Asian Fisheries Science **17** (2004): 377-384
ISSN: 0116-6514
https://doi.org/10.33997/j.afs.2004.17.4.010

Asian Fisheries Society, Manila, Philippines

Concentrations of Trace Metals in the Flesh of Nine Fish Species Found in a Hydropower Reservoir in Sri Lanka

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Abstract

Concentrations of trace metals in the flesh of nine fish species commonly found in commercial catches of a hydro-power reservoir in Sri Lanka (Victoria) were detected using the Neutron Activation Technique. High concentrations of Al (37.8 - 208.0 $\mu g \bullet g^{-1}$ dry wt.) and Rb (20.90 - 70.75 $\mu g \bullet g^{-1}$ dry wt.) were found in all nine species while the concentration of Zn ranged from 20.29 to 92.00 $\mu g \bullet g^{-1}$ dry wt. but was found only in four species. Au was detected in seven species but the concentration ranged from 0.004 to 0.043 $\mu g \bullet g^{-1}$ dry wt. The concentration of Mn (4.30-6.62 $\mu g \bullet g^{-1}$ dry wt.) and V (0.245 to 0.43 $\mu g \bullet g^{-1}$ dry wt.) were also relatively low and found in three and two species respectively.

Bio-accumulation of the above-said trace metals in fish could be directly or indirectly attributed to their food and feeding and environmental condition. The highest and the lowest concentrations of Al were detected in *Anguilla nebulosa* (Family, Anguillidae) and *Ompok bimaculatus* (Family, Siluridae), carnivorous species. On the contrary, Al concentrations were relatively low in omnivorous cichlids. Bio-accumulation of Al and Zn in fish flesh was high in the fish species containing more fat. Availability of some exotic elements such as Au, Rb and V in fish flesh in addition to Al, Mn and Zn, indicates the occurrence of these trace metals in the environment and the possibility of selective accumulation.

Introduction

Trace metals, such as Co, Cu, Mn, Mo and Zn are essential nutrients for organisms including humans but are toxic if consumed in large quantities. Many fish species are top predators in aquatic food webs and are therefore, susceptible for the food chain bioaccumulation of toxic contaminants. In such situations, high concentrations of metals in fish may present a health risk to man if consumed in large quantities. For this purpose fish are frequently used for bio-monitoring for the presence of contaminants in aquatic environments, particularly in relation to effluent discharges (Boelens 1987; Martin et al. 1987; Mason 1991; Friedrich et al. 1992).

The concentrations of certain trace elements (e.g., Cd, Co, Cu, Pb, V and Zn) in Sri Lanka's surface water have been studied in the Mahaweli river (Dissanayake and Weerasooriya 1986) Kalani river (Dissanayake and Weerasooriya 1985) and Kandy Lake (Dissanayake et al. 1986). Apparently the concentrations of certain trace metals (e.g., Cu, V and Zn) of the Mahaweli and Klani rivers (e.g., Mn, Pb and Zn) are relatively high. It was evident that these metals entered through waterways as industrial effluent. Relatively high enrichment of Pb and Zn in the river water has been attributed to extensive emanation of automobile exhaust fumes as well as the wide use of galvanized materials as household utensils and appliances (Dissanayake and Weerasooriya, 1985).

Wijesinghe et al. (1999) have determined the concentrations of several trace metals in three species of fresh water fish with different feeding habits from Weras Ganga in the Colombo district in Sri Lanka, which receives industrial effluents. They found varying concentrations of Cd, Cr, Cu, Fe, Mn, Ni, Pb, Ti, and Zn in different organs such as muscles, gills, gonad, kidney and liver. The present study is an attempt to compare the levels of trace metals in the flesh of several fish species found in the commercial catches of the Victoria, a hydro-power reservoir in Sri Lanka which is assumed to be a non-significant recipient of industrial effluents.

