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Distribution pattern of some heavy metals in Egyptian fish organs

M. N. E. Gomaa, A. A. K. Abou-Arab, A. Badawy & Naguib Khayria

Department of Food Science and Technology, National Research Centre, Dokki, Cairo, Egypt

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Distributions of some heavy metals in different fish organs were studied. Maximum concentrations (ppm) of lead (1·24), cadmium (0·82), chromium (0·721), zinc (10·9), copper (2·26), manganese (0·33), and iron (1·41) were found in the brain, whereas the minimum concentration detected in flesh samples were lead (0·149), cadmium (0·050), chromium (0·080), zinc (0·820), copper (0·420), manganese (0·048), and iron (0·191 ppm).

INTRODUCTION

Fish are often at the top of the aquatic food chain and may concentrate large amounts of some metals such as lead, cadmium, chromium, copper, zinc, and iron. These metals accumulate differently in fish organs (bone, brain, flesh, gills, gonad, and liver). Eisenberg and Topping (1986) in Maryland (USA), determined cadmium concentrations in fish tissues and they found that the highest concentration (0·87 ppm) was higher than the permissible limits (0·50 ppm) of FAO (1983). They also found a significant increase in Cd concentrations in liver tissue in comparison to flesh tissue. This is consistent with the finding of Hegi and Geiger (1970) who found similar results in livers of fresh water finfish and also with the finding of Barak and Mason (1990) who reported that Cd concentrations were higher in the liver than flesh. However, Hernandez *et al.* (1990) found low Cd concentrations in muscle as well as in gonad and gills. They also reported that an important accumulation of this metal took place in liver and kidney, in the order, muscle < liver < kidney. The results obtained by Eisenberg and Topping (1986) indicated that no detectable concentrations of lead were found in any liver samples and only 2 of 24 gonad samples showed detectable concentrations, indicating preferential bioaccumulation in flesh tissue (mean value, 1·52 ppm) in samples of various species of finfish harvested from the Maryland section of the Chesapeake Bay. Also, Hernandez *et al.* (1990) reported that the gonad and flesh (muscle tissue) showed the lowest metal content. Hegi and Geiger (1979) found enrichment of lead in the liver of freshwater finfish. Moreover, Halocombe *et al.* (1976) and Dallinger *et al.* (1987) concluded that liver and other soft organs are important targets for lead. Barak and Mason (1990) showed that lead concentrations were higher in liver (ranging from 0·01 to 0·36 ppm) than in fish flesh (ranging from 0·01 to 0·30 ppm). However, Hernandez *et al.* (1990) reported that high concentrations of lead accumulated in gills. Different concentrations of zinc were found in different organs. Eisenberg and Topping (1986) reported that the concentrations of Zn ranged from 2·9 to 3·8 ppm in flesh and ranged from 9·4 to 23·0 ppm in gonad samples of American shad harvested from the water of Harford county. Also, the concentrations of Zn were lower in axial muscle tissue than in liver tissue. Wiener and Giesy (1979) observed that axial muscle contained 4·9–48·7 ppm; however, the liver contained 18·9 to 48·7 ppm dry weight. Copper also may accumulate in different organs. Eisenberg and Topping (1986) found that this metal accumulated at higher concentrations in gonad (1·21–7·22 ppm) than flesh (0·40–0·78 ppm). Also, Wiener and Giesy (1979) reported that Cu concentrations were lower in axial muscle tissue than in liver tissue, which ranged from 0·06 to 2·52 ppm, and 4·10–918·90 ppm dry weight, respectively.

Chromium is another metal detected in different organs of fish, Hernandez (1990) reported that the lowest value of Cr was detected in muscle (ranging from 0·0 to 0·10 ppm) and was increased in gills (0·125–0·775 ppm). Manganese also is a heavy metal, which accumulates in fish organs. Wiener and Giesy (1979) reported that the concentration of manganese in muscle ranged from 0·13 to 0·70 ppm) which is lower than in liver (0·80–12·96 ppm, dry weight).

