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Heavy Metal Concentrations in Nine Species of Fishes Caught in Coastal Waters off Ann-Ping, S.W. Taiwan

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ABSTRACT

Nine species of the most commonly found fishes in the Ann-Ping coastal waters, were selected and analyzed for the Zn, Fe, Cu, Mn and Cd concentrations in the muscles, livers and gonads. The results revealed that the Zn and Fe concentrations were the highest; followed by Cu and Mn, Cd being the lowest in the three kinds of fish tissues. The liver metal concentrations showed the highest values among the three tissues, whereas the muscle concentrations were the lowest. The muscle concentrations of Zn, Fe, Cu , Mn and Cd ranged 4.00-7.28, 2.35-7.72, 0.20-0.45, 0.20-0.83 and <0.0005 μg/g wet weight, respectively. The liver concentrations of the five elements were in the range of 23.0-66.6, 131-646, 3.34-48.2, 0.75-1.94, and 0.08-0.70 μg/g wet weight, respectively. A significant species-specific difference was found. The *Sardinella lemuru* contained higher muscle concentrations of Zn, Mn and Cd than the other species of fishes. However, the *Liza macrolepis* contained the highest liver concentrations of Fe and Cu. The metal concentrations found in this study were similar to the metal levels of the fishes collected from slightly polluted waters all over the world and Taiwan. Therefore, no public health problem would be raised in the consumption of the fishes.

Key words: heavy metals, zinc, iron, manganese, copper, cadmium, fishes, muscle, liver, gonad

INTRODUCTION

Due to industrialization, the number of factories and population has increased rapidly. Massive amounts of domestic wastewater and industrial effluents are transported by rivers and discharged into the sea, contaminating rivers and coastal waters. Such anthropogenic pollutants are the main sources of heavy metal contaminants in the ocean(1). These contaminants entering the aquatic ecosystem may not directly damage the organisms; however, they can be deposited into aquatic organisms through the effects of bioconcentration, bioaccumulation and the food chain process(2,3), and eventually threaten the health of humans by seafood consumption. For example, Minamata Disease, which happened in Kumamoto, Japan in 1953, was a result of the residents consuming fish and shrimps contaminated by methyl mercury and non-organic mercury from the wastewaters discharged by Chlor-alkali factories. Another example is the Ita-Ita Disease in Fugawa, Japan in 1955. It was the result of consuming rice, fish and bivales that were Cd-contaminated from wastewaters discharged by nearby mining(4).

Ann-Ping is a small fishing port located in southwestern Taiwan, and fish is harvested from the nearby coastal waters from Ssu-Tsao extending southward to the Erh-Jen River. This region is adjacent to the Ann-Ping Industrial Park and the Water Treatment Plant that receives household and industrial wastewaters. The area also receives inputs from the Erh-Jen River and the Yen-Shui River, two seriously polluted rivers. This study is concerned about the influence on fish quality under such a long-term discharge of wastewaters into the coastal waters. Since there is no relevant research report about the heavy metal levels in the fishery products of this region, this study was conducted.

In this study, nine species of common fishes in the Ann-Ping coastal waters were chosen based on their economic value. The heavy metal concentrations, Zn, Fe, Cu, Mn and Cd, were analyzed on the eatable portions of fishes, i.e. meat and gonad, as well as on the non-eatable parts, liver, in this study. The results would be able to evaluate the seafood consumption safety of the Ann-Ping coastal fisheries. It could also establish a baseline for the heavy metals deposited in the fishes of this region in order to monitor heavy metal pollution trends in the future.

MATERIALS AND METHODS

I. *Materials*

(I) *Collection of Specimens*

A total of fifty of nine fish species were purchased from local fishermen at the Ann-Ping fishing port in January, 1998. Species including *Siganus canaliculatus*, *Liza macrolepis*, *Leiognathus equulus*, *Alepes djedaba*, *Pelates quadrilineatus*, *Johnius sina*, *Sardinella lemuru*, *Nematalosa japonica*, and *Nematalosa come* were caught in the coastal waters between the Ssu-Tsao and Erh-Jen Rivers (Figure 1). After identifying the species, samples were sealed in PE bags and kept in the freezer at -20˚C.

