumulation pp 439 - 448 In Proc 2nd Alex Conf Food Sci Tech , Alexandria, Egypt, March 2 - 4, 1992

Abdelmoneim, M. A and Fattouh, F. A , 1994. Distribution of some heavy metals in coastal recreational areas off Port Said The Bulletin of the H I P H , Alexandria, **XXIV (2).** 315 - 338

Abdelmoneim M A.; El-Moselhy, Kh M and Hassan, S H , 1994a Trace metals content in three fishes from the Suez Gulf (Red Sea, Egypt) Symp on Red Sea Marine Environment (25-28 April, 1994), Jeddeh, Saudi Arabia J King Abdelaziz University, Mar Sci , Special volume "in press"

Abdelmoneim M A ; Khaled, A M. and Iskander, M F , 1994 b A study on the levels of some heavy metals in El Mex, West of Alexandria, Egypt pp 155 - 174 In The 4th Conf of the Environmental Protection is a must, 10 - 12 May 1994

Abdelmoneim, M. A.; El-Deek, M S.; Beltagy, A I Naguib, Kh M. and Naguib, M M , 1994 c: Distribution of heavy metals in some species of edible fish from the Red Sea The Bulletin of The H I P H , **XXIV (4)** 957 - 972

Abdel-Salam, H A-M , 1981: Occurrence and distribution of some heavy metals in water and in some fish species from the Red Sea M Sc Thesis, Cairo University

Aboul Dahab, O M , 1985: Chemical cycle of inorganic pollutants in the ecosystem west of Alexandria between Anfoushy and Agamy Ph D Thesis, Fac Sci , Alexandria University

Ahmed, N S ; El-Deek, M S. and Emara, H I., 1994: Trace metals in the muscle and bone of some fish species from the Red Sea Symp on Red Sea Marine Environment (25 - 28 April, 1994), Jeddeh, Saudi Arabia J King Abdelaziz University, Mar Sci , Special volume "in press"

Ahsanullah, M. and Arnott, G. H , 1978 Acute toxicity of copper, cadmium and zinc to larvae of the crab *Paragrapsus quadridentatus* (H Milne Edward), and implications for water quality criteria Aust J Mar Freshwat Res , **29**· 1 - 8

Ahsanullah, M ; Negilski, D S. and Mobley, M C , 1981 Toxicity of zinc, cadmium and copper to the shrimp *Callianassa australiensis* I Effect of individual metals Mar Biol , **64** 299 - 304

Ahsanullah, M , Mobley, M. C and Negilski, D. S , 1984: Accumulation of cadmium from contaminated water and sediment by the shrimp *Callianassa australiensis* Mar Biol , **82** 191 - 197

Alexander, G V and Young, D. R , 1976 Trace metals in southern Californian mussels Mar Pollut Bull , **7 (1):** 7 - 9

Allen, G ; Nickless, G., Wibberley, B. and Pickard, J., 1974: Heavy metal particle characterization Nature (Lond), **252:** 571 - 572

Al-Mohanna, M. M , 1994 Residues of some heavy metals in fishes collected from (Red Sea coast) Jizan, Saudi Arabia J Environ Biol , **15 (2)** 149 - 157

Amiard, J. C ; Amiard, T. C , Berthet, B. and Metayer, C., 1987. Comparative study of the patterns of bioaccumulation of essential (Cu, Zn) and nonessential (Cd, Pb) trace metals in various estuarine and coastal organisms J Exp Mar Biol Ecol , **106 (1)** 73 - 89

Andereotis, J S., Papadopoulou, C , 1980 A comparison of trace element content in muscle (dark and white) and liver of *Auxis rochei* I CSEM/UNEP 1980, workshop on pollution of the Mediterranean

Anil, A C and Wagh, A B , 1988· Accumulation of copper and zinc by *Balanus amphitrite* in a tropical estuary Mar Pollut Bull , **19 (4)** 177 - 180

APHA, 1989 Standard Methods for the Examination of Water and Wastewater, 17th ed Washington, D C American Public Health Association, American Water Works Association and Water Pollution Control Federation

Arnott, G. H. and Ahsanullah, M , 1979 Acute toxicity of copper, cadmium and zinc to three species of marine copepods Aust J Mar Freshwat Res , **30** 63 - 71

Ashraf, M , Tariq, J and Jaffer, M , 1992. Trace metals in fish, sediment and water from the south west coast of the Arabian Sea, Pakistan Toxicol Environ Chem , **24 (2-4)** 99 - 104

Ayling, G M , 1974: Uptake of Cd, Zn, Cu, Pb and Cr in the Pacific oyster *Crassostrea gigas* grown in the Tamar River, Tasmania Water Res , **8** 729 - 738

Balkas, T. I , Salihoglu, I ; Juncel, G Tugrul, S. and Ramelow, G , 1978: Trace metals and organochlorine residue content of *Mullidae* family fishes and sediments in the vicinity of Erdemli (Icel), Turkey IVes J Etud Pollut , 1978, 159 - 163

Ballin, U , 1988· Specific analysis as a necessary criterion to evaluate the element content in fish Procc Food Sci Adv Brd for the German Fisheries, 32, Annual Meeting (Noelle, H , ed), **16** 43-53

Barak, N A-E. and Mason, C F , 1990: Mercury, cadmium and lead in eels and roach The effect of size, season and locality on metal concentrations in flesh and liver Sci Total Environ , **92** 249 - 256

Bebbington, G. N ; Mackay, N. J., Chvolka, R.; William R J and Dunn, A , 1977 Heavy metals, selenium and arsenic in nine of Australian commercial fish Aust J Mar Freshwater Res , **28** 227 - 286

Bendell-Young, L I , Harvey, H H and Young, J. F , 1986: Accumulation of cadmium by white sackers (*Catostomus comersoni*) in relation to fish growth and lake acidification Can J Fish Aquat Sci , **43 (4)**· 806 - 811

Bender, M L. and Gagner, C L., 1976: Dissolved copper, nickel and cadmium in Sargasso Sea J Mar Res , **34:** 327 - 339

Benemariya, H., Robberecht, H. and Deelstra, H , 1991· Atomic absorption spectrometric determination of zinc, copper, and selenium in fish from Lake Tanganyika, Burundi, Africa Sci Total Environ , **105** 73 - 85

Bentley, P J , 1991 Accumulation of cadmium by channel catfish (*Ictalurus punctatus*) Influx from environmental solution Comp Biochem Physiol , **99C (3)**· 527 - 529

Bernhard, M , 1982. Levels of trace metals in the Mediterranean (Review Paper) VIes J Etud Pollut , Cannes, C I E S M , 237 - 243

Beveridge, M. C. M , Stafford, E. and Coutts, R., 1985. Metal concentrations in the commercially exploited fishes of an endorheic saline lake in the tin-silver province of Bolivia Aquacult Fish Manage , **16 (1)** 41 - 53

Bezuidenhout, L. M ; Schoonbee, H. J and de-Wet, L. P. D., 1990. Heavy metal content in organs of the African sharptooth catfish, *Clarias gariepinus* (Burchell) from a Transvaal Lake affected by mine and industrial effluents Part 1 Zinc and copper Water S A , **16 (2):** 125 - 129

Blevins. R. D and Pancorbo, O C., 1986 Metal concentrations in muscle of fish from aquatic systems in east Tennessee, USA Water Air Soil Pollut , **29 (4)** 361 - 371

Bolognari, A ; Ferro, R , Fossato, V. U , Piatelli, M , Renzoni, A and Viviani, R , 1978: Monitorage de l'etat de la pollution marine le long des cotes Italiennes avee l'emploide indicateurs biologiques IVes J Etud Pollut , 1978, 667 - 669

Borchardt, T., 1983 Influence of food quantity on the kinetics of cadmium uptake and loss via food and seawater in *Mytilus edulis* Mar Biol , **76.** 67 - 76

Bowen, H J M , 1966: Trace elements in biochemistry Academic Press, New York, 241p

Boyden, C R , 1974· Trace element content and body size in molluscs Nature, London, **251:** 311 - 314

Boyden, C R., 1975· Distribution of some trace metals in Poole Harbour, Dorset Mar Pollut Bull , **6** 180 - 187

Boyle, E. A , Sclater, F and Edmond, J M., 1976. On the marine geochemistry of cadmium Nature, **263** 42 - 44

Bradley, R W. and Morris, J R., 1986· Heavy metals in fish from a series of metal-contaminated lakes near Sudbury, Ontario Water Air Soil Pollut , **27 (3-4)** 341 - 354

Brooks, R R. and Rumsby, M G., 1967· Studies on the uptake of cadmium by the oyster, *Ostrea sinuata* (Lamarck) Aust J Mar Freshwater Res , **18·** 53 - 61