Metal concentrations in fish are mostly measured in liver or muscle (flesh), the latter being of most concern to man because it is the main tissue consumed as food. On the other hand, liver is now widely recognized as a valuable indicator of pollution (Hansen *et al.*, 1982;

Jensen, 1983; Phillips & Segar, 1986; Badsha & Goldspink, 1988). So, the objective of this study was to detect and determine the concentrations of contamination by heavy metals and distribution of these metals in different fish organs.

MATERIALS AND METHODS

Sample collection

Seven hundred and twenty-seven composed fish organ samples were collected from six Governorates (Damitta, Port-Said, Hourghada, Suez, Ismailia, and Alexandria) to assess the distribution of heavy metals in the Egyptian fish organs. All samples were taken at random through the period from January 1986 to January 1989. The number of the collected fish organs were as follows: bone (118), brain (77), flesh (128), gills (159), gonad (105) and liver (140).

Heavy metal standards

Stock standard solutions of lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe), were collected from Merck in concentrations of 1000 mg/l (Merck, Darmstadt, Germany).

Analytical methods

A Perkin-Elmer (2380) Atomic Absorption Spectrophotometer was employed for the analysis. The maximum absorbance was obtained by adjusting the cathode lamps at specific slits and wave lengths as shown in Table 1.

Fish organ samples

The samples were prepared by the method of the Association of Official Analytical Chemists (AOAC, 1980).

Statistical analysis

To detect the significance of differences in the tested heavy metals in fish organs, the data were analyzed using one-way analysis of variance according to the following model (Winer, 1971).

$$Y_{ij} = \mu + \alpha_i + \Sigma_{ij}$$

where Y_{ij} : observation on element j under effect of α_i, μ : general population mean, α_i : location effect and Σ_{ij} : experimental error associated with measurement on element j.

General Linear Model of SAS (SAS, 1988) were used to perform the analysis of variance.

Table 1. Wave lengths (nm) and slit width (nm) for determination of heavy metals

Metal	Wave length (nm)	Slit width (nm)
Cadmium (Cd)	228·8	0·7
Copper (Cu)	324·8	0·7
Ferrous (Fe)	248·3	0·2
Manganese (Mn)	279·5	0·2
Lead (Pb)	217·0	0·7
Zinc (Zn)	319·9	0·7
Chromium (Cr)	425·4	0·2

RESULTS AND DISCUSSION

The study was carried out to detect the differences among the heavy metal concentrations in different fish organs. The distributions of heavy metals in fish organs are given in Tables 2, 3 and 4. The obtained results showed that lead in the brain of the collected fish samples showed the highest mean concentration of 1·24 ppm wet weight, followed by gonad, liver and bone, being 0·981, 0·889 and 0·368 ppm, respectively. The lowest concentration was found in flesh which showed 0·149 ppm.

For cadmium, the lowest concentration was detected in flesh (0·05 ppm) and gills (0·15 ppm) followed by bone (0·27 ppm), liver (0·31 ppm) and gonad (0·37 ppm). The highest concentration of Cd recorded was in brain (0·82 ppm). Low concentrations of Cd in gills are deceptive, because Cd is extremely toxic and cumulative. Benoit *et al.* (1976), who measured Cd in water for up to 38 weeks, reported that kidney accumulated the highest concentration, followed by liver and gills. Exposed fish placed in fresh water lost Cd rapidly from gill tissue but did not lose it from either the kidney or liver.

The concentrations of chromium in the brain of fish samples showed the highest concentration (0·721 ppm wet weight). On the other hand, flesh samples were found to have the lowest concentration (0·08 ppm). Bone, gonad and liver contained 0·308, 0·673 and 0·311 ppm wet weight.

The results clearly indicate that the brain samples examined during this study contained the highest concentration of zinc, which showed a mean value of 10·9 ppm wet weight, followed by gonad (5·32 ppm). Liver, bone and gills recorded intermediate values (3·78, 2·32 and 2·14 ppm, respectively). The lowest concentration was found in flesh which contained 0·82 ppm.

Copper was found at concentrations of 2·26 and 1·60 ppm in brain and gonad, respectively. Gills and flesh had the lowest concentrations (0·54 and 0·42 ppm). However, bone and liver had intermediate concentrations (0·88 and 0·78 ppm, respectively).