Materials and Methods

Fish samples

Specimen of nine fish species of different feeding habits (Table 1) were collected from commercial catches of the Victoria reservoir, the deepest and the largest hydropower reservoir in Sri Lanka (maximum depth, 102 m and area, 2370 ha). The Victoria reservoir is located in the central highland of the island (7°13'N; 80°47'E) at 438 m above mean sea level. Three specimens of the same size-class were collected from each species and brought to the laboratory within one hour in an ice box. In the laboratory, the skin was removed below the dorsal fin and about 50 g of muscle devoid of bones was separated using plastic dissecting instruments. The flesh was sun dried for several hours and then oven dried for 24 hrs at 70°C. Dried samples were powdered using a mortar and pestle and then ground into a fine powder using a blender, and stored in a desiccator. Subsequently, finely powdered samples were air freighted to Japan in vacuum bags.

Neutron activation analysis

Samples were analyzed for elements at the Reactor Research Institute of Kyoto University at Kumatori, Japan using Neutron Activation Technique. This technique was selected because it is fast, reliable, precise, sensitive, free of matrix effects and offers an excellent suite of cationic and anionic trace elements (Rahn et al. 1992). Further, the detection limit of this method is 0.001 $\mu g \cdot g^{-1}$ dry wt. Element activated by neutrons can be determined either by short term irradiation and counting for short half-life elements such as Al, Ca, Cd,, Co, Cr, Cu, K, Mg, Mn, Na, Ni, Pb, and V or long term irradiation and counting for long lived indicators (e.g., Au, Ba, Cd, Fe, Rb, Zn).

To determine characteristic gamma rays emitted from radioactive isotopes, pooled samples of fish flesh of each species (0.05 g) were placed in polyethylene scintillation vials with linerless screw caps and irradiated for 10 min with standard materials of known elemental concentrations in pneumatic tubes. Subsequently, samples were cooled for 10 min and transferred to fresh counting vials and counted for 30 min using a gel (Li) ë-ray detector (21-23% efficiency) coupled to a Nuclear Data Multiuser Multitask computer (model 6700). For the elements of long lived indicators, about 0.2 g aliquots of samples were irradiated for 1 hr, cooled for 30 min and ë-ray counted as in short term irradiation.

Results

Table 1. The nine fish species subjected to analyses of trace metals and their food and feeding habits

Family	Species	Food	Feeding
Anguillidae	*Anguila nebulosa*[n]	fish, crustaceans	carnivorous[2]
Cichlidae	*Oreochromis niloticus*[e]	algae, soft sediments	algal feeder[4]
	Tillapia rendalli[e]	macrophytes, detritus	macrophyte feeder[4]
	Oreochromis mossambicus[e]	detritus	detritivorous[4]
Cyprinidae	*Puntius sarana*[n]	aufwuchs, aquatic algae, insects	omnivorous[1]
	Puntius dorsalis[n]	zoobenthos detritus, algae aquatic, insects	omnivorous[1]
	Tor khudree[n]	macrophytes	omnivorous[2]
Gobiidae	*Glossogobius giuris*[n]	fish, worms	carnivorous[2]
Siluridae	*Ompok bimaculatus*[n]	fish	carnivorous[3]

[e]exotic
[n]native
[1]Schiemer and Hofer (1983)
[2]Pethiyagoda (1991)
[3]Silva and Davies (1987)
[4]Nathanael and Silva (1996)

Figures 1a and 1b are typical of the ë-ray spectra observed on irradiation of the fish species exposed to long term and short term irradiation respectively. With respect to trace metals, signals representing Rb are apparent in all nine spectra (all not shown). Small peaks of Au in the ë-spectra of *A. nebulosa, P. dorsalis, T. khudree* and *T. rendalli,* while peaks representing Zn were also visible in six species except in *G. giuris, P. sarana* and *T. khudree.* In spectra of fish flesh of nine fish species (all not shown) exposed to short term irradiation (Fig. 1b) prominent peaks of Al in all nine fish species were recognizable. Peaks representing V were also prominent but only in *P. dorsalis* and. *P. sarana.* Further, small peaks representing Mn in the spectra of *A. nebulos, O. niloticus* and *P. sarana* were also evident.