Brown, V M , 1973 Concepts and outlook in testing the toxicity of substances to fish pp 73 - 95 In Bioassay techniques and environmental chemistry (Ed by G E Glass) Ann Arbor Ann Arbor Science Publishers, USA

Brown, M. W.; Thomas, D. G., Shurben, D ; Solbe, J. F de-L. G., Kay, J. and Cryer, A., 1986 A comparison of the differential accumulation of cadmium in the tissues of three species of freshwater fish, *Salmo gairdneri, Rutilus rutilus* and *Noemacheilus barbatulus* Comp Biochem Physiol , **84C (2)** 213 - 217

Bruland, K W , Knauer, G A and Martin, J H , 1978 Cadmium in Northeast Pacific waters Limnol Oceanogr , **23:** 618 - 625

Bryan, G W , 1971· The effects of heavy metals (other than mercury) on marine and estuarine organisms Proc R Soc Lond (B), **177** 389 - 410

Bryan, G. W., 1973: The occurrence and seasonal variation of trace elements in the scallops *Pecten maximum* (L) and *Chlamys opercularis* (L) J Mar Biol Assoc , U K , **53.** 145 - 166

Bryan, G W , 1976 Heavy metal contamination in the sea pp 185 - 302 In Marine pollution (Ed R Johnston), Academic Press, London

Bryan, G W , 1980: Recent trends in research on heavy-metal contamination in the sea Helgolander Meeresunters , **33:** 6 - 25

Bryan, G W. and Hummerstone, L G , 1973 Adaptation of the polychaete *Nereis diversicolor* to estuarine sediments containing high concentrations of zinc and cadmium J Mar Biol Assoc , UK , **53.** 839 - 857

Bucholtz, C. F , 1816 Chemische untersuchung der vanillenschuten (Siliqua vanillae) Repatorium Pharmacia, **2:** 253

Capelli, R., Contardi, V., Cosma, B., Minganti, V and Zanicchi, G., 1983· A four-year study on the distribution of some heavy metals in five marine organisms of the Lingurian Sea Mar Chem , **12** 281 - 293

Carmichael, N G and Fowler, B. A., 1981 Cadmium accumulation and toxicity in the kidney of the bay scallop *Argopecten irradians* Mar Biol , **65:** 35 - 43

Chizhikov, D M , 1966. Cadmium Pergamon Press, New York

Clark, R. B , 1993· Marine pollution, Oxford Univ Press, 171 p

Clary, J J. and Vignati, L , 1973 Nickel chloride-induced changes in glucose metabolism in the rat In Abstracts of Papers Society of Toxicology Twelfth Annual Meeting, New York, March 18-22 Academic Press

Coombs, T. L., 1972. The distribution of zinc in the oyster, *Ostrea edulis* and its relation to enzymic activity and other metals Mar Biol , **12** 170 - 178

Coombs, T. L , 1974 The nature of zinc and copper complexes in the oyster, *Ostrea edulis* Mar Biol , **28** 1 - 10

Cossa, D , Bourget, E and Piuze, J., 1979· Sexual maturation as a course of variation in the relationship between cadmium concentration and body weight of *Mytilus edulis* L Mar Pollut Bull , **10** 174 - 176

Coughtrey, P J , 1975 A study of the effects of atmospheric pollution by heavy metal oxides, from the Imperical Smelting Complex at Avonmouth, Bristol, on the surrounding natural soils, vegetation and animals B Sc Thesis, Botany Department, University of Bristol, UK

Coughtrey, P J and Martin, M H , 1977 The uptake of lead, zinc, cadmium, and copper by the pulmonate mollusc, *Helix aspersa* muller, and its relevance to the monitoring of heavy metal contamination of the environment Oecologia, **27.** 65 - 74

Cross, F A , Hardy, L A.; Jones, N. Y. and Barber, R T., 1973: Relation between total body weight and concentrations of manganese, iron, copper, zinc and mercury in white muscle of bluefish (*Pomatomus saltatrix*) and a bathyl-demersal fish *Antinora rostrata* J Fish Res Board, Can , **30 (9):** 1287 -1291

Cui-Keduo; Liu-Yumei and Hou-Lanying, 1987 Effects of sex heavy metals on hatching eggs and survival of larval of marine fish Oceanol Limnol Sin / Haiyang-Yu-Huzhao, **18 (2)** 138 - 144

Dai-Quanyu, Zhang-Yushu, Licun-Gao and Zhuang-Dadong, 1990 Metal element contents in commercial freshwater fishes from lakes of different trophic types in Suzhou Region Acta Hydrobiol Sin, **14 (2)** 97 - 107

Das, S K. and Kaviraj, A, 1990: Accumulation of cadmium in *Heteropneutes fossilis* and changes in haematological parameters J Nat Conserv, **2 (1)**· 25 - 30

de Leon, A R; Mas, J; Guerrero, J and Jornet, A, 1984: Monitoring of heavy metals in superficial sediment and some marine organisms from the western Mediterranean coast VII[es] J Etud Pollut, 11 - 13 Oct, 1984, Lucerne, 321 - 326

del Ramo, J; Martinez, M, Pastor, A., Torreblanca, A and Diaz-Mayana, J, 1993 Effect of cadmium pre-exposure in cadmium accumulation by brine shrimp *Artemia* Involvement of low-molecular weight cadmium- binding ligands Mar Environ Res, **35** 29 - 33

de Nicola Giudici, M; Migliore, L., Guarino, S. M and Gambardella, C., 1987· Acute and long-term toxicity of cadmium to *Idothea baltica* (Crustacea, Isopoda) Mar Pollut Bull, **18 (8).** 454 - 458

de Nicola Giudici, M. and Guarino, S M, 1989 Effects of chronic exposure to cadmium or copper on *Idothea baltica* (Crustacea, Isopoda) Mar Pollut Bull, **20 (2)** 69 - 73

Denton, G R W and Burdon-Jones, C., 1986 a· Trace metals in fish from the Great Barrier Reef Mar Pollut Bull, **17 (5):** 201 -209

Denton, G R. W and Burdon-Jones, C., 1986 b Environmental effects on toxicity of heavy metals to two species of tropical marine fish from Northern Australia Chem Ecol, **2 (3)**· 233 - 249

Devi, S, 1989 Heavy metal levels in Malaysian fish Fish Bull Dep Fish, (Malays), **No 58:** 16p

Dodoo, D K , Engel, D. W. and Sunda, W G , 1992 Effect of cupric ion activity on calcium accumulation in juvenile flounder (*Paralichthys spp*) Mar Environ Res , **33 (2)** 101 - 109

Eaton, A , 1976· Marine geochemistry of cadmium Mar Chem , **4·** 141 - 154

Eisler, R , 1971 Cadmium poisoning in *Fundulus heteroclitus* (L) (Pisces Cyprinodontidae) and other marine organisms J Fish Res Bd Can , **28·** 1225 - 1234

Eisler, R , 1974: Radiocadmium exchange with seawater by *Fundulus heteroclitus* (L) (Pisces Cyprinodontidae) J Fish Biol , **6** 601 - 612

Eisler, R., Zaroogian, G. E. and Hennekey, R H , 1972 Cadmium uptake by marine organisms J Fish Res Board Can , **29·** 1367 - 1369

El-Deek, M S ; Abbas, M. M ; Naguib, Kh M. and Naguib, M. M , 1994 a· Cu, Zn and Pb in *Epinephelus sp* in the Red Sea pp 229 - 236 In Proc 4th Internat Conf (Environmental Protection is a must), NIOF and USPD, 10 - 12 May 1994, Alexandria

El-Deek, M S ; Abdelmoneim, M. A., Beltagy, A I.; Naguib, Kh M. and Naguib, M. M., 1994 b· Distribution of Cu, Cd, Fe, Pb and Zn in some fish families from the Suez Canal and Mediterranean Sea (Egypt) pp 195 - 203 In Proc 4th Internat Conf (Environmental Protection is a must), NIOF and USPD, 10 - 12 May 1994, Alexandria

Elliott, N G ; Swain, R. and Ritz, D H , 1986· Metal interaction during the accumulation by the mussel *Mytilus edulis planulatus* Mar Biol , **93 (3).** 395 - 399

El-Moselhy, Kh M , 1993· Studies on the heavy metals level in some economic fishes in the Suez Gulf M Sc Thesis, Fac Sci , El-Mansoura University, 126 p

El-Moselhy, Kh. M and El Samra, M I., 1994 Metals in fish from Red Sea Symp on Red Sea Marine Environment (25 - 28 April, 1994), Abst , Jeddeh, Saudi Arabia, p 37

El-Nabawi, E ; Heinzow, B. and Kruse, H , 1987 As, Cd, Cu, Pb, Hg, and Zn in fish from the Alexandria region, Egypt Bull Environ Contam Toxicol , **39:** 889 - 897

