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EFFECTS OF LOCALITY AND TISSUE TYPE ON HEAVY METAL LEVELS OF SOME COMMERCIAL FISHES FROM ALEXANDRIA-EGYPT.

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ABSTRACT

Concentrations of 4 metals (Cu, Cd, Pb and Hg) were determined in 2 freshwater fishes (**Claris lazera and Tilapia nilotica**) and 2 marine water fishes (**Sparus aurata** and **Tilapia zillii**). The freshwater fishes were collected from 3 localities: Rakta Co., Abu-Quir Fertilizer Co., General channel. The marine water fishes were collected from 4 localities: El-Temsah Shipping Co., Abu-Quir beach, El-Max beach and Anfoushy beach. Water, in which fishes live, was analysed for these metals.

Metal levels in the 4 fish species were affected by the locality. Higher metal concentrations were found in final waste water and fishes taken from the vicinity of industrial effluent discharge sites (Rakta Co., Abu-Quir Fertilizer Co., and El-Temsah Shipping Co.). Water and fishes collected from Anfoushy beach had the lowest metal levels. The type of the tissue analysed showed different levels of metal concentration. Elevated concentrations of the test metals were noted in the gills and liver, and lesser amounts were accumulated in kidneys, ileum, skeleton and muscles. The high levels of metal input to the localities in concern; were not reflected as high muscle concentrations in the 4 fish species. Trace accumulations of the test metals were found in the muscles.

INTRODUCTION

In the development of many industries, it is important to ensure that industrial effluent particularly heavy metals, are discnarged off in a way that will lead to minimal pollution. High concentrations of such elements may supress the physiological action, leading to growth of particular abnormalities in the organisms. The most important aspects of the metal contamination are the hazards to man caused by consuming contaminated fishery products. Hence, the analyses of metal levels in the different tissues of the fishes-especially edible ones are very important in the pollution studies. It is a preferable practice to investigate the metal levels in edible fishes in areas where new industries were set up; thus any significant changes in biological metal levels due to industrial activities may be detected. This is of great importance in Alexandria because a substantial portion of the human's diet consists of fishes; which may concentrate noxious materials resulting from the disposal of industrial effluents.

We have been concenrned with the region of Alexandria on which this study was carried out. The levels of Cu, Cd, Pd and Hg were determined in the four commercial fish species (**Clarias lazera, Tilapia nilotica, Sparus aurata** and Tilapia zillii) which are widely distributed in Alexandria region and are also important as food resources. Although only muscles of the fishes are eaten, samples of inedible tissues were also analysed. The results of chemical analyses were used to test for the effects of locality of capture and types of tissue of the fishes on their Cu, Cd, Pb and Hg contents. The sampling localities were choosen for the availability of each species and their proximity to known industrial effluent discharge points.

MATERIAL & METHODS

Experimental animals :

Two fresh water species (Clarias lazera and Tilapia nilotica) and two marine water species (Sparus aurata and Tilapia zillii) were used in this study.

Groups of 10 medium sized specimens of each species were obtained during summer seasons of 1985 and 1986. The weights of the collected individuals of the tested species were shown in table (1).

Sites of collection of water and fish samples were : Rakta, Co., Abu-Quir Fertilizer Co., General channel, El-Temsah shipping Co., Abu-Quir beach, El-Max beach and Anfoushy beach. Water samples were placed in plastic bags. As soon as fishes had been sorted into appropriate locality and species classes, they were placed in plastic bags kept on ice, taken to the laboratory and prepared for chemical analyses within 24 hr.

Water-metal analyses :

For estimating Cu, Cd and Pb in water of the localities where fishes were collected, samples of water (one litre) were obtained in glass bottles and then filtered in other bottles each containing 5 ml of 50 % (v/v) nitric acid. Stock standard solutions of Cu, Cd and Pb were prepared and substandard concentrations of 1,2,3,4,5,6 and 10 ppm were then prepared from them. The levels of Cu,Cd and Pb in water of the different localities were determined according to Bone and Hibbert (1979).

Table (1)

Weights of the fishes used in tissue analysis

Fish species	Weight (range in g)
Fresh water :	
Clarias lazera	100-140
Tilapia nilotica	130-170
Sea water :	
Sparus aurata	100-140
Tilapia zillii	170-220

Regarding the estimation of Hg level in water of the mentioned localities, samples of water were collected in bottles containing 50 ml of 4 % of potassium dichromate solution for preservation. Substandard solutions of 1,2,3,4,5,6 and 10 were prepared from Hg stock standard solution. Hg levels in water samples of the different localities were determined by the method of Johnson et al. (1965).