The collected fish samples, indicated that the concentration of manganese in brain (0·33 ppm) was higher than in other organs. However, flesh samples had the lowest concentration, (0·048 ppm). The concentrations of Mn in gonad, bone, liver and gills were 0·281, 0·158, 0·152 and 0·136 ppm, respectively.

It is also noticed from the data, that fish brain samples contained a larger amount of iron (1·41 ppm) than the other organs. In contrast, flesh samples had the lowest concentration of iron (mean value, 0·191 ppm). The concentrations of iron in liver, gonad, gills and bone were 1·16, 0·93, 0·601 and 0·356 ppm, respectively.

Table 2. The concentrations of lead, cadmium, chromium, and zinc in organ fish samples collected from different localities in Egypt

Organ	No. of samples	Concentration in ppm (mg/kg wet weight)							
		Lead		Cadmium		Chromium		Zinc	
		Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE
Bone	118	0–1·91	0·368 ± 0·034	0–1·50	0·270 ± 0·03	0–1·99	0·308 ± 0·037	0–16·4	2·32 ± 0·26
Brain	77	0–5·61	1·24 ± 0·150	0–7·60	0·820 ± 0·17	0–3·96	0·721 ± 0·110	0–64·6	10·9 ± 1·76
Flesh	128	0–0·95	0·149 ± 0·017	0–0·30	0·050 ± 0·01	0–0·54	0·080 ± 0·010	0– 7·2	0·82 ± 0·10
Gills	159	0–1·29	0·262 ± 0·022	0–2·00	0·150 ± 0·02	0–0·76	0·139 ± 0·013	0–12·4	2·14 ± 0·20
Gonad	105	0–5·95	0·981 ± 0·140	0–9·20	0·370 ± 0·10	0–5·46	0·673 ± 0·120	0–39·4	5·32 ± 0·82
Liver	140	0–6·39	0·889 ± 0·110	0–4·80	0·310 ± 0·06	0–3·43	0·311 ± 0·049	0–23·8	3·78 ± 0·44

Table 3. The concentrations of copper, manganese, and iron in organ fish samples collected from different localities in Egypt

Organ	No. of samples	Concentration in ppm (mg/kg wet weight)					
		Copper		Manganese		Iron	
		Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE
Bone	118	0–12·2	0·88 ± 0·16	0–0·72	0·158 ± 0·016	0–1·64	0·356 ± 0·034
Brain	77	0–15·4	2·26 ± 0·42	0–2·11	0·333 ± 0·057	0–5·05	1·41 ± 0·150
Flesh	128	0– 7·4	0·42 ± 0·10	0–0·56	0·048 ± 0·070	0–1·44	0·191 ± 0·025
Gills	159	0–13·6	0·54 ± 0·12	0–1·29	0·136 ± 0·015	0–3·24	0·601 ± 0·052
Gonad	105	0–14·0	1·60 ± 0·26	0–2·00	0·281 ± 0·049	0–5·73	0·930 ± 0·110
Liver	140	0–14·8	0·78 ± 0·16	0–1·58	0·152 ± 0·024	0–7·77	1·16 ± 0·140

Table 4. The maximum and the minimum mean levels of the tested metals in organs from collected fish samples

Metal	Maximum Mean ± SE	Organ	Minimum Mean ± SE	Organ
Lead**	1·24 ± 0·110	Brain[a]	0·149 ± 0·017	Flesh[c]
Cadmium**	0·820 ± 0·170	Brain[a]	0·050 ± 0·010	Flesh[d]
Chromium**	0·721 ± 0·110	Brain[a]	0·080 ± 0·010	Flesh[c]
Zinc**	10·9 ± 1·760	Brain[a]	0·820 ± 0·100	Flesh[d]
Copper**	2·26 ± 0·420	Brain[a]	0·420 ± 0·100	Flesh[c]
Manganese**	0·333 ± 0·057	Brain[a]	0·048 ± 0·080	Flesh[c]
Iron**	1·41 ± 0·150	Brain[a]	0·191 ± 0·025	Flesh[d]