El-Nady, F E , 1981 Survey of some heavy metals in Alexandria water and its effect on some marine animals Ph D Thesis, Fac of Sci , Alexandria University

El-Rayis, O A and Ezzat, A A., 1986 Bioaccumulation of some heavy metals in coastal marine animals in the vicinity of Alexandria (Egypt) 2 Surveying FAO Fish Res , **No 334** 67 - 72

El-Sokkary, I H , 1980 Mercury accumulation in fish from Mediterranean coastal area of Alexandria, Egypt Ves J Etud Pollut , 9 - 13 Oct , 1980, Cagliari, 493 - 496

Emara, H I , 1982· Study of some heavy metals in Abu Qir Bay and Lake Idku VIes J Etud Pollut , Cannes, C I E S M , 395 - 399

Emara, H I and Shriadah, M A , 1991. Manganese, iron, cobalt, nickel and zinc in the Eastern Harbour and El-Mex Bay water, Alexandria pp pp - 112 In Proc Symp Mar Chem in the Arab Region, April, 1991, Suez

Emara, H I., El-Deek, M S and Ahmed, N S , 1993: A comparative study on the levels of trace metals in some Mediterranean and Red Sea fishes Chem Ecol , **8:** 119 - 127

Emara, H. I ; Shriadah, M A , Moustafa, Th. H and El-Deek, M S., 1995 Trace metals-nutrient salts relationship in coastal sea-water of Alexandria pp 1457 - 1464 In Proc 2nd Internat Conf on The Mediterranean Coastal Environment, (Ed , E Ozhan), MEDCOAST 95, Oct 24 - 27, 1995, Tarragona, Spain

Engel, D W and Fowler, B A , 1979 Factors influencing cadmium accumulation and its toxicity to marine organisms Environ Health Prespect , **28·** 81 - 88

Ezzat, A. A , El-Rayıs, O A and El-Nady, F E , 1985: Bıoaccumulatıon of some heavy metals ın coastal marıne anımals ın the vıcınıty of Alexandrıa (Egypt) (II Bıoassay) J Fac Mar Scı , Kıng Abdelazız Unıversıty, Jeddeh, Saudı Arabıa, **4**· 167 - 180

FAO, 1976 Manual of methods ın aquatıc envıronment research Part 3, Samplıng and analyses of bıological materıal FAO Fısh Tech Pap , **No 158**, Rome, Italy

FAO, 1983· Manual of methods ın aquatıc envıronment research Part 9, Analyses of metals and organochlorınes ın fish FAO Fısh Tech Pap , **No 212**, Rome, Italy

FAO, 1992: Commıttee for ınland fisherıes of Afrıca, Workıng party on pollutıon and fisherıes FAO Fısh Rep , **No 471**· 24p

FAO, 1993 Water qualıty and fish health FIFAC, Tech Pap , **54** 67p

Fınney, D J , 1971. Probıt analysıs, 3rd ed , Cambrıdge Unıv Press, London & New York

Forstner, U and Prosı, F , 1979 Heavy metal pollutıon ın freshwater ecosystem pp 129 - 161 In Bıological aspects of freshwater pollutıon (Edıted by Ravera, O), Pergamon Press, Oxford, UK

Fouda, M. M , 1987: The elemental composıtıon of *Oreochromıs nıloticus* tıssues Bull Inst Oceanogr Fısh , ARE, **13 (2):** 169 - 179

Frazıer, J. M , 1975 The dynamıcs of metals ın the Amerıcan oyster, *Crassostrea vırgınıca* I Seasonal effects Chesapeake Scı , **16 (3):** 162 - 171

Frıberg, L and Kjellstrom, T , 1981: Cadmıum pp 318-334 In Dısorders of mıneral metabolısm (Bronner, F and Coburn, J W , eds), **Vol 1,** Trace metals Academıc Press, Inc , New York, USA

Fujıse, Y , Honda, K ; Tatsukawa, R and Mıshıma, S , 1988 Tıssue dıstrıbutıon of heavy metals ın Dall's Porpoıse ın the north-western Pacıfic Mar Pollut Bull , **19 (5)**· 226 - 230

Gaikwad, S A., 1989 Acute toxicity of mercury, copper and selenium to the fish *Etroplus maculatus* Environ Ecol, **7 (3)** 694 - 696

George, S G and Coombs, T L., 1977. The effects of chelating agents on the uptake and accumulation of cadmium by *Mytilus edulis* Mar Biol, **39:** 261 - 268

GESAMP, 1985 Joint group of experts on the scientific aspects of marine pollution, IMO/FAO/UNESCO/WHO/IAEA/UNEP Review of potentially harmful substances- cadmium, lead and tin Rep Stud, GESAMP, **(22):** 116p and UNEP Reg Seas Rep Stud, **(56).** 85 p

GESAMP, 1988· Joint group of experts on the scientific aspects of marine pollution, IMO/FAO/UNESCO/WHO/IAEA/UNEP Review of potentially harmful substances- arsenic, mercury and selenium Rep Stud, GESAMP, **(28)** 172p and UNEP Reg Seas Rep Stud, **(92)** 172 p

Giles, M. A, 1988 Accumulation of cadmium by rainbow trout, *Salmo gairdneri*, during extending exposure Can J Fish Aquat Sci, **45 (6):** 1045 - 1053

Gill, T. S and Epple, A, 1992: Impact of cadmium on the mummichog *Fundulus heteroclitus* and the role of cadmium in suppressing heavy metal toxicity Comp Biochem Physiol, **101C (3)·** 519 - 523

Glynn, A W., Haux, C. and Hogstrand, C., 1992: Chronic toxicity and metabolism of Cd and Zn in juvenile minnows (*Phoxinus phoxinus*) exposed to a Cd and Zn mixture Can J Fish Aquat Sci, **49 (10)** 2070 - 2079

Gould, E, Thompson, R. J., Buckley, L. J; Rusanowsky, D. and Sennefelder, G. R., 1988. Uptake and effects of copper and cadmium in the gonad of the scallop *Placopecten magellanicus* Concurrent metal exposure Mar Biol, **97 (2)·** 217 - 223

Greig, R A, 1979 Trace metal uptake by three species of mollusks Bull Environ Contam Toxicol, **22** 643 - 647

Greig, R A and Wenzloff, D R, 1978· Metal accumulation and depuration by the American oyster, *Crassostrea virginica* Bull Environ Contam Toxicol, **20:** 499 - 504

Grimanis, A. P; Zafiropoulos, D.; Papadopoulou, C. and Vassilaki- Grimani, 1980: Trace elements in the flesh of different fish species from three Gulfs of Greece V^es J Etud Pollut, 1980, Cagliari, 407 - 412

Gutierrez-Galindo, E A, 1980 Etude de l'elimination du cadmium par *Mytilus edulis* en presence d'EDTA et de phosphate Chemosphere, 495 - 500

Hafez, H. H., 1982 Distribution of heavy metals in Lake Mariut and Nozha Hydrodrome and their accumulation in fish M Sc Thesis, Fac Sci, Alexandria University

Hamed, M. A-F., 1992· Seawater quality at the northern part of the Gulf of Suez and the nearby area of the Suez Canal M Sc Thesis, Fac Sci, El-Mansoura University

Hamilton, S J and Buhl, K. J, 1990· Safely assessment of selected inorganic elements to fry of Chinook salmon (*Oncorhynchus tshawytscha*) Ecotoxicol Environ Saf, **20 (3)** 307 - 324

Handy, R D., 1992. The assessment of episodic metal pollution II The effects of cadmium and copper enriched diets on tissue contaminant analysis in rainbow trout (*Oncorhynchus mykiss*) Arch Environ Contam Toxicol, **22 (1)·** 82 - 87

Hardisty, M. W; Karter, S and Sainsbury, M., 1974. Dietary habits and heavy metal concentrations in fish from the Severn Estuary and Bristol Channel Mar Pollut Bull, **5 (4)** 61 - 63

Haynex, D, Leeder, J. and Rayment, P, 1995: Temporal and spatial variation in heavy metal concentrations in the bivalve *Donax deltoids* from the ninety mile beach, Victoria, Australia Mar Pollut Bull, **30 (6):** 419 - 424

Hernandez, H. F , Medina, J ; Ansuategui, J and Conesa, M , 1990. Heavy metal concentrations in some marine organisms from the Mediterranean Sea (Castellon, Spain) Metal accumulation in different tissues Sci Mar , **54 (2)** 113 - 129

Hilmy, A. M.; El-Domiaty, N. A.; Daabees, A. Y. and Alsarha, A., 1987: The toxicity to *Clarias lazera* of copper and zinc applied jointly Comp Biochem Physiol (C), **87 (2)** 309 - 314

Hoar and Randall, 1969 Fish physiology **Vol. I**

Hobden, D J , 1967· Iron metabolism in *Mytilus edulis* I- Variation in total content and distribution J mar Biol Ass , U K , **47.** 597 - 606