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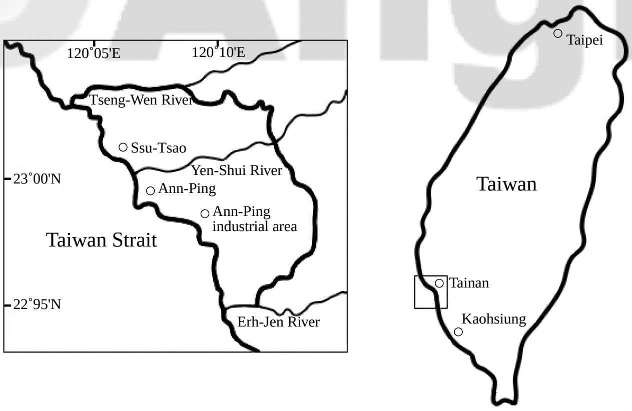

Figure 1. The map showing the sampling area.

(II) *Reagents*

Nitric acid and sulfuric acid used in the study were GR grade from Merck Company. Mn, Cd, Zn, Fe and Cu standard solution were also purchased from Merck Company. The standard reference material, DOLT-2 (dogfish liver), purchased from the National Research Council of Canada, was used to control the analytical quality.

II. *Methods*

(I) *Measurements of the Basic Biological Parameters*

Fishes used in the study were first identified by species and gender, followed by measuring the fork length and body weight. The detailed information is listed in Table 1.

(II) *Digesting Method*[(5)]

The muscles of the dorsal flank, livers and gonads were collected after autopsy. Five grams of muscle, 2 g of liver and 3 g of gonad (in wet weight) were weighted and put into the conical flasks, added 10 mL nitric acid, then covered the opening with pear drop and sat still overnight. When the fish tissue was dissolved completely, the sample was placed on a hot plate and gradually heated to 120˚C until the vapor and the acid fluid inside the flask turned clear. During the heating process, the speed of temperature increase must be monitored carefully to avoid the leakage of the brown vapor. When the vapor and sample liquid were clear, the pear drop was removed and the flask heated at 110-115˚C to evaporate the excess acid till the remaining digested fluid was at 1 mL. The fluid was cooled at room temperature, then the 1M nitric acid was used to wash and filtrate the digests (using Whatman No.540 filter paper). Finally, the digests were quantified into twenty-five mL in a volumetric flask. The analysis was done at least twice as long as the tissue amounts were sufficient.

(III) *Analysis of Heavy Metal Concentrations*[(5)]

1. Measurement of Zn, Fe, Cu and Mn

Flame atomic absorption spectrophotometer (Hitachi Zeemen-8200) was used to measure the Zn, Fe, Cu and Mn concentrations in the digested samples.

2. Measurement of Cd

After a proportional dilution of the digested fluid with 0.4% sulfuric acid, the standard addition method was used for Cd-analysis. This method was done by using four sample cups (2.5 mL) filled with 1 mL of sample fluid, and added equivalent amount of standard Cd solution at 0, 1, 2, and 4 ng/mL respectively. The advantage of this method was to avoid any possible interferences of other chemical ingredients and the aging of the graphite furnace. The analysis was performed by an automatic micro-injector connected to the graphite atomic absorption spectrophotometer.

3. Detection limit[(6,7,8)]

In order to find out the minimum amount of concentration that could be detected by the equipment, absorption values of 1M nitric acid were measured in every 10 samples to obtain the average and standard deviation. The detection limits of each element were then calculated by the sum of the average and the 10 times of the standard deviation. The instrumental detection limits of Zn, Fe, Cu, Mn and Cd were 0.02, 0.1, 0.03, 0.01 and 0.001 μg/mL respectively. The detection limits of Zn, Fe, Cu, Mn and Cd in fish muscles were 0.1, 0.5, 0.15, 0.05 and 0.005 μg/g wet wt, in liver were 0.25, 1.25, 0.375, 0.125 and 0.0125 μg/g wet wt, and in gonad were 0.17, 0.83, 0.25, 0.08, and 0.008 μg/g wet wt, respec-

Table 1. List of fish species, number of fishes and size of fishes used in this study

