Singapore

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1. Introduction

In 2007, Singapore's per capita consumption of fish is 19.5 kg. Though highly nutritious, fish pose potential health concern, as it could be contaminated with environmentally persistent chemicals. Fish is able to accumulate large amounts of toxic contaminants from their living environment. One group of contaminants accumulated by aquatic organisms is heavy metals such as Mercury, Arsenic, Cadmium and Lead. They are cumulative poisons, which are not detoxified by metabolic activities.

The United States Environmental Protection Agency (USEPA) has divided metals into two categories, namely hazardous and non-hazardous. Hazardous metals includes Mercury, Cadmium and Lead. Inorganic Arsenic, though known to be toxic to human beings, is not included in this list because its concentration in the environment is low.

The heavy metals are usually released to the atmosphere from both natural and human activities with the majority being terrestrial sources. Most of the toxic action of heavy metals involve binding to the metabolically amino-, sulphydryl-, carboxyl-, phenolic- or phosphoryl- groups. Toxicity is mainly determined by its solubility, stability and biological reactivity.

Mercury poisoning can result in loss of vision, hearing and intellectual abilities and nervous disorder and the degree of poisoning is dependent on many factors such as the dietary level and the age of the fish, microbial activity, salinity, pH and redox potential.

Cadmium, on the other hand, is a highly toxic metal because of the absence of homeostatic control for the metal in the human body. Ingestion of small amounts of cadmium would cause symptoms of nausea and headache while long-term exposure to the metal could cause renal damage and bone brittleness. Cadmium poisoning also leads to kidney malfunction and a drop in the phosphate level of the blood serum.

Lead is another metal that can affect the nervous system and the intellectual development in children. It is a general protoplasmic poison, which is cumulative and slow-acting due to its relatively low solubility in water and in cells. It inhibits the normal functioning of many enzymes. It also obstructs the utilization of oxygen and glucose for life sustaining energy production. Higher level of lead in the blood can cause kidney dysfunction and brain damage.

Arsenic and its compounds are widely distributed in nature primarily in two oxidation states, arsenite (trivalent) and arsenate (pentavalent). Inorganic arsenic is toxic to the liver and causes necrosis and cirrhosis. It also affects the bone marrow and cellular elements of blood.

2. Objectives And Goals

The objective of this survey is to ascertain the levels of heavy metals, namely total Arsenic, Mercury, Lead and Cadmium, in edible portions in commonly consumed fresh fish and those that are used in delicacies in Singapore. This would give an indication of the extent of consumers' exposure to the named heavy metals from consumption of these fishes.

3. Survey Methodologies

a. Sampling Method, Location, Species, Number of Samples and Sampling Size

Six species of fish and shellfish were used in this study. The species selected for analysis were based on their popularity among local consumers, habitat and feeding habits. All samples were obtained fresh from different locations, mainly from three wet-markets in Singapore. These wet-markets were Zhujiao market located in Upper Serangoon Road, Geylang Serai market in Jalan Pasar Baru and Chinatown market situated near New Bridge Road. Fishes were randomly selected and purchased. The fishes collected were of “market” size. The fishes were packed in ice and transported in an insulated container back to the laboratory. Upon arrival at the laboratory, the specimens were identified. Sea cucumbers could not be identified as the samples were bought in the processed form where most physical features had been largely destroyed.

The total length, standard length and body weight of the samples were measured. Only the edible portions were sampled. For finfish, the samples used were right skin-off fillets except for Spanish mackerel where skin-on fillets were used. Whole squids with their eyes, viscera and softshell removed were used. As for mud crabs and blood cockles, only the muscles were studied. For shellfish, a composite sample was prepared from a pool of at least 1 kg of the shellfish. In composite samples, only samples of similar size were used. After sampling, a mill was used to mince and blend the tissue to obtain a homogeneous sample. Seven samples of each type of species (n = 7) were used for analysis. Each sample was analysed in duplicates. Two portions of the minced tissue were weighed. These were dried at 102^{o}C overnight for the determination of moisture. The dried samples were used directly for analysis.

b. Method of Analysis

The instrument used for all analysis is Perkin Elmer 3300 AAS, FIAS 100, HGEA-600 and AS-60.

c. Limit of Detection and Limit of Quantification

All values are in dry weight basis.
Mercury:
Limit of detection $_{sample}$: 0.026 ug/g
Limit of quantitation $_{sample}$: 0.088ug/g

Arsenic:
Limit of detection $_{sample}$: 0.340 ug/g
Limit of quantitation $_{sample}$: 1.133 ug/g

Cadmium:
Limit of detection $_{sample}$: 0.091 ug/g
Limit of quantitation $_{sample}$: 0.305 ug/g

Lead:
Limit of detection $_{sample}$: 0.189 ug/g
Limit of quantitation $_{sample}$: 0.632 ug/g

d. National Regulatory Limits

Country	Cadmium	Lead	Arsenic	Mercury
Singapore	• 1 ppm in molluscs	• 2 ppm in fish, crustaceans, molluscs and in canned fish	• 1 ppm in fish, crustaceans, molluscs and in canned fish	• 0.5 ppm in fish and fish products
	Reference: Sale of Food Act, Chapter 283, Section 56 (1), Food Regulations, 2005 Revised Edition			