Holwerda, D A , 1991 Cadmium kinetics in freshwater clams 5 Cadmium- copper interaction in metal accumulation by *Anodonta cygnea* and characterization of the metal-binding protein Arch Environ Contam Toxicol , **21 (3)** 432 - 437

Honda, K., Tatsukawa, R.; Itano, K.; Miyazaki, N. and Fujiyama, T , 1983· Heavy metals concentrations in muscle, liver, kidney tissues of striped dolphin, *Stenella coeruleoalba*, and their variations with body length, weight, age and sex Agric Biol Chem , **47 (6)** 1219 - 1228

Honda, K., Yamamoto, Y; Kato, H. and Tatsukawa, R , 1987: Heavy metal accumulations and their recent changes in southern minke whales *Balaenoptera acutorostrata* Arch Environ Contam Toxicol , **16** 209 - 216

Hornung, H and Ramelow, G I , 1987 Distribution of Cd, Cr, Cu, and Zn in Eastern Mediterranean fishes Mar Pollut Bull , **18.** 45 - 49

Howard, A G , 1975. The nature of heavy metal complexes in molluscs Ph D Thesis, University of Bristol, UK

Huggett, R J , Bender, M. E and Slone, H D, 1973 Utilizing metal concentration relationships in the Eastern oyster *Crassostrea virginica* to detect heavy pollution Water Res , **7** 451 - 460

Hutcheson, M S, 1974· The effect of temperature and salinity on cadmium uptake by the blue crab, *Callinectes sapidus* Chesapeake Sci., **15** 237 - 241

Hutchison, T C. and Meema, K M, 1987 Lead, mercury and arsenic in the environment SCOPE 31 Chichester, John Wiley and Sons, 360 p

Ikeda, Y, Koyama, J and Ozaki, H, 1986 Heavy metal levels in tissues of fish exposed to cadmium Bull Jap Soc Sci Fish /Nissuishi, **52 (12)·** 2055 - 2059

Ikuta, K., 1987: Localization of heavy metals in the viscera and the muscular tissues of *Haliotis discus* exposed to selected metal concentration gradients Bull Jap Soc Sci Fish, **53 (12)·** 2269 - 2274

Ismail, P., Samin, K., Mohsin, A. K. M. and Mohamed, M I H., 1988 Heavy metal content in fish from Sarawak waters Occas Publ Fac Fish Mar Sci Univ Pertanian Malays, **8** 161 - 166

Jackim, E, Morrison, G and Steele, R., 1977: Effects of environmental factors on radiocadmium uptake by four species of marine bivalves Mar Biol, **40** 303 - 308

Jensen, A and Cheng, Z, 1987: Statistical analysis of trend monitoring data of heavy metals in flounder (*Platichthys flesus*) Mar Pollut Bull, **18 (5)** 230 - 238

Jansen, H H and Scholz, N., 1979 Uptake and cellular distribution of cadmium in *Mytilus edulis* Mar Biol, **55** 133 - 141

Jennings, J R and Rainbow, P S., 1979. Studies on the uptake of cadmium by the crab *Carcinus maenas* in the laboratory I Accumulation from seawater and a food source Mar Biol, **50.** 131 - 139

Kakulu, S E; Osibanjo, O and Ajayi, S O., 1987. Trace metal content of fish and shellfishes of the Niger delta area of Nigeria Environ Int, **13 (3)** 247 - 251

Kalal, L ; Pruzina, I.; Cibulka, J, Svatos, Z and Szakova, J , 1990 Hazardous metals in intensively - farmed rainbow trout Sbornik-Vysoke- Skoly- Zemedelske-v-Praze,-Fakulta-Agronomicka,-B, **No 52** 17 - 26

Karbe, L , Dembinski, M ; Gonzalez-Valero, J., Mueller, M. and Zeitner, R., 1989: Regional distribution of heavy metals in benthic organisms of the North Sea and adjacent waters Ecological Fisheries Problems of Water pollution in The Coastal Zone of The North Sea **No 48** 95 - 105

Khalaf, A N , Al-Jafari, A. R ; Elias, S S and Warda, M I , 1986· Bioaccumulatiom of some heavy metals in some tissues of *Barbus belaywi* from Dyala river J Biol Sci Res , **17 (1):** 27 - 46

Kleinert, S J , Degurse, P E. and Ruhland, J , 1974· Surveys of toxic metals in Wisconsin, concentration of metals in fish Tech Bull No 74 8-15 Dept Nat Resources, Madison, Wisconsin, USA

Knauer, G and Martin, J , 1973: Seasonal variation of cadmium, copper, manganese, lead and zinc in water and phytoplankton in Monterey Bay, California Limnol Oceanogr , **18·** 597 - 604

Krishnaja, A. P., Rage, M. S. and Joshi, A. G., 1987. Toxic effects of certain heavy metals (Hg, Cd, Pb, As and Se) on the intertidal crab *Scylla serrata* Mar Environ Res , **21 (2)** 109 - 119

Kucuksezgin, F. and Balci, A , 1994· Heavy metal concentrations in selected organisms from Izmir Bay, Turkey Mar Pollut Bull , **28 (5)** 333 - 335

Kutsuna, M , 1968: Minamata disease Study groups of minamata disease, Kumamoto University Japan

La Bella, F ; Dular, R , Vivian, S and Queen, G , 1973 a. Pituitary hormone releasing or inhibiting activity of metal ions present in hypothalamic extracts Biochem Biophys Res Commun , **52:** 786 - 791

La Bella, F., Dular, R ; Vivian, S and Queen, G , 1973 b Prolactin secretion is specifically inhibited by nickel Nature, **245:** 330 - 332

Lakshmanan, P. T. and Nambisan, P. N L , 1989: Bioaccumulation and depuration of some trace metals in the mussel, *Perna viridis* (Linnaeus) Bull Environ Contam Toxicol , **43 (1):** 131 - 138

Law, A. T and Singh, A., 1991 Relationships between heavy metals content and body weight of fish from the Kelang Estuary, Malaysia Mar Pollut Bull , **22 (2):** 86 - 89

Liao-IChiu and Hseih Chieh-Shih, 1988· Toxicity of heavy metals to *Penaeus japonicus* 1- Toxicity of copper, cadmium and zinc to *Penaeus japonicus* J Fish Soc Taiwan, **15 (2)** 69 - 78

Liao-IChiu, Hseih Chieh-Shih, Hirano, R and Hanya, 1990· Toxicity of three heavy metals to *Macrobrachium rosenbergii* pp 923-926 In Proc Sec Asian Fish Forum, 17-22 April, 1989, Tokyo, Japan

Lucas, H F JR and Edgington, D N , 1970: Concentrations of trace elements in Great Lake fishes J Fish Res , Bd Can , **27** 677 - 684

MacInnes, R , 1973· The toxicity of heavy metals to embryos of the American oyster *Crassostrea virginica* Mar Biol , **18 (3):** 162 - 166

Maher, W A , 1986 Trace metal concentrations in marine organisms from St Vincent Gulf, South Australia Water Air Soil Pollut , **29 (1)** 77 - 84

Majori, L and Petranio, F , 1973 a. Marine pollution by metals and their accumulation by biological indicators (accumulation factor) Rev Int Oceanogr Med , **31-32:** 55 - 90

Majori, L and Petranio, F , 1973 b: Accumulation phenomenon which in an artificially polluted environment Verification of a simplified model of the dynamic equilibrium of metal distribution between mussel and sea water Note II- Pollution from cadmium Fish Serv Transl Ser , **66:** 39 - 63

Marcovecchio, J E ; Moreno, V J and Perez, A., 1988· Determination of heavy metal concentrations in biota of Bahia Blanca, Argentina Sci Total Environ , **75 ((2/3).** 181 - 190

Marcovecchio, J E , Moreno, V J. and Perez, A , 1991: Metal accumulation in tissues of sharks from the Bahia Blanca estuary, Argentina Mar Environ Res , **31 (4)** 263 - 274

Marigomez, J A and Ireland, M P , 1989· Accumulation, distribution and loss of cadmium in the marine prosobranch *Littorina littorea* (L) Sci Total Environ , **78.** 1 - 12

Marks, P J., Plaskett, D.; Potter, J C and Bradley, J. S , 1980· Relationship between concentration of heavy metals in muscle tissue and body weight of fish from the Swan-Avon Estuary, West Australia Aust J Mar Freshwater Res , **31** 783 - 793

Martin, J H and Felgal, A R , 1975 High Cu concentrations in Squid livers in association with elevated levels of Ag, Cd and Zn Mar Biol , **30 (1)** 51 - 56

Martin, J H , Bruland, K. W and Broenkow, W. W., 1976. Cadmium transport in California current pp 159 - 184 In Marine Pollutant transfer (Eds H L Windom and A R Duce) D C Health and Co , Lexington, MA, USA