Table 2 summarizes the concentrations of Al, Au, Mn, Rb, V and Zn in Victoria reservoir fish flesh. The highest concentration of Al (208.56 $\mu g \bullet g^{-1}$ dry wt) was found in *A. nebulosa* and the lowest in *O. bimaculatus* (37.8 $\mu g \bullet g^{-1}$ dry wt.). Rb concentration was highest (70.75 $\mu g \bullet g^{-1}$ dry wt) in *T. rendalli* and the lowest in *P. dorsalis* (20.9 $\mu g \bullet g^{-1}$ dry wt). The highest concentration of Zn (92.00 $\mu g \bullet g^{-1}$ dry wt) was found in *A. nebulosa,* while the lowest was 20.29 $\mu g \bullet g^{-1}$ dry wt in *O. niloticus*. Mn was found only in three species and the concentration ranged from 4.3 $\mu g \bullet g^{-1}$ dry wt in *A. nebulosa* to 6.62 $\mu g \bullet g^{-1}$ dry wt in *O. niloticus*. Vanadium was found only in two cyprinids in a relatively low concentration (i.e. 0.43 $\mu g \bullet g^{-1}$ dry wt in *P. sarana* and 0.24 $\mu g \bullet g^{-1}$ dry wt in *P. dorsalis*). Although Au is present in seven species its concentrations were extremely low compared to other trace metals and ranged from 0.004 to 0.04 $\mu g \bullet g^{-1}$ dry wt.

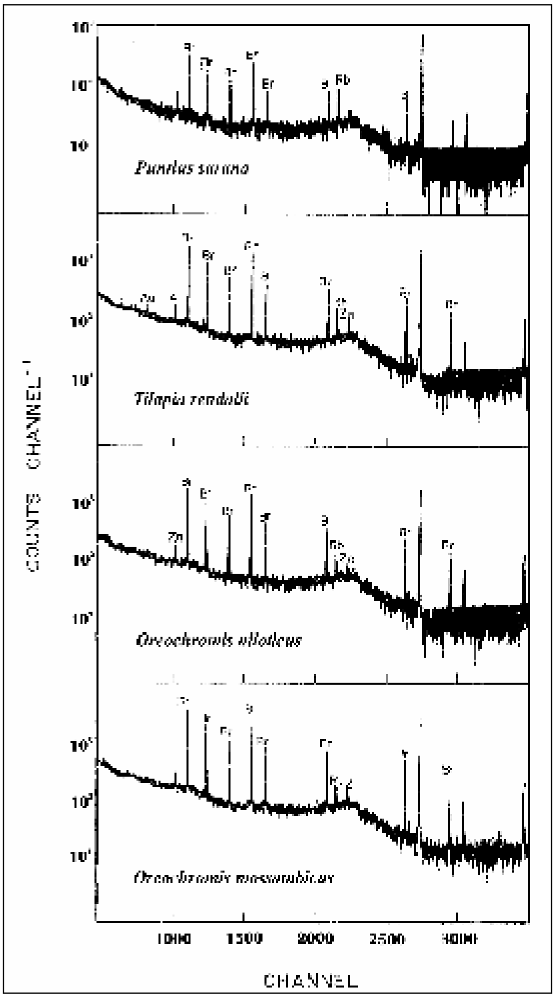

Fig. 1a. A typical of the ã ray spectra for long term radiation

Discussion

The natural concentrations of trace metals in freshwater results from a complex set of processes. For example, production and decomposition of autochthonous and allochthonous biomass, precipitation, rock dominance and crystallization in the drainage basin, and adsorption, sedimentation and coagulation processes in aquatic systems. Fish can take up trace metals either in their diet or through their gills, with the former is the predominant route in many cases (Dallinger et al. 1987).

The Victoria reservoir does not receive industrial effluent to any marked extent, but the inflows drain intensively cultivated tea plantations resulting in an enormous sediment loading into the reservoir. Therefore, the source of aluminum is most probably alumina in the form of $Al_2O_3.3H_2O$, which is present in both clay and soft sediment. Detritivrorous and omnivorous fish usually ingest a fair amount of soft sediment with their food (e.g. debris, aufwuchs and littoral benthos) during feeding. Aluminum trihydrate readily converts into tripositive aqua ion, $Al(H_2O)_6^{3+}$ below pH 4.0 and further dissociates into Al^{3+} at very low pH. Stomachs of some fish are extremely acidic it has been reported that stomach pH is less than 2.0 in many freshwater fishes such as chiclids (Moriarty 1973; Schiemer and Hofer 1983; Maitipe and De Silva 1984). Under strong acidic conditions $Al_2O_3.H_2O$ might