Species	Chinese name	No. of fish		TL(cm)	BW(g)
		male	female		
Sardinella lemuru	黃小鯵魟	3	2	20.6 ± 34.3	71.7 ± 9.7
Nematalosa come	環球海鰶	1	3	21.7 ± 13.2	98.6 ± 6.0
Nematalosa japonica	日本海鰶	0	2	19.5 ± 15.5	89.1 ± 2.8
Liza macrolepis	大鱗鮻	4	4	21.9 ± 25.5	112.1 ± 2.6
Siganus canaliculatus	長鰭籃子魚	5	1	17.0 ± 8.4	78.2 ± 6.1
Leiognathus equulus	短棘鰏	7	0	15.5 ± 20.4	60.2 ± 3.5
Alepes djedaba	吉打鮎	4	2	21.4 ± 17.9	98.0 ± 2.5
Pelates quadrilineatus	四線列牙鯻	2	4	16.0 ± 11.5	57.7 ± 3.2
Johnius sina	中華叫姑魚	3	3	16.5 ± 11.3	57.3 ± 3.7

TL = Total length, BW = Body weight.

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tively.

III. *Analytical Quality Control and Ensuring the Accuracy*[9,10]

All samples were analyzed at least twice. During the experiment, regent blanks were inserted in every 20 samples to detect the alien containment. In addition, duplicates of the standard reference material (DOLT-2) were added simultaneously in each digesting process. The metal concentrations of DOLT-2 were then measured to verify the analytical quality. In this study, except the recovery rate of Mn was at 83%, the other elements were all within 100% ± 15% (Table 2).

IV. *Statistics Analysis*[1]

The statistics analysis was performed by the SAS software ANOVA (one-way Analysis of Variance). The Duncan's multiple range test was adopted to inspect the differences of metal concentrations between species ($p<0.05$).

Table 2. The analytical results of standard reference material (DOLT-2) in this study

Element	Sample size	Certified value	This study	Recovery (%)
Zn	6	85.8 ± 2.5	88.6 ± 21.5	103
Fe	6	1103 ± 47	1001 ± 34	91
Cu	6	25.8 ± 1.1	25.7 ± 0.5	100
Mn	6	6.88 ± 0.56	5.7 ± 0.1	83
Cd	6	20.8 ± 0.5	24 ± 2.7	115

RESULTS AND DISCUSSION

I. *Zn, Fe, Cu, Mn and Cd Concentrations in Fishes*

Whether in tissues or by gender, the concentrations of Zn, Fe, Cu, Mn and Cd in the nine common fishes from Ann-Ping coastal waters all showed in the ranking of Zn=Fe>Cu=Mn>Cd. The ranges of essential elements, Zn, Fe, Cu and Mn, in fish muscles were 4.00-7.28, 2.35-7.72, 0.20-0.45, and 0.10-0.83 μg/g wet wt., respectively. The muscle concentration of non-essential element Cd was below the detection limit (0.005 μg/g wet wt). The ranges of Zn, Fe, Cu, Mn and Cd in livers were 23.0-66.6, 131-646, 3.34-48.2, 0.75-1.94 and 0.08-0.70 μg/g wet wt., respectively. The Zn concentration in gonads was different between females and males, with the ranges at 51.2-242 and 13.2-53.4 μg/g wet wt. The Zn concentration in females was 4 to 11 times higher than that of males, which was concordat with other documented reports[11]. In gonads, the ranges of concentration were : Fe=13.0-44.8, Cu=0.8-22.5, Mn=0.28-2.04 and Cd = <0.0125 μg/g wet wt.