McFarlane, G A and Franzin, W. G , 1980· An examination of Cd, Cu, and Hg concentrations in liver of northern pike, *Esox lucius*, and white sucker, *Catostomus commersoni*, from five lakes near a base metal smelter at flin flon, Manitoba Can J Fish Aquat Sci , **37** 1573 - 1578

Meissner, W , 1817. Sur la presence du cuirre dans les cendres des vegetaux Ann Chem et Phys , **4:** 106

Merancer, J C and Somers, E , 1968 Determination of the heavy metal content of sea-food by atomic absorption spectro-photometry Bull Environ Contam Toxic , **3** 360 - 365

Miettinen, J K, 1973· The accumulation and excretion of heavy metals in organisms In Heavy metals in the aquatic environment proceeding of the international conference held in Nashville, USA, Pergamon Press

Miklovics, M H, Kovacs-Gayer, E and Szakolczai, J., 1985: Accumulation and effect of heavy metals in the fish of Lake Balaton In Heavy metals in water organisms, Salanki, J (ed) **29** 111 - 118

Miller, P. A; Munkittrick, K R and Dixon, D G, 1992 Relationship between concentrations of copper and zinc in water, sediment, benthic invertebrates, and tissues of white sucker (*Catostomus commersoni*) at metal-contaminated sites Can J Fish Aquat Sci, **49 (5).** 978 - 984

Mowdy, D. E, 1981 Elimination of laboratory - acquired cadmium by the oyster *Crassostrea virginica* in the natural environment Bull Environ Contam Toxicol, **26·** 345 - 351

Mukhopadhyay, M K; Ghosh, B. B and Bagchi, M. M., 1987 Toxicity behaviour of heavy metals on estuarine organisms Symp on the Impact of Current Land Use Pattern and Water Resources Development on Riverine Fisheries April, 25 - 27, 1987, Abst, p 26

NAS/NAE, 1973 National Academic of Science-National Academic of Engineering Water quality criteria Washington, D C, US Government Printing Office, 594 p

Nimmo, D W R., Lightner, D. V and Bahner, L H, 1977. Effects of cadmium on shrimps, *Penaeus duorarum*, *Palaemonetes pugio* and *Palaemonetes vulgaris*, pp 131-183 In Physiological responses of marine biota to pollutants (Eds F J Vernberg, A Calabrese, F P Thurberg and W B Vernberg), Academic Press, New York

Nomiyama, K., 1980 Recent progress and perspectives in cadmium health effects studies Sci Total Environ, **14·** 199 - 232

Nordberg, G F, 1972: Cadmium metabolism and toxicity Environ Physiol Biochem, **2:** 7 - 36

Norey, C G , Brown, M W ; Cryer, A and Kay, J , 1990 a A comparison of the accumulation, tissue distribution and secretion of cadmium in different species of fresh water fish Comp Biochem Physiol , **96C (1)**· 181 - 184

Norey, C. G , Cryer, A and Kay, J , 1990 b Cadmium uptake and sequestration in the pike (*Esox lucius*) Comp Biochem Physiol , **95C (2)** 217 - 221

Nriagu, J O , 1980 Human influence on the global cadmium cycle, pp 2-12 In Cadmium in the environment (Ed J O Nriagu) Wiley- Interscience, New York

Orren, M J., Eagle, G A., Hennig, H. F-H O and Green, A., 1980 Variations in trace metal content of the mussel *Choromytilus meridionalis* (Kr) with season and sex Mar Pollut Bull , **II** 253 - 257

Pagenkopf, G K , 1986. Metal ion speciation and toxicity in aquatic systems Concepts on Metal Ion Toxicity (Sigel, H ed), **20.** 101 - 118

Pentreath, R. J , 1973. The accumulation from S W of Zn^{65}, Mn^{54}, Co^{58} and Fe^{56} by the thornback ray, *Raja clavata* (L) J Exp Mar Biol Ecol , **12 (3)** 327 - 334

Pentreath, R. J., 1977· The accumulation of cadmium by the plaice, *Pleuronectes platessa* L and the thornback ray, *Raja clavata* L J Exp Mar Biol Ecol , **30** 223 - 232

Peterson, R H.; Sreedharan, A and Ray, S , 1989 Accumulation of trace metals in three species of fish from lakes in New Brunswick and Nova Scotia (Canada) Influence of pH and other chemical parameters Water Pollut Res J Can , **24 (1).** 101 - 117

Phillips, D J H., 1976: The common mussel *Mytilus edulis* as an indicator of pollution by zinc, cadmium, lead and copper I Effect of environmental variables on uptake of metals Mar Biol , **38**· 59 - 69

Portmann, J E, 1972. Results of acute toxicity testes with marine organisms, using a standard method pp 212 - 217 In Marine pollution and sea life (Ed by M Ruivo), London Fishing News, Books, Ltd

Prabhudeva, K. N and Menon, N. R, 1986. Toxicity of metal mixtures to *Perna viridis* (Mollusca Pelecypoda) pp 319 - 322 In Proc of the First Asian Fisheries Forum (Maclean, J L, Dizon, L B and Hosillos, L V eds), 26 - 31 May, 1986, Manila, Philippines

Preston, A, Jefferies, D F., Dutton. J. W, Harvey, B, R. and Steele, A K., 1972 British Isles coastal waters The concentrations of selected heavy metals in sea water, suspended matter, and biological indicators A pilot survey Environ Pollut, **3:** 69 - 82

Pringle, B H, Hissong, D E, Katz, E L and Mulawk, S. T., 1968: Trace metal accumulation by estuarine mollusks J Sanit Eng Div, **94 (3)** 445 - 475

Rani, A U and Ramamurthi, R, 1987: Toxicity of copper to some freshwater organisms Environ Ecol, **5 (2)** 407 - 408

Raspor, B, 1980 Distribution and speciation of cadmium in natural waters pp 147 - 236 In Cadmium in the environment, part I, (Ed J O Nriagu), Wiley - Interscience, New York

Ray, S, 1984. Bioaccumulation of cadmium in marine organisms Experientia, **40** 14 - 23

Ray, S., McLeese, D. W. and Pezzack, D., 1979: Chelation and interelemination effects on the bioaccumulation of heavy metals and Environment pp 35 - 38 In Proc Conf Manage Control, Heavy metals and Environment

Ray, S.; McLeese, D W. and Pezzack, D, 1980 a: Accumulation of cadmium by *Nereis virens* Arch Environ Contam Toxicol, **9:** 1 - 8

Ray, S ; McLeese, D W ; Waiwood, B A. and Pezzack, D , 1980 b Disposition of cadmium and zinc in *Pandalus montagui* Arch Environ Contam Toxicol , **9.** 675 - 681

Regoli, F., Orlando, E , Mauri, M., Nigro, M and Cognetti, G A , 1991 Heavy metals accumulation and calcium content in the bivalve *Donacilla cornea* Mar Ecol Prog Ser , **74 (2-3).** 219 - 224

Ringwood, A. H , 1991 Short-term accumulation of cadmium by embryos, larvae, and adults of an Hawaiian bivalve, *Isognomon californicum* J Exp Mar Biol Ecol **149 (1)** 5 - 66

Roberts, D , 1976 Mussels and pollution pp 67 - 80 In Marine mussels The ecology and physiology (Ed by Bayne, B L), Cambridge Univ Press, Cambridge

Robinson, W E and Ryan, D. K., 1986 Metal interactions within the kidney gill, and digestive gland of the hard clam, *Mercenaria mercenaria*, following laboratory exposure to cadmium Arch Environ Contam Toxicol , **15 (1):** 23 - 30

Romeo, M , 1987· Trace metals in fish roe from the Mauritania coast Mar Pollut Bull , **18 (9):** 507 - 508

Romeril, M. B , 1971. The uptake and distribution of ^{65}Zn in oysters Mar Biol , **9.** 347 - 354

Roth, I and Hornung, H , 1977. Heavy metal concentrations in water, sediments and fish from the Mediterranean coastal area, Israel Environ Sci Tech , **11:** 265 - 269

Saad, M. A H., 1985: Influence of pollution on Lake Mariut, Egypt III- Heavy metals Rapp P -V Reun CIESM, **29 (4)·** 145 -147

Saad, M. A H , 1987· Limnological studies on he Nozha Hydrodrome, Egypt, with special reference to the problems of pollution Sci Total Environ , **67** 195 - 214

Salanki, J ; Kataline, V-B and Erzsebet, B , 1982. Heavy metals in animals of Lake Balaton Water Res , **16:** 1147 - 1152

Sarzeau, A , 1830 Sur la presence du cuivre dans les vegetaux et dans le sang J Pharmacia et Sci Accessoires, **16:** 505