** highly significant $P < 0·001$.
Means having the same letters is where significant differences were detected.

Statistical analysis proved highly significant differences among selected organs in fish samples tested for Cu, Zn, Mn, Pb, Cr, Cd and Fe ($P < 0·001$). For copper concentrations, Duncan's test for mean separation indicated that brain has a significantly higher concentration than gonad, bone, liver, gills and flesh, and flesh showed the lowest concentration. Zinc concentration in brain was also significantly higher than gonad, liver, bone, gills and flesh. However, no significant differences were recorded between gonad and liver, and among bone, gills and flesh. For manganese, brain has significantly higher values than other organs. No significant differences were recorded between brain and gonad. Also, no significant differences were detected among bone, liver, gills and flesh. The fish brain samples examined were significantly higher in lead content than those of other organs. On the other hand, no significant differences were observed between gonad and liver or among bone, gills and flesh. With cadmium the mean separation analysis showed that brain had significantly higher values than did liver, bone, gills and flesh. However, no significant differences were observed between brain and gonad. Nor were there any significant differences between liver, bone and gills. Brain had the highest Cd content, whereas flesh and gills had the lowest concentration. No significant differences were detected among gonad, liver and bone. The concentration of iron was significantly higher in brain than gonad, gills, bone and flesh. However, flesh was significantly lower in iron than were brain, liver, gonad and gills.

The maximum and minimum concentrations of the tested metals in fish organs are summarized in Table 4. As shown, the maximum concentrations (ppm) of lead (1·24), cadmium (0·82), chromium (0·721), zinc, (10·9), copper, (2.26), manganese (0·33) and iron (1·41) were found in brain, whereas, the minimum concentrations were detected in flesh samples which showed 0·149,

0·05, 0·08, 0·82, 0·42, 0·048 and 0·191 ppm for Pb, Cd, Cr, Zn, Cu, Mn and Fe, respectively.

Most previous reports have shown trial accumulation patterns of metals in fish are dependent both on uptake and elimination rates. The uptake of metals in fish is influenced by many factors, including the species, the specific organs studied and various environmental factors, for example temperature and pH (Hakanson, 1984). Badsha and Goldspink (1988) showed that the factors affecting uptake and accumulation of pollutants were locality, species, sex, age and state of gonadal maturation, as well as environmental factors.

Elimination of metals is an active biochemical and physiological process. One problem which often remains unresolved is to know the pathways by which metals are incorporated into the fish. Several authors demonstrated that gills play an important, perhaps even a dominant, role in metal uptake (Part & Svanberg, 1981; Thomas *et al.*, 1983; Hughes & Flos, 1978). This may be true primarily for the water-soluble fractions of metals.

Metal concentrations in fish are mostly measured in liver or muscle (flesh), the latter being of most concern to man because it is the main tissue consumed as food. On the other hand, liver is now widely recognized as a valuable indicator of pollution (Hansen *et al.*, 1982; Jensen, 1983; Phillips & Segar, 1986; Badsha & Goldspink, 1988).

Lead

It can be seen that the highest mean values of lead were found in brain followed by gonad and liver, which showed mean values of 1·24, 0·981 and 0·889 ppm, respectively, while the lowest concentration was found in flesh (0·149 ppm). The results of this study completely disagree with the results of Eisenberg and Topping (1986), who reported that no detectable concentrations of Pb were found in any liver samples and only 2 of 24 gonad samples showed detectable concentrations indicating preferential bioaccumulation in flesh tissue (1·52 ppm) in samples of various species of finfish harvested from the Maryland section of the Chesapeake Bay. Also Hernandez *et al.* (1990) reported that gonad and flesh (muscle tissue) showed the lowest metal content. These results partially agreed with the data obtained in this study in the case of the lowest concentration of Pb in flesh, but contrast in the case of gonad. However, this study agrees with Hegi and Geiger (1979) who found enrichment of lead in the liver of freshwater finfish. Moreover, Halocombe *et al.* (1976) and Dallinger *et al.* (1987) concluded that liver and other soft organs are important targets for lead. Also the data obtained agree with those obtained by Barak and Mason (1990) who showed that Pb concentrations were higher in liver (0·01–0·30 ppm) than in flesh (0·01–0·36 ppm). In the current study, although gills showed lower mean values than other organs (0·262 ppm), their contents were higher than flesh. However, Hernandez *et al.* (1990) reported that high concentrations of Pb accumulated in gills.