Tissue-metal analyses :

Gills, liver, kidneys, ileum, skeleton and muscles were selected for metal analyses. The tissues were excised in pooles and washed to remove particles of sediments. Each type of tissue was grouped according to locality and species.

Cu,Cd and Pb analyses of tissue were according to Langmyhr and Amodt (1976). Hg level in tissues was determined using the method of Aliseda et al. (1979).

The atomic absorption spectrophotometer used in the present study was of the type "Shimadzu seisakusho LT-D.A.A." The detection limits for the estimated elements their comparable wave lengths were shown in table (2).

RESULTS

Water-metal analyses demonstrated the relative persistence of four toxic metals (Cu,Cd,Pb and Hg). There were great variations in the metal concentrations among the different localities (tables 3-6).

Table (2)

Detection limits and the comparable wave lengths of the estimated metals

Metal	Wave length (A°)	Detection limit (ppm)
Cu	3248	0.0010
Cd	2288	0.0005
Pb	2170	0.0006
Hg	2537	0.5000

Table (3)

Levels of heavy metals in different tissues of **Clarias lazera** collected from three localities in Alexandria

Locality	Tissues and Water	Concentrations of heavy metals (ug/g wet weight)			
		Mercury	Copper	Cadmium	Lead
Rakta Co.	Gills	6.1 ± 0.3	4.6 ± 0.02	1.5 ± 0.1	4.1 ± 0.3
	Liver	4.3 ± 0.3	3.8 ± 0.2	1.3 ± 0.2	3.2 ± 0.3
	Kindey	3.1 ± 0.2	3.7 ± 0.1	1.4 ± 0.3	1.3 ± 0.3
	Ileum	2.7 ± 0.3	2.3 ± 0.2	0.8 ± 0.01	2.5 ± 0.3
	Skeleton	1.3 ± 0.1	0.5 ± 0.02	0.1 ± 0.03	3.4 ± 0.2
	Muscle	0.2 ± 0.01	0.2 ± 0.02	0.1 ± 0.01	0.9 ± 0.05
	Water	55.5± 0.5	49 ± 1.2	49 ± 0.5	58.5± 0.6
Abu-Quir Fertilizer Co.	Gills	5.6 ± 0.04	4.7 ± 0.1	2.2 ± 0.1	4.3 ± 0.3
	Liver	4.3 ± 0.2	3.7 ± 0.2	1.5 ± 0.1	3.0 ± 0.1
	Kindey	1.2 ± 0.1	2.5 ± 0.2	1.5 ± 0.01	1.7 ± 0.1
	Ileum	2.7 ± 0.2	2.1 ± 0.3	0.2 ± 0.01	1.6 ± 0.2
	Skeleton	0.9 ± 0.03	0.8 ± 0.03	0.2 ± 0.01	3.4 ± 0.2
	Muscle	0.5 ± 0.02	0.2 ± 0.01	0.1 ± 0.01	1.0 ± 0.01
	Water	66 ± 0.7	37 ± 0.5	48 ± 1.0	110 ± 1.0
General channel	Gills	5.0 ± 0.2	4.2 ± 0.04	1.2 ± 0.06	5.8 ± 0.1
	Liver	5.0 ± 0.1	6.1 ± 0.3	1.5 ± 0.1	2.3 ± 0.2
	Kindey	2.4 ± 0.3	5.3 ± 0.2	1.6 ± 0.1	1.6 ± 0.3
	Ileum	2.0 ± 0.1	3.6 ± 0.3	0.7 ± 0.04	2.7 ± 0.2
	Skeleton	1.3 ± 0.2	1.2 ± 0.05	0.2 ± 0.3	3.4 ± 0.3
	Muscle	0.6 ± 0.01	0.4 ± 0.01	0.1 ± 0.04	0.9 ± 0.04
	Water	28 ± 0.6	25 ± 0.5	29 ± 1.0	122 ± 1.1

Values are means ± SE of 6 individual observations.