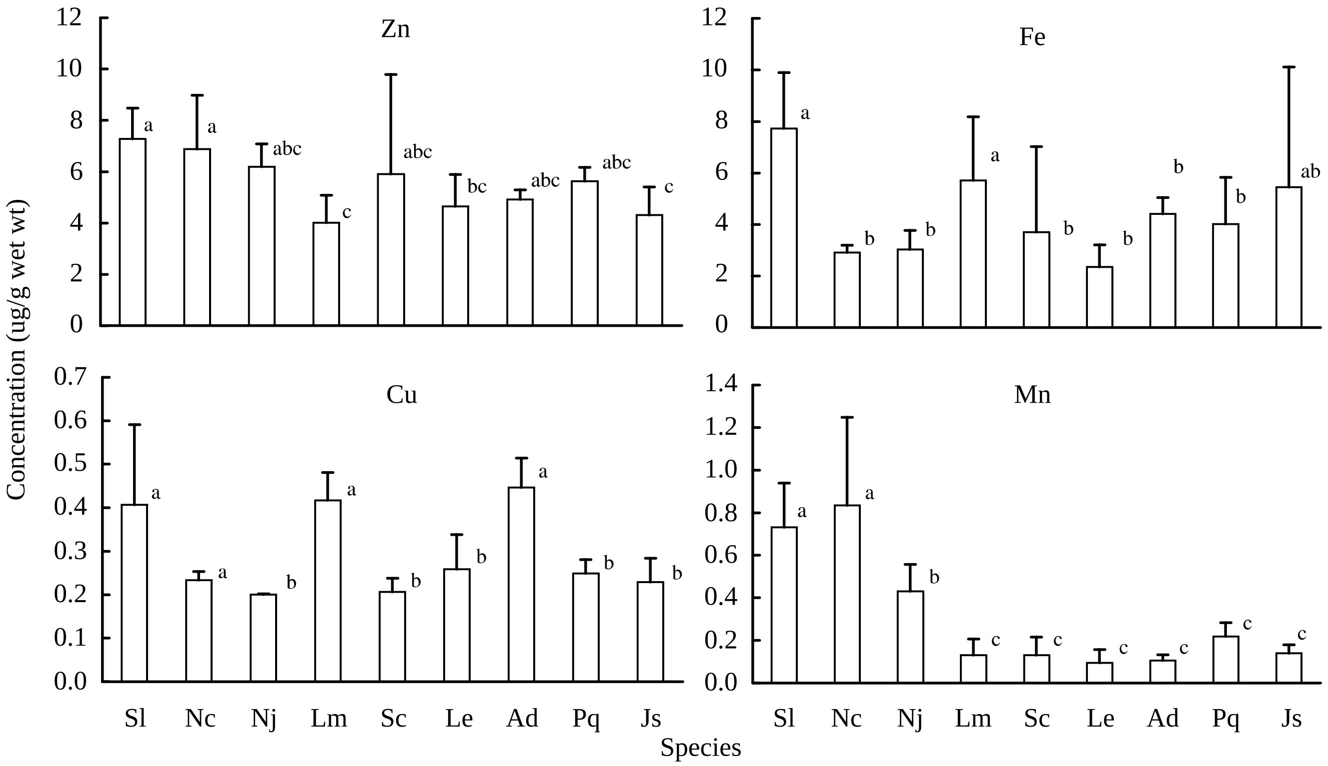

Figure 2. The means and standard deviations (vertical line) of heavy metal concentrations in the muscles of 9 species of fishes from Ann-Ping coastal water. Sl = *Sardinella lemuru*, Nc = *Nematalosa come*, Nj = *Nematalosa japonica*, Lm = *Liza macrolepis*, Sc = *Siganus canaliculatus*, Le = *Leiognathus equulus*, Ad = *Alepes djedaba*, Pq = *Pelates quadrilineatus*, Js = *Johnius sina*. a, b, c = The same letters beside the vertical bars in each graph indicate the values are not significantly different ($p > 0.05$).

II. *Metal Concentrations in Different Tissues*

There were vast differences among the heavy metal concentrations in fish muscles, livers and gonads. Except Zn, the concentrations of heavy metals were found the highest in livers, followed by gonads, and were the lowest in muscles. The highest Zn concentrations were found in gonads, followed by livers, and the lowest in muscles. The liver concentrations of

Table 3. Heavy metal concentrations (μg/g wet wt) in the gonads of 9 species of fish