Scholz, N , 1980 Accumulation, loss and molecular distribution of cadmium in *Mytilus edulis* Helgolander Meeresunters , **33:** 68 - 78

Schulz-Baldes, M , 1974· Lead uptake from seawater and food, and lead loss in the common mussel *Mytilus edulis* Mar Biol , **25** 177 - 239

Shi, J. X and Yu, J. L , 1986: A preliminary study of influences of several heavy metal ions on the development of early embryo of thick shell mussel (*Mytilus coruscus* Gould) Donghai-Mar Sci / Donghai-Haiyang, **4 (1)** 46 - 50

Shiber, J G. and Salanki, J , 1981 Metal concentrations in certain coastal organisms from Beirut Lebanon Hydrobiologia, 181 - 196

Shimazu, Y., 1972 The Itai-Itai disease in polluted Japan Jisnu-Kora, Tokyo

Shriadah, M A and Emara, H I., 1991 The distribution of chromium, copper, cadmium and lead in areas of multi-polluting factors of Alexandria pp 39 - 50 In Proc Symp Chem in the Arab Region, April, 1991, Suez

Shriadah, M A and Emara, H. I , 1992: Iron, manganese, nickel, lead and cadmium in fish and crustacea from the Eastern Harbour and El-Mex Bay of Alexandria Bull High Inst Public Health, **XXII (3):** 515 - 525

Shuster, C N Jr. and Pringle, B. H., 1969: Trace metal accumulation by the American eastern oyster, *Crassostrea virginica* Proc Nat Shellfish Assoc , **59:** 91 - 103

Siewicki, T C ; Van-Dolah, F M. and Sydlowski, J S., 1986 Factors affecting the depuration of chemical contaminants by molluscan shellfish 11th Annual Tropical and Subtropical Fisheries Technological Conference of The Americas (Otweu, S W and Koburger, J A eds), **No 45** 15

Skul'-skıı, I A , Pıvovarova, N B and Kulebakıua, L G , 1987 Cadmıum accumulatıon ın tıssues of the mussel *Myıılus galloprovıncıalıs* Zh Evol Bıokhım Fızıol , **23 (3):** 281 - 286

Spehar, R L , 1976 Cadmıum and zınc toxıcıty to flagfish, *Jordanella florıdae* J Fısh Res Bd Can , **33** 1939 - 1945

Sprague, J B , 1967· Measurement of pollutant toxıcıty to fish I Bıoassay methods for acute toxıcıty Water Res , **3** 793 - 821

Tacon, A G J and De Sılva, S S , 1983: Mıneral composıtıon of some commercıal fish feed avaılable ın Europe Aquaculture, **31·** 11 - 20

Tarıq, J ; Jaffer, M. and Moazzam, M , 1991 Concentratıon correlatıons between major catıons and heavy metals ın fish from the Arabıan Sea Mar Pollut Bull , **22 (11)** 562 - 565

Tarzwell, C. M , 1958: The use of bıoassay ın the safe dısposal of electroplantıng wastes Amer Electroplanters Soc 44th Annu Tech Proc , 60

Tarzwell, C M , 1971 Bıoassays to determıne allowable waste concentratıons ın the aquatıc envıronment I Measurement of pollutıon effects on lıvıng organısms Proc R Soc London B , **177** 279

Taylor, D , 1981· A summary of the data on the toxıcıty of varıous materıals to aquatıc lıfe 2 Cadmıum Report Bl/A/2073, ICI Brıxham Laboratory, Freshwater quarry, Overgang, Brıxham, Devon

Thomas, D G ; Brown, M. W.; Shurben, D., del-G.-Solbe, J. F.; Cryer, A and Kay, J , 1985. A comparıson of the sequestratıon of cadmıum and zınc ın the tıssues of raınbow trout (*Salmo gaırdnerı*) followıng exposure to the metals sıngly or ın combınatıon Comp Bıochem Physıol , **82C (1)·** 55 - 62

Thorp, V J. and Lake, P. S., 1974. Toxıcıty bıoassay of cadmıum on selected freshwater ınvertebrates and the ınteractıon of cadmıum and zınc on the freshwater shrımp, *Paratya tasmanıensıs* Rıek Aust Mar Freshwat Res , **25:** 97 - 104

Thorpe, G J ; Costlow, J. D ; Cowgill, U. M. and Williams, L R , 1989 The relation of the acute (96h) uptake and subcellular distribution of cadmium and zinc to cadmium toxicity in larvae of *Rhithropanopeus harrisii* and *Palaemonetes pugio* Aquat Toxicol Hazard Assess , **12**· 82 - 94

Tsoukali-Papadopoulou, H.; Kaniou-Gregoriades, I.; Epivatianos, P. and Stratis, J. A., 1989: Heavy metals in marine organisms of Geras Gulf, Lesvos, Greece J Environ Sci Health, Part A, **A24 (1).** 39 - 47

Ueda, T., Nakamura, R. and Suzuki, Y., 1976. Comparison of ^{115m}Cd accumulation from sediments and sea water by polychaete worms Bull Jap Soc Sci Fish , **42:** 299 - 306

Underwood, E. J , 1956: Trace elements in human and animal nutrition Academic Press, New York

UNEP, 1984. Sampling of selected marine organisms and sample preparation for trace metal analysis Reference methods for marine pollution studies **No 7** Rev 2

Uysal, H and Tuncer, S , 1984 A comparative study on the heavy metal concentrations in some fish species and sediments from Izmir Bay VIIes J Etud Pollut , 11 - 13 Oct , 1984, Lucerne, 275 - 284

Vasilikiotis, G.; Fytianos, K. and Zotou, A., 1982: Heavy metals in marine organisms of the North Aegean Sea VIes J Etud Pollut , 1982, 303 - 306

Vos. G ; Hovens, J P. C. and Hagel, P., 1986: Chromium, nickel, copper, zinc, arsenic, selenium, cadmium, mercury and lead in Dutch fishery products 1977 - 1984 Sci Total Environ , **52 (1/2):** 25 - 40

Voutsinou, F , 1980. Trace metals in marine organisms from the Saronikos Gulf (Greece) Summary Reported on the Scientific Results of Mediterranean Pollution, pp 97 - 99

Voutsinou-Taliadouri, F , 1982· Monitoring of some metals in some marine organisms from the Saronikos Gulf VI[es] J Etud Pollut , 1982, 329 - 333

Vukadin, I ; Stegnar, P.; Tusek, M. and Zvonaric, T., 1984: Heavy metals analysis in sediments and marine organisms of the Bay of Mali Ston and the adjacent sea VII[es] J Etud Pollut , 11 - 13 Oct , 1984, Lucerne, 327 - 330

Wagemann, R., Stewart, R. E A ; Beland, P. and Desjardins, C, 1990: Heavy metals and selenium in tissues of Beluga Whales, *Delphinapterus leucas*, from the Canadian Arctic and the St Lawrence Estuary Advances in Research on The Beluge Whale, *Delphinapterus leucas* (Smith, T G , St-Aubin, D J and Geraci, J R eds), **No 224** 191 - 206

Wahbeh, M I and Mahasneh, D M., 1987 Concentration of metals in the tissues of six species of fish from Aqaba, Jordan Dirasat Sci , **14 (12)** 119 - 129

Ward, T. J., 1982: Laboratory study of the accumulation and distribution of cadmium in the Sydney rock oyster *Saccostrea commercialis* (I & R) Aust J Mar freshwater Res , **33** 33 -44

Ward, T J , 1984 Role of acute metal toxicity in structuring seagrass fauna near a lead smelter Mar Ecol Prog Ser , **17** 117 - 124

Watling, H. R. and Watling, R. J., 1976: Trace metals in *Choromytilus meridionalis* Mar Pollut Bull , **7.** 91 - 94

Westernhagen, H. von; Dethlefsen, V. and Rosenthal, H., 1979: Combined effects of cadmium, copper and lead on developing herring eggs and larvae Helgolander Meeresunters, **32:** 257-278

White, S L and Rainbow, P. S., 1982: Regulation and accumulation of copper, zinc and cadmium by the shrimp *Palaemon elegans* Mar Ecol Progr Ser , **8:** 95 - 101

Wicklund, A. and Runn, P , 1988. Calcium effects on cadmium uptake, redistribution, and elimination in minnows, *Phoximux phoximus*, acclimated to different calcium concentrations Aquat Toxicol , **13 (2):** 109 - 122

Arabic Summary

مدى إستجابة الأسماك للتلوث بالمعادن على طول السواحل المصرية

رسالة مقدمة من

خالد محمد إبراهيم المصيلحى
(ماجستير علوم «علم الحيوان» - ١٩٩٣)

مدرس مساعد
بالمعهد القومى لعلوم البحار والمصايد
فرع حلجى السويس والعقبة

لنيل

درجة دكتوراة الفلسفة فى العلوم
(علم الحيوان)