Table (4)

Levels of heavy metals in different tissues of **Tilapia nilotica** collected from three localities in Alexandria

Locality	Tissues and water	Concentrations of heavy metals (ug/g wet weight)			
		Mercury	Copper	Cadmium	Lead
	Gills	6.3 ± 0.5	6.7 ± 0.3	1.8 ± 0.02	5.3 ± 0.3
	Liver	5.6 ± 0.3	4.9 ± 0.2	0.8 ± 0.01	2.9 ± 0.2
	Kindey	2.8 ± 0.3	3.2 ± 0.1	0.8 ± 0.03	1.6 ± 0.3
Rakta Co.	Ileum	1.9 ± 0.1	4.2 ± 0.2	0.1 ± 0.01	1.5 ± 0.1
	Skeleton	0.3 ± 0.01	0.2 ± 0.01	0.1 ± 0.01	3.2 ± 0.3
	Muscle	0.7 ± 0.03	1.6 ± 0.01	0.2 ± 0.01	0.4 ± 0.1
	Water	55.5± 0.5	49 ± 1.2	49 ± 0.5	58.5± 0.6
	Gills	5.8 ± 0.3	5.9 ± 0.06	1.0 ± 0.02	4.5 ± 0.2
	Liver	4.7 ± 0.2	4.8 ± 0.3	0.9 ± 0.01	4.5 ± 0.2
Abu-Quir Fertilizer Co.	Kindey	2.7 ± 0.1	3.6 ± 0.3	0.5 ± 0.03	0.7 ± 0.2
	Ileum	2.0 ± 0.2	4.6 ± 0.3	0.2 ± 0.04	1.4 ± 0.09
	Skeleton	0.4 ± 0.03	1.7 ± 0.1	0.2 ± 0.02	3.3 ± 0.04
	Muscle	0.1 ± 0.01	0.3 ± 0.02	0.1 ± 0.01	0.5 ± 0.03
	Water	66 ± 0.7	37 ± 0.5	48 ± 0.1	110 ± 0.1
	Gills	4.5 ± 0.08	5.5 ± 0.05	1.4 ± 0.1	5.9 ± 0.2
	Liver	4.6 ± 0.2	6.2 ± 0.3	1.9 ± 0.04	3.4 ± 0.2
General channel	Kindey	2.9 ± 0.1	2.5 ± 0.1	0.4 ± 0.03	1.9 ± 0.05
	Ileum	2.7 ± 0.2	1.4 ± 0.3	0.5 ± 0.01	1.5 ± 0.1
	Skeleton	0.5 ± 0.02	1.2 ± 0.06	0.3 ± 0.01	3.7 ± 0.4
	Muscle	0.3 ± 0.01	0.3 ± 0.04	0.1 ± 0.01	0.4 ± 0.02
	Water	28 ± 0.6	25 ± 0.5	29 ± 1.0	122 ± 0.1

Values are means ± SE of 6 individual observations.

The fresh water species (**Clarias lazera** and **Tilapia nilotica**) were collected from three localities: Rakta Co., Abu-Quir Fertilizer Co. and General channel. The data of metal analyses in the selected tissues of the two fresh water species were shown in tables (3 and 4). It is apparent from the tables that litte differences were found between the metal contents of the two fresh water species.

It is of great interest to note that the metal accumulation by the fresh water species was found to depend on its concentration in the different localities. The accumulations of Hg, Cu and Cd in gills of **Clarias lazera** and **Tilapia nilotica** caught from Rakta Co. and Abu-Quir Fertilizer Co. were found higher ($p < 0.05$, Student's t-test) than those in the General channel. Lead, in contrast to the other metals was found to be higher ($p < 0.05$, Student's t-test) in the gills of fishes caught from the General channel. Mercury reached its maximum value in the samples

Table (5)

Levels of heavy metals in different tissues of Sparus aurata collected from three localities in Alexandria