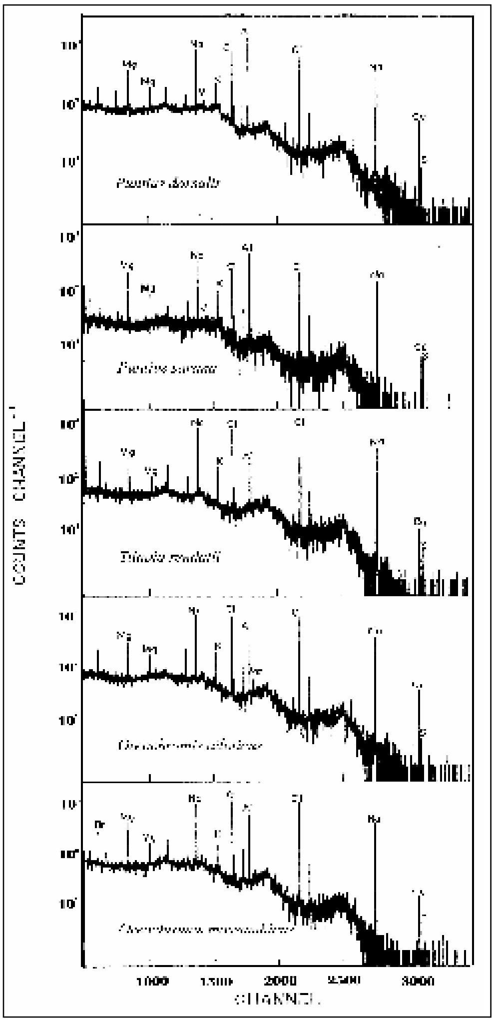

Fig. 1b. A typical of the ã ray spectra for short term radiation

Table 2. Concentrations of trace elements in $\mu g \cdot g^{-1}$ dry wt in nine fresh water fish species (L - long term irradiation; S - short term irradiation)

Fish species	Al^L	Au^S	Mn^L	Rb^S	V^L	Zn^S
A. nebulosa	208.00	0.008	4.30	21.50		92.00
O. mossambicus	60.05	0.011		30.10		
O. niloticus	92.20	0.004	6.62	21.60		20.29
T. rendalli	69.90	0.004		70.75		32.90
P. sarana	78.40	0.005	6.43	24.90	0.43	
P. dorsalis	117.50	0.043		20.90	0.24	29.85
T. khudree	63.60	0.024		22.20		
G. giuris	45.20			46.70		
O. bimaculatus	37.80			57.10		

readily convert into Al^{3+} which may be extremely toxic and which may also migrate to other tissues such as lipids where it could be accumulated.

Apparently, the aluminum concentration is relatively high in *A. nebulosa*, which contains a fair amount of lipids in its body tissues (Alabaster 1977). Though eels are true carnivores they also spend much of their time in contact with the sediment from which they may absorb contaminants and therefore they are considered as potentially useful indicator organisms (Beumer and Bacher 1987). *P. dorsalis*, which has the next highest concentration of Al, feeds predominantly on zoobenthos and their pH is not strongly acidic (Schiemer and Hofer 1983). Therefore, *P. dorsalis* may ingest a large amount of soft sediment with its food. Relatively low Al concentrations are found in *G. giuris* and *O. bimaculatus*, which are pure carnivores and adult *O. bimaculatus*, is exclusively a piscivore in Sri Lankan reservoirs (Silva and Davies 1987).

The highest concentration of Rb was found in *T. rendalli*, which is predominantly a macrophyte feeder (Nathanael and Silva 1996). In contrast, the Rb concentration in *A. nebulosa* was relatively low. The sources of Rb are essentially natural minerals. Martin et al. (1987) have reported the occurrence of Rb in Lorie, Rhone, Gironde and Huanghe rivers. In stream sediments about 70% of Rb stays as an acid reducible fraction. Therefore, there is a good potential of bioaccumulation of acid reducible Rb during gut passage of the fish when they ingest Rb containing sediment with food. However, toxic effects of Rb at low levels of animals and humans have not been reported.