Sex	Speices	Number	Zn	Fe	Cu	Mn
Female	*Nematalosa come*	3	143 ± 39.7 [a]	41.9 ± 14.7 [a]	2.67 ± 0.77 [a]	2.04 ± 1.15 [a]
	Nematalosa japonica	2	51.2 ± 12.6 [a]	20.3 ± 0.90 [b]	1.00 ± 0.04 [c]	1.14 ± 0.17 [ab]
	Liza macrolepis	4	197 ± 187 [a]	29.9 ± 11.6 [ab]	1.14 ± 0.10 [bc]	0.69 ± 0.18 [b]
	Alepes djedaba	2	242 ± 18.1 [a]	39.9 ± 7.30 [a]	1.97 ± 0.87 [ab]	0.29 ± 0.01 [b]
	Pelates quadrilineatus	4	225 ± 98.2 [a]	13.0 ± 1.70 [b]	1.07 ± 0.20 [bc]	0.45 ± 0.19 [b]
Male	*Nematalosa come*	1	13.2[a]	43.7[a]	0.80[a]	0.29[a]
	Nematalosa japonica	0	—	—	—	—
	Liza macrolepis	4	21.6 ± 3.80 [a]	22.3 ±16.4 [a]	0.56 ± 0.12 [a]	0.56 ± 0.38 [a]
	Alepes djedaba	3	53.4 ± 39.5 [a]	44.8 ±19.6 [a]	3.17 ± 2.26 [a]	0.35 ± 0.04 [a]
	Pelates quadrilineatus	2	30.3 ± 8.50 [a]	20.8 ±8.50 [a]	22.5 ± 28.9 [a]	0.28 ± 0.18 [a]

[a, b, c] = The values with the same letter in each column indicate these values are not significantly different (p>0.05).