Cadmium

The highest mean concentrations of cadmium (ppm) were detected in brain (0·82) followed by gonad (0·37) and liver (0·31) while the lowest concentration was found in flesh (0·05 ppm). These results accorded with those obtained by Eisenberg and Topping (1986), who found a significant increase in Cd concentration in liver tissue in comparison to flesh tissue. This is consistent with the findings of Hegi and Geiger (1979) who found similar enrichment in livers of fresh water finfish and also with the findings of Barak and Mason (1990) who reported that Cd concentrations were higher in the liver (0·01–0·41 ppm) than flesh (0·01–0·60 ppm). The results obtained also agreed with those reported by Hernandez *et al.* (1990), who found that low Cd concentrations were detected in muscle, as well as in gonad and gills. They also reported that an important accumulation of this metal took place in liver and kidney, in the order: muscle < liver < kidney. On the other hand, Szefer and Falandysz (1985) found lower concentrations of Cd in muscle tissue of fish from the southern Baltic, which ranged from 0·001 to 0·057 ppm.

Chromium

The lowest mean concentrations of Cr were found in flesh (0·08 ppm) and increased in gills (0·139 ppm). Concentrations found in liver, gonad and brain (0·311, 0·673 and 0·721 ppm) were much higher than those in flesh (0·08 ppm). Therefore, it would be advisable not to eat these organs, if possible, in order to avoid potential risks to human health derived from the high toxicity and persistence of heavy metals (Hernandez *et al.* 1990). Similar results were observed by Hernandez *et al.* (1990) who found that the lowest values of Cr were detected in muscle (0–0·1 ppm), and were increased in gills (0·125–0·775 ppm). Eisenberg and Topping (1986) reported that mean Cr concentrations in finfish flesh were below the detection limit in 1978 and 0·16 ppm in 1979. All the above mentioned reports agree with the results obtained in this study which showed that flesh contained the lowest concentration of Cr.

Zinc

Zn was found at the highest concentration (10·9 ppm) in brain, with, the lowest concentration being detected in flesh (0·82 ppm). The results also indicated higher concentrations in the gonads (5·32 ppm). These results are in accordance with those obtained by Eisenberg and Topping (1986), who found that the mean concentrations were 2·9–3·8 ppm in flesh and 9·4–23·0 ppm, respectively, in gonad samples of American shad harvested from the waters of Harford county. However, the samples of fish collected from Chesapeake Bay (Rock Hall) showed Zn ranging from 5·9 to 8·9 ppm in flesh and 15·3 to 80·1 ppm in gonad. Also the concentrations of Zn were observed to be lower in axial muscle tissue than in liver tissue, Wiener and Giesy (1979) (axial muscle, 4·9–48·7 ppm and liver 18·9–48·7 ppm).

Copper

Copper was found at the highest mean concentration in brain (2·26 ppm), while the lowest concentration was detected in flesh (0·42 ppm). Copper was shown to accumulate higher concentrations in gonad and liver tissues (0·61 and 0·78 ppm, respectively). These results agree with those obtained by Eisenberg and Topping (1986), who found that copper showed higher concentrations in gonad (1·21–7·22 ppm) than flesh (0·40–0·78 ppm). Also Wiener and Giesy (1979) reported that Cu concentrations were lower in axial muscle tissue than in liver tissue, which showed 0·06–2·52 ppm and 4·1–918·9 ppm dry weight, respectively.

Manganese

The highest mean concentration of Mn was detected in brain while the lowest concentration found in flesh (0·048 ppm). There was a lower concentration in flesh (0·048 ppm) than in liver (0·152 ppm). These results agree with those obtained by Wiener and Giesy (1979) who reported that the concentration of Mn in muscle (0·13–0·70 ppm) was lower than in liver (0·80–12·96 ppm dry weight).

CONCLUSION

From the data presented, it can be concluded that all heavy metals studied were detected at the highest mean concentrations in brain followed by liver, and gonad. It is therefore inadvisable to eat the brain or liver to avoid potential risks to human health arising from the high toxicity and persistence of heavy metals.