Locality	Tissue and water	Concentrations of heavy metals (µg/g wet weight)			
		Mercury	Copper	Cadmium	Lead
El-Tabiah shipping Co.	Gills	5.1 ± 0.3	3.0 ± 0.2	1.7 ± 0.1	4.2 ± 0.2
	Liver	5.4 ± 0.2	4.6 ± 0.4	1.9 ± 0.1	3.2 ± 0.1
	Kidney	3.2 ± 0.1	3.3 ± 0.2	0.9 ± 0.1	2.0 ± 0.3
	Ileum	3.1 ± 0.2	3.5 ± 0.3	0.5 ± 0.1	2.9 ± 0.2
	Skeleton	0.3 ± 0.1	1.5 ± 0.2	0.2 ± 0.01	3.9 ± 0.3
	Muscle	0.6 ± 0.1	1.0 ± 0.1	0.1 ± 0.01	0.7 ± 0.1
	Water	75 ± 2.2	47 ± 0.3	28 ± 1.3	48 ± 1.4
Abu-Qir beach	Gills	4.0 ± 0.3	3.6 ± 0.2	0.8 ± 0.1	3.3 ± 0.2
	Liver	3.1 ± 0.2	3.2 ± 0.4	0.7 ± 0.1	2.1 ± 0.1
	Kidney	1.1 ± 0.1	2.0 ± 0.05	0.1 ± 0.08	1.8 ± 0.3
	Ileum	1.3 ± 0.1	2.2 ± 0.3	0.2 ± 0.08	2.2 ± 0.3
	Skeleton	0.1 ± 0.05	0.9 ± 0.1	0.1 ± 0.08	2.0 ± 0.4
	Muscle	0.1 ± 0.04	0.1 ± 0.02	0.1 ± 0.08	0.9 ± 0.2
	Water	25 ± 1.3	36 ± 2.0	14 ± 0.6	36 ± 0.9
El-Max beach	Gills	3.4 ± 0.3	3.9 ± 0.3	1.2 ± 0.1	3.1 ± 0.2
	Liver	3.2 ± 0.1	3.1 ± 0.2	0.9 ± 0.2	3.1 ± 0.08
	Kidney	2.1 ± 0.3	1.2 ± 0.2	0.9 ± 0.2	3.3 ± 0.04
	Ileum	1.7 ± 0.2	2.9 ± 0.08	0.8 ± 0.1	3.0 ± 0.06
	Skeleton	0.3 ± 0.1	1.1 ± 0.2	0.3 ± 0.1	3.5 ± 0.4
	Muscle	0.2 ± 0.04	0.4 ± 0.1	0.1 ± 0.03	0.9 ± 0.1
	Water	33 ± 1.0	26 ± 0.7	16 ± 0.6	30 ± 0.5
Anfoushy	Gills	2.8 ± 0.3	3.5 ± 0.3	0.9 ± 0.1	2.2 ± 0.2
	Liver	2.6 ± 0.2	3.4 ± 0.3	0.8 ± 0.2	3.0 ± 0.09
	Kidney	1.2 ± 0.05	3.2 ± 0.06	0.6 ± 0.05	1.5 ± 0.1
	Ileum	1.0 ± 0.04	2.2 ± 0.3	0.8 ± 0.01	1.9 ± 0.07
	Skeleton	0.2 ± 0.02	1.5 ± 0.07	0.3 ± 0.01	3.4 ± 0.1
	Muscle	0.1 ± 0.05	0.4 ± 0.05	0.2 ± 0.06	0.9 ± 0.1
	Water	18 ± 0.5	16 ± 0.7	16 ± 0.4	27 ± 0.5

Values are means ± SE of 6 individual observations.

Table (6)

Levels of heavy metals in different tissues of **Tilapia zillii** collected from three localities in Alexandria