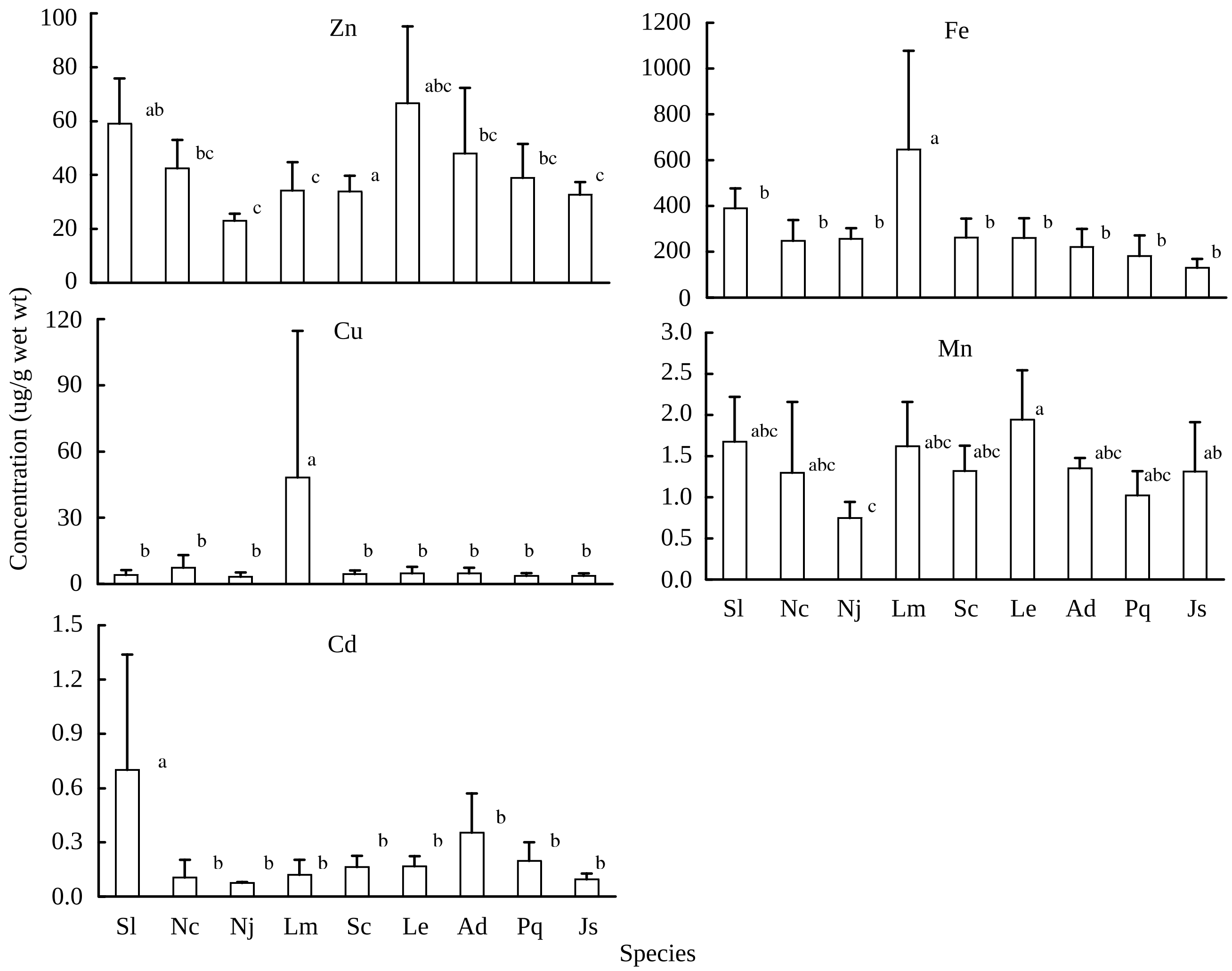

Figure 3. The means and standard deviations (vertical line) of heavy metal concentrations in the livers of 9 species of fishes from Ann-Ping coastal water. Sl = *Sardinella lemuru*, Nc = *Nematalosa come*, Nj = *Nematalosa japonica*, Lm = *Liza macrolepis*, Sc = *Siganus canaliculatus*, Le = *Leiognathus equulus*, Ad = *Alepes djedaba*, Pq = *Pelates quadrilineatus*, Js = *Johnius sina*. a, b, c = The same letters beside the vertical bars in each graph indicate the values are not significantly different (p > 0.05).

Zn, Fe, Cu and Mn were 4-14, 24-113, 10-112 and 2-21 times higher than those of muscles. This was because liver is one of the major detoxication organs, and also related to the physiological activity of fish metabolism. The high Zn concentration in gonads was because Zn is a necessary element for embryo development[12], and is important to reproductive organs[14]. There are reports indicating that the Zn concentration could reach 10 times higher than that of muscles; our study showed that the concentration in gonads was 4-49 times higher than that in muscles.

To summarize, the heavy metal concentrations in fish differed in tissues. They were the lowest in muscles, and higher in livers and gonads. The results matched other reports indicating heavy metal concentrations in edible portions was lower than that in other portions[1, 16].

III. *Metal Concentrations in Different Species*

Distinctive species differences of metal concentrations were found in the 9 species ($p<0.05$) of our study. Zn, Fe, Cu, Mn concentrations in muscles differed greatly between species ($p<0.05$), showing the higher levels in *Sardinella lemuru*. Fe and Cu concentrations were marked high in *Liza macrolepis*, whereas in *Johnius sina* showed the lowest metal concentrations (Figure 2).

The Zn, Fe, Cu, Mn and Cd concentrations in livers also displayed species differences ($p<0.05$). Zn and Mn were found the highest in *Leiognathus equulus*, and the lowest in *Nematalosa japonica*. Fe and Cu were highest in *Liza macrolepis*, reaching 646 and 48.2 μg/g wet wt. respectively; while others presented levels below 389 and 7.35 μg/g wet wt. Previous research has pointed out that the Cu concentrations in the liver of mugilidae were higher than the other species[13], this result matched with our study. Cd concentrations in liver were higher in *Sardinella lemuru*, which could reach as high as 0.70 μg/g wet wt. and differed greatly from other species that all contained levels below 0.35 μg/g wet wt. (Figure 3).

Except for Zn; Fe, Cu, and Mn concentrations, all showed significant species differences in the ovaries of five species. However, the concentrations in gonads were not different in male fish ($p>0.05$) (Table 3). The concentrations of Fe, Cu and Mn were found higher in the ovaries of *Nematalosa come* than others.

Generally speaking, among the nine species, higher concentrations of Zn, Fe, Cu, Mn and Cd in all tissues were found in *Sardinella lemuru* and *Liza macrolepis*.

IV. *Comparison of the Metal Levels in Fishes from Other Regions*

Metal concentrations in fish tissues are related to the pollution status of the regions[12]. In order to evaluate the contamination and the heavy metals bioaccumulated in the

Table 4. Heavy metal concentrations (ug/g wet wt) in different fishes from various countries