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REFERENCES

AOAC (1980). *Atomic Absorption Methods of Fish*, chapter 29. Official Methods of the Association Official Analytical Chemists, Washington DC.

Badsha, K. S. & Goldspink, C. R. (1988). Heavy metal levels in three species of fish in Tjeukemeer, a Dutch Polder lake. *Chemosphere*, **17** 459–63.

Barak, N. A. E. & Mason, C. F. (1990). Mercury, cadmium, and lead in eels and roach: the effects of size, season, and locality on metal concentrations in flesh and liver. *Science Total Environ.*, **92**, 249–56.

Benoit, D. A. Leonard, E. N., Christensen, G. M. & Fiandt, J. T. (1976). Toxic effect of cadmium on three generations of brook trout (*Salvelinus fontinalis*). *Trans. Am. Fish. Soc.*, **105**(4), 550–60.

Dallinger, R., Prosi, F., Segner, H. & Back, H. (1987). Contaminated food and uptake of heavy metals by fish: a review and proposal for further research. *Oecologia*, **73**, 91.

Eisenberg, M. & Topping, J. J. (1986). Trace metal residues in finfish from Maryland waters, 1978–1979. *J. Environ. Sci. Health, B*, **21**(1), 87–102.

Hakanson, L. (1984). Metals in fish and sediment from the river kolbacksan water system. *Sweden. Arch. Hyrobiol.*, **101**, 373–400.

Halocombe, G. W., Benoit, D. A., Leanard, E. N. & Mckinn, J. M. (1976). Long-term effect of lead exposure on three generations of brook trout (*Salvelinus fontinalis*). *J. Fish. Res. Board Can.*, **33**, 1731–41.

Hansen, M. M., Jensen, A. & Lasen, H. (1982). Trend monitoring. I. Problems in the interpretation of concentration using fish as indicator organisms. *ICES, C.M.E.*, **25**.

Hegi, H. P. & Geiger, W. (1979) *Schweiz Z. Hydrol.*, **41**, 94–107.

Hernandez, F., Medira, J., Ansuategui, J. & Lopeg, F. J. (1990). Application simple procedure of digestion for the determination of trace metals in marine organisms. *Analysis*, **18**, 327–30.

Hughes, G. M. & Flos, R. (1978). Zinc content of the gills of rainbow trout (*S. gairdneri*) after treatment with zinc solutions under normoxic and hypoxic conditions. *J. Fish Biol. B* (6), 717.

Jensen, A. (1983). Problems related to trend monitoring of trace metals in marine areas by use of fish and blue mussel. In *Renewable Resources for Monitoring Changes and Trends*, eds J. Fa. Bell & L. Atterbutry, Proc. Int. Conf., Corvallis, OR, pp. 488-501.

Part, P. & Svanberg, O. (1981). Uptake of cadmium in perfuse rainbow trout (*Salmo gaindneri*) gills. *Can. J. Fish Aquat. Sci.*, **38**, 917–23.

Phillips, D. J. H. & Segar, D. A. (1986). Use of bio-indicator in monitoring conservative contaminants, Program design imperatives. *Mar. Pollut. Bull.*, **17**, 10–17.

SAS (1988) SAS/STAT User's guide release 6·03 edition, SAS Institute, Cary, NC, USA.

Szefer, P. & Falandysz, J. (1985). *Sci. Total Environ.*, **29**, 269–76.

Thomas, D. G., Cryer, A., Solbe, J. & Kay, J. (1983). A comparison and protein binding of environmental cadmium in the gills, kidney, and liver of rainbow trout (*Salmo gairdneri* Richardson). *Comp. Biochem. Physiol.*, **76C**(2), 241–6.

Wiener, J. G. & Giesy, J. P. (1979). Concentration of Cd, Cu, Mn, Pb, Zn, in fishes in highly organic soft water pond. *J. Fish Res. Board Can.* **36**, 270–8.

Winer, B. J. (1971). *Statistical Principles in Experimental Design*, 2nd edn. McGraw-Hill, Kogakusha.