Locality	Tissues and water	Concentrations of heavy metals (ug/g wet weight)			
		Mercury	Copper	Cadmium	Lead
	Gills	6.7 ± 0.2	5.2 ± 0.2	1.9 ± 0.1	6.8 ± 0.3
	Liver	4.8 ± 0.3	6.1 ± 0.2	1.8 ± 0.1	3.5 ± 0.1
El-Temsah	Kindey	2.7 ± 0.1	3.8 ± 0.1	0.7 ± 0.04	1.9 ± 0.2
shipping	Ileum	2.7 ± 0.05	5.7 ± 0.3	0.8 ± 0.1	4.2 ± 0.4
Co.	Skeleton	0.7 ± 0.06	2.5 ± 0.2	0.2 ± 0.01	4.7 ± 0.3
	Muscle	0.4 ± 0.03	1.5 ± 0.1	0.1 ± 0.04	0.7 ± 0.04
	Water	75 ± 2.2	47 ± 0.3	23 ± 2.3	48 ± 1.4
	Gills	3.9 ± 0.2	2.9 ± 0.3	0.5 ± 0.01	5.1 ± 0.5
	Liver	3.0 ± 0.2	4.2 ± 0.C1	0.3 ± 0.01	2.6 ± 0.2
Abu-Quir	Kindey	1.2 ± 0.1	2.7 ± 0.1	0.3 ± 0.02	1.7 ± 0.2
beach	Ileum	1.5 ± 0.1	1.8 ± 0.2	0.4 ± 0.01	4.0 ± 0.3
	Skeleton	0.5 ± 0.04	1.2 ± 0.1	0.1 ± 0.02	4.3 ± 0.2
	Muscle	0.1 ± 0.03	0.9 ± 0.1	0.1 ± 0.03	0.4 ± 0.01
	Water	25 ± 1.5	24 ± 2.0	14 ± 0.06	34 ± 0.5
	Gills	5.0 ± 0.2	3.4 ± 0.2	0.6 ± 0.01	3.2 ± 0.1
	Liver	3.0 ± 0.1	3.5 ± 0.06	0.9 ± 0.1	3.1 ± 0.2
El-Max	Kidney	1.6 ± 0.1	2.2 ± 0.1	0.7 ± 0.03	3.2 ± 0.1
beach	Ileum	1.6 ± 0.2	3.1 ± 0.2	0.9 ± 0.03	3.0 ± 0.06
	Skeleton	0.6 ± 0.1	0.6 ± 0.2	0.3 ± 0.06	3.7 ± 0.1
	Muscle	0.1 ± 0.04	0.4 ± 0.03	0.1 ± 0.01	1.0 ± 0.04
	Water	33 ± 1.1	26 ± 0.7	16 ± 0.6	30 ± 0.52
	Gills	4.1 ± 0.05	2.5 ± 0.1	0.6 ± 0.02	2.0 ± 0.2
	Liver	4.3 ± 0.3	2.9 ± 0.2	0.8 ± 0.05	3.0 ± 0.1
Anfoushy	Kidney	2.2 ± 0.1	2.1 ± 0.1	0.6 ± 0.05	1.0 ± 0.01
	Ileum	1.9 ± 0.06	3.0 ± 0.2	0.9 ± 0.04	3.1 ± 0.2
	Skeleton	0.7 ± 0.1	0.6 ± 0.04	0.3 ± 0.03	4.1 ± 0.2
	Muscle	0.1 ± 0.03	0.4 ± 0.04	0.1 ± 0.01	0.9 ± 0.1
	Water	18 ± 0.5	16 ± 0.7	16 ± 0.4	27 ± 0.5

Values are means ± SE of 6 individual observations.

of both **Clarias lazera** and Tilapia nilotica obtained from the final waste water of Rakta Co. (6.1 and 6.3 ug/g wet weight respectively).

The highest values of Cu and Cd in **Clarias lazera** were found in gills of specimens obtained from the final waste water of Abu-Quir Fertilizer Co. (4.7 and 2.2 ug/g wet weight respectively). While in Tilapia nilotica, Cu and Cd were found mostly in gills of specimens obtained from the final waste water of Rakta Co. (6.7 and 1.8 ug/g wet weight respectively).

Cu (as an essential metal) in gills of Clarias lazera obtained from the three mentioned localities ranged from 4.2 to 4.7 ug/g wet weight and in **Tilapia** nilotica it ranged from 5.5 to 6.7 ug/g wet weight i.e. its range of variation is small. In a parallel comparison, the other three nonessential metals studied; Hg;Cd and Pb had each a relatively higher range of variation.

In both fresh water species, metals were consistently higher in gills of fishes obtained from Rakta Co. and Abu-Fertilizer Co. In contrast, the fresh water fishes of the general channel and Cu and Cd contents in their livers higher ($p < 0.05$, Student's t-test) than in their gills. The accumulation of the estimated heavy metals was of lesser amounts in kidney, ileum and skeleton.

Of particular interest was the muscle response to accumulate metals. On the basis of g wet weight samples, trace accumulations of the test metals were found in muscles of both fresh water species. The maximum accumulations of Hg,Cu,Cd **and Pb in muscle samples reached** 0.7, 1.6, 0.2 and 1.0 **ug/g respectively on a wet weight basis.**

Marine fishes (Sparus aurata and Tilapia zillii) were collected from four different localities; El-Temsah shipping Co; Abu-Quir beach, El-Max beach and Anfoushy beach. Levels of the test metals in their tissues were given in table (5 and 6).

Tissue concentration analyses showed that the levels of the metals in gills of the marine fishes caught from El-Temsah Shipping Co. were higher ($p < 0.05$, Student's t-test) than those found in gills of fishes collected from the other three localities. Conversely, minimal values of the metals were observed in the gills of fishes caught from the Anfoushy locality.

The results reported herein showed low levels of Hg,Cu,Cd and Pb in the muscles of both **Sparus aurata** and Tilapia zillii collected from the 4 mentioned localities.

DISCUSSION

It would be of great interest if the concentrations of the pollutants were determined simultaneously in the water which fishes live and in the fishes themselves. From the interrelationship between the pollutant concentrations in the source of contamination and that in the organism, it would be possible to reveal regulation of the pollutant.