Tissue	Species	Location	PS[a]	Zn	Fe	Cu	Mn	Cd	Reference
Muscle	21 species of estuarine fishes	Chi-Ku Lagoon	S	2.3~13.7	1.2~3.4	0.11~0.41	0.1~0.9	<0.0005	Chen[c]
	Liza species	Jiang-Jiun Estuary	S	2.48	—	0.45		0.41	(17)
	Liza macrolepis	Ann-Ping coastal waters	S	4.01	5.71	0.43	0.13	<0.0005	This study
		Chi-Ku Lagoon	S	5.44	3.71	0.38	0.21	<0.0005	Chen[c]
	Liza affinis	Chi-Ku Lagoon	S	5.25	8.81	0.81	0.2	0.004	Chen[c]
	Liza aurate	Tunisia	P	6.40 [b]	—	1.14 [b]	—	0.018 [b]	(12)
		Mediterranean	P	10.6	—	0.70	—	0.05	(18)
	6 species of marine fishes	Ann-Ping coastal waters	S	4.63~6.88	2.35~5.45	0.20~0.45	0.09~0.83	<0.0005	This study
	Sardinella lemuru	Ann-Ping coastal waters	S	7.28	7.72	0.41	0.73	<0.0005	This study
	Pelates quadrilineatus	Ann-Ping coastal waters	S	5.63	4.02	0.25	0.22	<0.0005	This study
		Keelung Harbor	P	14.9	—	0.98	—	<0.004	(19)
		Kaohsiung harbor	P	11.6	—	1.60	—	0.01	(20)
Liver	21 species of estuarine fishes	Chi-Ku Lagoon	S	23.3~59.9	99~357	1.7~11.4	0.85~3.8	<0.0125~0.091	Chen[c]
	5 species of marine fishes	Ann-Ping coastal waters	S	23.0~48.0	130~261	3.33~7.35	0.75~1.35	0.07~0.35	This study
	Liza affinis	Chi-Ku Lagoon	S	26	822	3.21	1.78	0.085	Chen[c]
	Liza macrolepis	Chi-Ku Lagoon	S	32.5	1452	31.9	1.63	0.12	Chen[c]
		Ann-Ping coastal waters	S	34.2	646	48.2	1.62	0.12	This study
	Liza aurate	Tunisia	P	32.0 [b]	—	55.2 [b]	—	1.25 [b]	(12)
	Sardinella lemuru	Ann-Ping coastal waters	S	59.1	389	4.13	1.67	0.70	This study
	Leiognathus equulus	Ann-Ping coastal waters	S	66.6	261	4.78	1.94	0.17	This study
	Pelates quadrilineatus	Ann-Ping coastal waters	S	38.9	182	3.65	1.02	<0.0125	This study
		Keelung Harbor (Viscera)	P	31.5	—	1.97	—	0.01	(19)
		Kaohsiung Harbor (Viscera)	P	73.8	—	2.60	—	0.04	(20)
Gonad	3 species of marine fishes	Ann-Ping coastal waters	S	30.3~242	13.0~44.8	1.00~22.5	0.28~1.14	<0.0125	This study
	Nematolosa come	Ann-Ping coastal waters	S	10.4	42.4	1.47	1.61	<0.0125	This study
	Liza macrolepis	Ann-Ping coastal waters	S	109	26.1	0.95	0.59	<0.0125	This study
	Liza aurate	Tunisia	P	103 [b]	—	0.6 [b]	—	0.044 [b]	(12)

[a] PS = Polluted status, S= Slightly polluted, P = Polluted.

[b] The values are transferred by a dry to wet ratio = 1/5 expressed as ug/g wet wt.

[c] unpublished data of Meng-Hsien Chen.

Table 5. Seafood standards of heavy metal concentrations (μg/g wet wt) in various countries

Country	Standard[a]	Zn	Cu	Cd	Reference
America	FDA	—	—	2 [b]	(11)
America	NAS	—	—	0.5 [b]	(21)
Australia	NHMRC	1000	30	2	(22)
Australia	TPHR	40	30	5.5	(23)
Canada	—	—	100	—	(24)
Japan	—	—	—	1	(24)
United Kingdom	MAFF	50	20	—	(10)
United Kingdom	FSC	50	—	—	(2)
Taiwan	—	4.00 - 7.28	0.20 - 0.45	<0.0005	This study (muscle)

[a] FDA = Food and Drug Administration, NAS = National Academy of Science, NHMRC = National Health Medical Research Council, TPHR = Tasmania Public Health Regulation, MAFF = Ministry of Agriculture Fisheries & Food, FSC = Food Standards Committee.
[b] μg/g dry wt.

fishes of Ann-Ping coastal waters, we compared our study results with the heavy metal deposits in fishes from slightly polluted and polluted regions in Taiwan and elsewhere. The results indicated that the heavy metal concentrations in nine species from Ann-Ping coastal waters were similar to those of slightly polluted regions (Table 4).