قسم علم الحيوان
كلية العلوم
جامعة طنطا

١٩٩٦

بسم الله الرحمن الرحيم

"ظَهَرَ الفَسَادُ فِى البَرِّ والبَحرِ بِمَا كَسَبَتْ أَيدِى النَّاسِ
لِيُذِيقَهُم بَعضَ الَّذِى عَمِلُواْ لَعَلَّهُم يَرجِعُونَ" (الروم - ٤١)

صدق الله العظيم

المشرفون

عنوان الرسالة **مدى إستجابة الأسماك للتلوث بالمعادن على طول السواحل المصرية**

إسم الطالب **خالد محمد إبراهيم المصيلحى**

لجنة الإشراف

أ د / محمد إبراهيم السمرة

أستاذ التلوث البحرى ومدير المعهد القومى لعلوم البحار والمصايد – فرع حليجى السويس والعقبة – السويس

أ د / ميرفيت أنور أحمد منصور

أستاذ الفسيولوجى بقسم علم الحيوان – كليه العلوم – جامعة طنطا – طنطا

أ د / محمود أحمد عبد المنعم

استاذ التلوث البحرى بالمعهد القومى لعلوم البحار والمصايد – الإسكندرية

الملخص العربى

تعد العناصر الثقيلة من الملوثات البحرية الخطرة حيث أنها تتواجد فى البيئة البحرية من خلال المصادر الطبيعية وكذلك خلال النشاط الإنسانى فالتلوث البحرى بالمعادن يمكن ان يودى الى تأثيرات ضاره فى اماكن تراكمه والذى يكون ذو تأثير حاد او مزمن على الحياة البحرية فى تلك المنطقة معظم النتائج المنشورة فى تأثير العناصر على الكائنات البحرية سجلت تأثيرات بالغة عند تركيزات أعلى من التركيز المتواجد فى البيئة فالمعادن تتراكم فى أنسجة الأعضاء وتؤدى الى تزايد تركيزها داخل الكائنات من خلال السلسلة الغذائية لا تكمن خطورة المعادن فى تأثيرها المباشر على الصحة العامة فقط ولكنها تعد ملوث واسع الإنتشار ومن الصعب التحكم فى خطورته

يهدف هذا العمل الى دراسة تراكيز المعادن داخل أنسجة الأسماك الإقتصادية من أماكن مختلفة على االساحل المصرى وكذا استجابة تلك الأسماك للتلوث فى تلك الأماكن وفى محاوله لتدبر مشكلة تراكم المعادن فى الأسماك، تم دراسة معدلات التراكم والتخلص من عنصرى الكادميوم والنحاس خلال تجربة طويلة المدى.

أوضحت نتائج الدراسة الآتى -

I- الدراسة الحقلية

١- مستوى العناصر فى الأسماك:

أ- العضلات

كانت اعلى قيم للكادميوم والنحاس (٠,٠٩ و١,٣٦ جزء فى المليون) والماغنسيوم والبوتاسيوم والصوديوم (٠,٤٦٥ و٤,٩٩٥ و٢,٨٩١ جزء فى الألف) فى الأسماك المجموعة من منطقة بورسعيد بينما كان الرصاص والزنك والكوبلت والنيكل والحديد (٠,٦١ و١٣,٥١٢ و٠,١٨٩ و٢,٤٦٨ و٤٧,٤٦ جزء فى المليون) والكالسيوم (٠,١٩٦ جزء فى الألف) فى اسماك خليج السويس

ب-الكبد

سجلت اعلى قيم للكادميوم والرصاص والكوبلت والنيكل (١,١٦ و١,٨٥١ و١,١١ و١٩,٧٦ جزء فى المليون) والكالسيوم والماغنسيوم والبوتاسيوم والصوديوم (١,٨٧٥ و٠,٧٣١ و٩,٦٣٣ و٢,٦٠٣ جزء فى الألف) فى أسماك جليج السويس اوضح النحاس اعلى تركيزاته (٨١,١٧ جزء فى المليون) فى اسماك الهليلى المجموعة من منطقة بورسعيد فى حين سجلت أسماك السيجان المجموعة من الاسكندرية والبحر الأحمر تركيزات عالية من الزنك (١٠٢,٩٠ جزء فى المليون) والحديد (٥٧٣,٥٩ جزء فى المليون) على التوالى

جـ- الخياشيم

سجلت الخياشيم اعلى قيم للكادميوم والرصاص والزنك والكوبلت والنيكل (٠,١٩٤ و ١,٢٤ و ٤٩,١ و ٠,٨١ و ٣,١٣ جزء فى المليون) والكالسيوم و البوتاسيوم (٠,١٩٤ و ٢,٤١١ جزء فى الألف) فى أسماك جليج السويس بينما كان النحاس والحديد (٣,٠٢ و ١١٩١,٣٠ جزء فى المليون) والماغنسيوم والصوديوم (١,٣٢ و ٢,٨٤٥ جزء فى الألف) فى الأسماك المجموعة من البحر الأبيض امام منطقة بور سعيد

٢- إستجابة الأسماك للعناصر.

أ- قابلية الأسماك للعناصر فى المناطق المختلفة

كان ترتيب العناصر الثقيلة فى عضلات الأسماك طبقاً للتركيز فى كل المناطق (ماعدا بورسعيد) كالآتى الحديد > الزنك > النيكل > النحاس > الرصاص > الكوبلت > الكادميوم، بينما فى منطقة بورسعيد كان الترتيب الحديد > الزنك > النحاس > النيكل > الرصاص > الكوبلت > الكادميوم

ب- طرق التغذية والمعيشة

بالنسبة لكل العناصر ماعدا الكادميوم، أوضحت الخياشيم تركيزات عالية فى الأسماك الشاطئية والتى تتغذى بطريقة الترشيح عن الأسماك القاعية آكلة اللحوم اوضح النحاس والزنك والكوبلت والحديد فى الكبد تركيزات عالية فى الأسماك التى تتغذى بطريقة الترشيح، بينما باقى العناصر (الكادميوم والرصاص والنيكل) كانت موجودة فى الأسماك المفترسة اما بالنسبة للعضلات فقد تواجدت العناصر (الرصاص والنحاس والزنك والكوبلت والحديد) فى الأسماك التى تتغذى بالترشيح بتركيزات عالية كان الكادميوم هو العنصر الوحيد الذى اوضح تركيزاته العالية فى الأسماك القاعية المفترسة بالنسبة لكل الأعضاء

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جـ- المحتوى الدهنى فى الأنسجة لأنواع الأسماك المختلفة

أوصح الكبد "والدى يعد من الأعضاء التى تحتوى عل نسبة عالية من الدهون" اعلى معدل تراكم بالنسبة لمعظم العناصر عن الأعضاء الأخرى

د- طرق تناول وحفظ العناصر فى الأماكن المختلفة (*دراسة حالة*)

اختيرت سمكة الحارت من مناطق الأسكندرية وبورسعيد وخليج السويس لايجاد بعض العلاقات الإحصائية للنتائج

i- علاقات العناصر فى العضلات بطول الأسماك

سجلت معظم العناصر فى عضلات أسماك الحارت علاقات غير معنوية سواء كانت طردية أو عكسية مع طول الأسماك، ماعدا القليل مثل الكالسيوم (معامل الإرتباط "r" = - ٠,٧٦٦) فى اسماك الأسكندرية، البوتاسيوم (معامل الإرتباط = ٠,٥٨٩) فى اسماك بورسعيد، والزنك (r = - ٠,٦٨٢) والحديد (r = - ٠,٨٠٤) فى أسماك السويس

ii- علاقات النحاس فى العضلات بطول الأسماك

فى الأسماك الصغيرة (الطول < ٢٢ سم) أوضح النحاس علاقات طردية مع الطول (r= ٠,٣٨٠٢ و ٠,٧١٣٧ و ٠,٨٧١١ لأسماك الاسكندرية وبورسعيد والسويس عل التوالى) بينما فى الأسماك الكبيرة (الطول ≥ ٢٢ سم) كانت العلاقات عكسية، وكان معامل الإرتباط = ٠,١٤١٥ و ٠,٥٤٥٠ و ٠,٥٤٩٠ لأسماك الاسكندرية وبورسعيد والسويس على التوالى

iii- علاقات العناصر فى عضلات الأسماك مع بعضها البعض

اوضحت أسماك منطقة بورسعيد علاقات معنوية ضعيفة بين العناصر ولم يسجل الرصاص اى علاقة ذات معنى مع العناصر الأخرى فى كل الأماكن فى حين كانت معظم العلاقات المعنوية بين العناصر العالية (الكالسيوم والماغنسيوم والبوتاسيوم والصوديوم) والعناصر الضرورية (النحاس والزنك والنيكل) ومن خلال هذه العلاقات اوضح الكالسيوم والماغنسيوم تشابه كبير فى علاقاتهما بالعناصر الأخرى وكذا طول الأسماك

iv- مستوى العناصر فى أسماك الحارت ومعامل التركيز

لوحظ وجود أعلى تركيز للكادميوم والزنك والكوبلت والحديد والصوديوم (٠,٠٤٤ و٢,٢٩٦ و٠,٠٨٥ و٢,٨٧٩ و٨١١,٩٤ جزء فى المليون) فى أسماك مياه بورسعيد بينما