Alexandria receives in its aquatic environment various and different pollutants. Saleh (1984) recorded many pollutants in the contaminated areas of Alexandria, such as wastes of Rakta Co., in the form of suspended matter, sulphides, volatile solids, settled solids, Mn, Fe, Cu, Cd, Ag, Zn and Pb. Heavy metals represent the major toxic pollutants associated with most industries in Alexandria. Murphy (1979) showed that several industries discharge a suit of metals in their effluents.

The present investigation showed that the metal levels at each locality reflect contributions from natural as well as man induced sources such as industrial input. The pattern of metal ontents of fish from the localities where fishes were collected varies (described in the results section). However, it is not difficult to rank these localities in order of metal contents. Higher metal concentrations were found in the samples of final waste water and fishes taken from the vicinity of industrial effluent discharge sites (Rakta Co., Abu-Quir Fertilizer Co. and El-Temsah Shipping Co.). This ties in with the data of Walker (1982) who observed that the effect of locality on metal concentrations in teleosts (**Platycephalus bassensis**) and **Platycephalus caeruleopunctatus**) was highly significant.

In the present study metal uptake was found linearly related to metal concentration in water. Fishes and final waste water from the locality of El-Temsah Shipping Co. had the highest level of mercury. Brown (1977) found that the teleost **Platycephalus bassensis** was a good indicator of mercury contamination. The evidence from determinations of the test metals in water and fish samples from Anfoushy beach suggest that the area is not heavily contaminated with heavy metals.

In the investigation designed here, the bioaccumulations of metals were greatly affected by the types of tissues analysed; being higher in gills and liver, and lesser in kidneys, ileum, skeleton and muscles. Similar results have been obtained by other authors (e.g. Vinogradoc, 1953; Brungs and Mount, 1967; Wobeser, 1975). This probably reflects the direct contact of gills with the contaminated water and possible detoxification of the liver by the metals.

It is important to know to what extent the edible parts of fishes are contaminated. The data obtained from the metal distribution among the tissues in concern suggested that muscles do not have so great an ability to accumulate metals as other tissues.

REFERENCES

Aliseda, J.R.; R. Ankersmit; G.W. Zshley; J. Bult, R.; W.T. Carter; W. Durr; J. Garbayo; M. Garica; CH. Killens; L. Mariant; S.A. Norbers; F. Nouyrigat; M. Olivier and Romies, 1979. Standardization of methods for the determination of trace of mercury. Analytica Chemica Acta 109: 209-228.

Bone, K.M. and W.D. Hibbert, 1979. Solvent extraction with ammonium pyrrolidine dithiocarbamate and 2,6-dimethyl-4-Heptanone for determination of trace metals in effluents and natural water. Analytica Chemica Acta 107: 219-229.

Brown, I.W., 1977. Ecology of three sympatric flat heads (Platycephalidae) in Port Phillip Bay, Victoria. Ph.D. Thesis, Monash University.

Brungs, W.A. and D.I. Mount, 1967. Lethal endrin concentration in the blood of gizzard shad. J. Fish. Res. Board Can. 24: 429-433.

Johnson, W.C.; J.C. Gage and E.T. Johnson, 1965. The determination of small amounts of mercury in organic matter. The Analyt. 90: 1074-1083.

Langmyher, F.J. and J. Amodt, 1976. Atomic absorption spectrophotometric determination of some trace metals. Analytica Chemica Acta 78: 483-486.

Murphy, P.J., 1979. A report to the Cockburn Sound Study: technical report on industrial effluents. Department of Conservation and Environment, Western Australia, Rep. No. 6.

Saleh, H.H., 1984. Effect of industrial waste water from Tabia pumping station in Abu-Quir Bay (Mediterranean Sea) on Mugil capito Cur. VIIes (1984) Journees Etud. Pollution lucerne, C.I.E.S.M.

Vinogradov, A.P., 1953. The elementary chemical composition of marine organisms. Sears Found. Mar. Res., New Haven, Conn., 647 p.

Walker, T.I., 1982. Effects of length and locality on the mercury content of blacklip abalone, blue mussel, sand flathead and long-nosed flathead from Port Phillip Bay, Victoria Aust J. Mar. Freshwater Res. 33: 553-560.

Wobeser, G., 1975. Prolonged oral administration of methyl mercury chloride to rainbow trout and fingerlings. J. Fish. Res. Board Can. 32: 2015-2023.