Table 4 indicates that, except for Zn and Mn concentrations in the muscles of *Sardinella lemuru* being higher than those of the slightly polluted Chi-Ku Lagoon, the heavy metal concentrations in the fishes of Ann-Ping coastal waters were similar to those of slightly polluted regions(17). The concentrations in *Liza* were comparatively lower than that of Mediterrancean waters(18). Except for the Zn concentration in *Leiognathus equulus*, the heavy metal concentrations in the fish livers of the study were similar to those of slightly polluted regions all over the world. In this study, we found that despite the Cu concentration in the liver of *Liza macrolepis* (48.2 μg/g wet wt) higher than that of other fish species from other regions, it was lower than that of the same species in polluted regions of Tunisia. The Zn and Cu concentrations in gonads of fish in this study were higher than the *Liza aurate* in Tunisia.

Generally speaking, the heavy metal concentrations of the nine species in Ann-Ping coastal waters were similar to those of slightly polluted waters, and were far below the daily intake allowance (Table 5) set for safety metal concentrations in fisheries products by various countries.

V. *Consumption Safety*

The results show that consuming fish from the Ann-Ping coastal waters is not harmful to the general public, as Zn, Fe, Cu and Mn were the micro essential elements which were important in maintaining regular physical functions in humans. These elements all play an important role in the human metabolism process. Only by consuming excessive amounts would they become hazardous. From a nutrition study on residents in the Taiwan region, the average daily fish consumption is 40 - 63 g(25). Based on this result to calculate the daily consumption of Zn, Fe, Cd, and Mn in the fishes of this study, the amounts would be 0.459, 0.486, 0.284, and 0.522 mg respectively. The amounts were far below the acceptable daily intake set by the USA and WHO/FAO(26, 27) (ADI : Zn=19 mg, Fe=10 mg, Cu=3.25-32.5 mg, Mn=2-5 mg). Therefore, under regular consuming habits, the intake of Zn, Fe, Cu and Mn from the nine species of Ann-Ping coastal waters achieved the basic nutritional requirement for normal physical functions and are not harmful to human health. Although Cd is a toxic element that would deposit in human body and is danger to human health(9), the concentration in fish meats in the study were far lower than the consumption safety tolerance in fish set by countries elsewhere (Table 5). The daily intake (<0.315 μg/g) was lower than the acceptable daily intake set by WHO/FAO(27) (Provisional Tolerable Daily Intake, PTDI=57-72 μg, calculated based on body weight at 70 kg). The Zn, Cu, and Cd concentrations in livers and gonads of some fish species were higher than the limitations set by some countries; however, since muscle was the major consuming portion, and that massive internal organs were rarely consumed, there should not be any health threat to the public resulting from the consumption of fish meat.

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安平海域九種魚類之重金屬含量

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摘　要

本研究選取安平海域九種常見魚類，分別測定其肌肉、肝臟與生殖腺三種組織中之鋅、鐵、銅、錳與鎘濃度。結果顯示不同魚種其體內重金屬之含量均以鋅、鐵含量為最高，銅、錳次之，而鎘為最低；不同組織間之重金屬含量亦皆以肝臟最高，生殖腺次之，肌肉為最低。其中肌肉中鋅、鐵、銅、錳與鎘之含量範圍分別為4.00~7.28、2.35~7.72、0.20~ 0.45、0.10~0.83與<0.0005 μg/g 濕重，而肝臟中則為23.0~66.6、131~646、3.34~48.2、0.75~1.94及0.08~0.70 μg/g 濕重。重金屬濃度在魚種間有明顯的種別差異，其中黃小鯵魟肌肉中的鋅、錳及鎘的濃度皆較其他魚種為高，而大鱗鮻肝臟中的銅與鐵則較其他魚種為高。本研究結果顯示安平海域魚類所蓄積之重金屬並無明顯偏高的現象，與台灣及世界其他國家未受污染或輕度污染地區之測值相近，因此食用此九種常見魚類對消費者並無重金屬食用安全性之問題。

關鍵詞：重金屬，鋅，鐵，銅，錳，鎘，魚類，肌肉，肝臟，生殖腺