Results of this study also show the highest bioaccumulation of Zn in *A. nebulosa* (92.00 $\mu g \bullet g^{-1}$ dry wt). In addition to A. *nebulosa*, Zn is also found in *O. niloticus, P. dorsalis* and *T. rendalli*. Concentration of Zn was extremely high (72-629 $\mu g \bullet g^{-1}$ dry wt) in fish analyzed from polluted waters in Weras Ganga (Wijsinghe et al. 1999). Zn is an essential trace element for living organisms, which is important for nucleic acid synthesis and also occurs in many enzymes, further Zn has been described as having the greatest variety of biochemical functions of any trace element (Jacknow 1986; Lewis 1987). It has been reported that environmental concentrations of Zn more than 180 $\mu g l^{-1}$ are extremely hazardous. Human tolerance of the metal is good and toxicity is only expressed at very high levels. However, the natural concentration of Zn in freshwater is less than Al (Buffle 1988) but the acid reducible component in river sediment is higher than that of Rb (Martin et al. 1987). Therefore an increased released from the sediment due to acidification causes local toxic effects to aquatic life (Paasivirta et al. 1991).

Mn was found in *A. nebulosa, O. niloticus* and *P. sarana* in relatively low concentrations (4-6 $\mu g \bullet g^{-1}$ dry wt). Wijesinghe et al. (1999) reported relatively high concentrations of Mn (43-183 $\mu g \bullet g^{-1}$ dry wt) in three spcies of fish inhabiting polluted water in Weras Ganga. Mn, which has a pedogenic origin, leaches out by rainwater as $Mn^{+}(OH)_2$ and remains in the water column (Buffle 1988). Mn is also an important trace element and may be essential for utilization of Vitamin B_1 but is toxic if consumed in large quantities. V was found only in two omnivorous cyprinids (*P. dorsalis* and *P.*

sarana) but in very small quantities. It is interesting to note that V was not detected in the flesh of *A. nebulosa*, which had the other five metals. Buffle (1988), has reported a fairly higher concentration of V in freshwater. The concentration of vanadium in Sri Lankan fresh water ranged from 6 to 32 mg l^{-1} (average vanadium concentration in natural freshwater is about 2 ppb) and it was attributed to the discharge of vanadium contaminated effluent (Dissanayake et al. 1986). In the case of Au, it was found in seven fish species except in two carnivores (i.e., *G. guiris* and *O. bimaculatus*) but in extremely low concentrations. It has been shown that certain stream sediments in Sri Lanka carry high concentrations of gold (Nawaratne and Wijeratne 1995).

Conclusions

Availability of six trace metals (viz., Al, Au, Mn, Rb, V and Zn) in the flesh of nine species of freshwater fishes is evident. The natural occurrence of these elements in different ecological components of the Victoria reservoir enhances the possibility of selective bioaccumulation. Bioaccumulation of these trace metals in fish flesh could be attributed predominantly to ingestion of sediment with food items or through the food chain. Evidently, fish flesh containing more fats accumulate higher concentrations of different trace metals but there are exceptions perhaps due to selective bioaccumulation. Non-availability of some toxic trace metals such as Cd, Cr, Cu, Hg and Pb in fish flesh subjected to this study indicates that either the Victoria reservoir is not contaminated with the above trace metals or concentrations are not sufficient for bioaccumulation in flesh.

Acknowledgments

Samples were analyzed using the facilities of the Reactor Research Institute (RRI) of the Kyoto University at Kumatory. Ms. S. Nathanael assisted in collecting and processing samples at the IFS laboratory. The analysis was carried out during the study visit by the first author to Nara women's university supported by Japanese International Cooperation Agency. Professors Rudy Hoper and U. S. Amarasinghe read the draft manuscript and made valuable suggestions. Mr. Takada of RRI at Kumatori assisted in analyzing the samples I. Meedeniya, T. Malavisooriya and I. Thumpela assisted during the preparation of the manuscript.

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Manuscript received 19 December 2001; Accepted 29 March 2003