سجل الرصاص والنحاس والنيكل والكالسيوم أعلى تركيز لهم (٠,٤٠٨ و٠,٣٢٨ و٠,٩١٩ و٣٩,٨٢٦ جزء فى المليون) فى اسماك مياهالاسكندرية فى حين ارتفع تركيز الماغنسيوم والبوتاسيوم فى الأسماك المجموعة من خليج السويس (٤٣٨,٢٤ و١٧٤٩,٢٧ جزء فى المليون)

وقد سجلت أسماك منطقة بور سعيد أعلى معامل تركيز للعناصر "الكادميوم والرصاص والنحاس والزنك" عن المناطق الأخرى

٧- استخدام التحليل الاحصائى One Way Anova

استخدم تحليل One Way Anova لحساب الإحتمالية والإختلاف فى محتوى العناصر بعضلات الأسماك المجموعة من المناطق المختلفة

وقد سجلت عضلات الأسماك إختلاف معنوى عالى فى محتواها من الكادميوم والكالسيوم والماغنسيوم والصوديوم بين كل المنطق المختبرة، وعلى النقيض اوضح الرصاص والنيكل والحديد اختلاف غير معنوى فى حين اوضح النحاس والزنك اختلاف غير معنوى بين الأسماك المجموعة من الإسكندرية وبور سعيد فقط، بينما الكوبلت والبوتاسيوم سجلا اختلاف غير معنوى بين أسماك بور سعيد وخليج السويس

٣- الاستهلاك الآمن للأسماك البحرية فى مصر.

تم حساب نسبة تركيز العناصر فى عضلات الأسماك الىالمستوى المسموح به استهلاكه آدمياً اسبوعيا Provisional Tolerable Weekly Intake (PTWI)، وقد اوضحت النتائج ان تركيز الكادميوم والرصاص والنحاس اقل من قيمة PTWI وعلى ذلك فليس هناك اى خطورة على الإنسان من تناول هذه الأسماك

وبمقارنة مستوى العناصر فى عضلات الأسماك لهذه الدراسة مع دراسات اخرى للأسماك المصرية لوحظ ان تركيز الكادميوم والرصاص فى هذه الدراسة اقل من المسجل فى الدراسات الأخرى بينما كان تركيز النحاس والزنك والحديد فى نفس مستوى التركيزات فى الأسماك المصرية الأخرى

وبمقارنة تركيز الكادميوم والرصاص والنحاس والزنك فى عضلات أسماك البربونى المجموعة من منطقة الاسكندرية بنتائج دراسات اخرى على ساحل البحر المتوسط لنفس النوع من الأسماك، وجد أن مستوى عناصرنا تقع فى مدى التركيزات المسجلة فى المناطق الأخرى بالبحر المتوسط

II- الدراسات المعملية

١- دراسة سمية الكادميوم والنحاس.

تم جمع صغار أسماك السهيلى من حوض الدرسه بقناة السويس وذلك لتقييم التأثير المميت للكادميوم والنحاس، وصنفت الأسماك لأحجام من ١,٨ الى ٣,٤ سم للطول الكلى ومن ٠,١ الى ٠,٤٥ جم للوزن الكلى وقد اوضح النحاس تأثير سام على صغار الأسماك (LC_{50}=١,٦٤ جزء فى المليون) أعلى من الكادميوم (LC_{50} = ٥,٢٧ جزء فى المليون)

٢- دراسات معدلات التراكم والتخلص من الكادميوم والنحاس

أ- الكادميوم

الكبد بعد حوالى ١٤ يوم من فترة التعرض، أوضح الكادميوم تزايد سريع ليصل الى ٣١٨ مرة أعلى من التركيز الأولى عند نهاية فترة التعرض (٨٤ يوم) فى المجموعة ٢,٠ ملليجم كادميوم/لتر، بينما التركيز الأقل للكادميوم (٠,٥ ملليجم/لتر) أوضح نقص الثبات (٤١ - ٦٢ مرة) حتى نهاية فترة التعرض خلال فترة التنقية، أوضح الكبد نمورج غير متوقع حيث استمر فى الزيادة بنفس اسلوب فترة التعرض حتى وصل الى ١٦٩ و٥٤٥ مرة أعلى من التركيز الأولى للمجموعتين ٠,٥ و٢,٠ ملليجم/لتر على التوالى، حتى نهاية التجارب (١٦٨ يوم)

الخياشيم كان تراكم الكادميوم فى الخياشيم سريع خلال اليوم الاول وسجل أعلى قيمه فى اليوم الرابع عشر (١٢ و٢٣ مرة للمجموعتين ٠,٥ و٢,٠ ملليجم/لتر على التوالى) خلال فترة التنقية، انخفض الكادميوم انخفاضا طبيعيا ليصل الى مستوى مجموعة المرجع (خوض خالى من العناصر) بالنسبة للمجموعة ٠,٥ ملليجم/لتر، فى حين وصل الى ٣ مرة فوق التركيز الأولى للمجموعة ٢,٠ ملليجم/لتر

الدم: تذبذب تركيز الكادميوم فى الدم بالقرب من تركيز مجموعة المرجع خلال كل اوقات التجربة

العضلات لم تستحب العصلات للكادميوم فى المجموعة ٠,٥ ملليجم/لتر حلال اوقات التحربة بينما فى المجموعة ٢,٠ ملليجم/لتر ارداد تركير الكادميوم ريادة طفيفة ليصل الى ٢ مرة فوق التركير الأولى وطل متدبدب حتى نهاية التحربة

ب- النحاس

الكبد حلال فترة التعرص، وصل تركير النحاس فى الكبد الى ٦ و٩ مرات فوق التركير الأولى للمجموعتين ٠,٢ و٠,٥ ملليجم نحاس/لتر على التوالى، ثم أوصح نمورح اكثر او اقل ثباتا حلال فترة التنقية حيث وصل الى ٨ و١٠ مرات للمجموعتين

الحياشيم أوصح النحاس تركيراته العالية فى الستة ساعات الأولى مسحلا حوالى ٤ و١٠ مرات للمجموعتين ٠,٢ و٠,٥ ملليجم/لتر، ثم تناقص وتدبدب حتى نهاية فترة التعرص بعد حوالى ٧ أيام من فترة التنقية، انحفص النحاس فى الحياشيم ليصل الى مستوى المرجع لكلا المجموعتين

الدم كان النحاس متدبدب حول مستوى المرجع فى كل اوقات التحربة

العضلات لم تسحل العصلات اى استحابة للنحاس فى كلا المجموعتين لكل اوقات التحربة، وكان مستواه متدبدب بالقرب من مستوى مجموعة المرجع

من نتائج التجارب السابقة يمكن ان نستنتج أن عضلات الأسماك "حيث انها الجزء الذى يستخدم كغذاء للانسان" تكون قليلة التأثر وحتى أنها يمكن أن لاتتأثر بتلوث مياهها بالمعادن (الكادميوم والنحاس فى هذه الدراسة) بينما الأعضاء الأخرى -مثل الكبد وهو عضو يخلص الجسم من السموم، والخياشيم بكونها متصلة اتصال مباشر بسطح المياه- يمكن أن تجمع تركيزات عالية من العناصر الموجودة فى بيئتها لتصل الى مستويات أعلى من تركيز الأمان المسموح به فى أنسجة الكائنات البحرية والتى لاتؤثر على الصحة العامة وعلى ذلك، فمستوى العناصر فى اعضاء الأسماك المجموعة من الأماكن عالية التلوث يجب أن تأخذ فى الاعتبار من المسئولين عن صحة الإنسان، حيث أنه من الضرورى منع الخطورة الناتجة عن احتواء الغذاء البحرى لمستويات عالية من العناصر فى أعضائها وتكون الخطوة الأولى بدأ برنامج قومى منظم ومستمر ومخطط تخطيط جيد لمتابعة مستوى العناصر فى البيئة البحرية المصرية

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بسم الله الرحمن الرحيم

"ظَهَرَ الفَسَادُ فِى البَرِّ والبَحرِ بِمَا كَسَبَت أَيدِى النَّاسِ
لِيُذِيقَهُم بَعضَ الَّذِى عَمِلُواْ لَعَلَّهُم يَرجِعُونَ" (الروم - ٤١)

صدق الله العظيم