4. Results And Discussion

a. Participation in Inter-laboratory Proficiency Testing and Results

Year of participation	Program Name	Analyte Tested	Reported results (ppb)	True value	z-score	Remarks
Jun 2004	FAPAS	Total As and Total Hg in canned fish	As: 937.9 Hg: 74.63	As: 1750 Hg: 74.63	As: **-3.2** Hg: -0.4	Passed for Hg, results rectified for As.
Nov 2004	FAPAS	Total As, Cd and Pb in canned fish	As: 597.35 Cd: 13.63 Pb: 30.75	As: 505 Cd: 12.9 Pb: 8.51	As: 1.0 Cd: 0.3 Pb: **11.9**	Passed for As and Cd, results rectified for Pb.
May 2005	FAPAS	Total As and Total Hg in canned fish	As: 850.4 Hg: 380.92	As: 1030 Hg: 397	As: -1.1 Hg: -0.2	Passed
Apr 2005	Canadian Food Inspection Agency (CFIA) Quality Assurance Program	Total Hg in Tuna	4 samples: 1) 0.306 2) 0.529 3) 0.249 4) 0.409	Not given	1) –0.908 2) –1.046 3) –0.838 4) –1.371	Passed
Mar 2006	FAPAS	Total As, Cd and Pb in canned fish	As: 479.64 Cd: 9.7427 Pb: ND	As: 499 Cd: 13.7 Pb: 9.13	As: -0.2 Cd: -1.3 Pb: -	Passed
Oct 2006	FAPAS	Total As, Total Hg, Cd and Pb in canned fish	As: 321.92 Hg: 14.28 Cd: 9.7674 Pb: 33.77	As: 344 Hg: 19.9 Cd: 2.59 Pb: not set	As: -0.3 Hg: -1.3 Cd: **12.6** Pb: -	Passed for As and Hg, results rectified for Cd.
Dec 2007	Hong Kong Government Laboratory Proficiency Testing Programme on Heavy Metals in Food	Total As, Cd and Pb in dried shrimp powder All in mg/Kg	As: 53.221 Cd: 0.145 Pb: 1.608	As: 60 Cd: 0.187 Pb: 1.20	As: -1.3 Cd: -1.0 Pb: 0.99	Passed
Jun 2007	FAPAS	Total As, Total Hg, Cd and Pb in canned fish	As: 749.88 Hg: 747.63 Cd: 49.23 Pb: ND	As: 1124 Hg: 704 Cd: 52.4 Pb: not set	As: **-2.1** Hg: 0.4 Cd: -0.3 Pb: -	Passed

b. Survey Results and Discussion

Table 1. Results for Total Mercury.

Year of analysis & Sampling location	Analyte	Fish sample analysed		No. of samples analysed	Min. value of results (ppm) – wet weight basis	Max. value of results (ppm) – wet weight basis	Average value of results (ppm) – wet weight basis	Average Recovery (%)	Remarks
		Common name	Scientific name						
2004	Total Mercury	Sea cucumber	-	n=7	ND	ND	ND	97.4%	*ND-not detected
		Blood cockle	*Anadara granosa*	n=7	0.012	0.019	0.014		
		Mitre squid	*Loligo chinensis*	n=7	0.008	0.029	0.018		
		Mud crab	*Scylla serrata*	n=7	0.018	0.069	0.053		
		Longtail tuna	*Thunnus tonggol*	n=7	0.014	0.117	0.069		
		Barred Spanish mackerel	*Scomberomorus commerson*	n=7	0.037	0.162	0.081		

Table 2. Results for Total Arsenic.

Year of analysis & Sampling location	Analyte	Fish sample analysed		No. of samples analysed	Min. value of results (ppm) – wet weight basis	Max. value of results (ppm) – wet weight basis	Average value of results (ppm) – wet weight basis	Average Recovery (%)	Remarks
		Common name	Scientific name						
2004	Total Arsenic	Sea cucumber	-	n=7	ND	0.034	ND	104.8%	*ND-not detected
		Blood cockle	*Anadara granosa*	n=7	0.432	1.116	0.741		
		Barred Spanish mackerel	*Scomberomorus commerson*	n=7	0.707	1.354	1.014		
		Longtail tuna	*Thunnus tonggol*	n=7	0.685	2.083	1.068		
		Mud crab	*Scylla serrata*	n=7	0.737	4.566	2.167		
		Mitre squid	*Loligo chinensis*	n=7	0.785	4.691	2.859		

Note: The method used was for the detection of total arsenic. Only approximately 10-20% of the arsenic in seafood is present in an inorganic form, which is toxic.

Table 3. Results for Cadmium.

Year of analysis & Sampling location	Analyte	Fish sample analysed		No. of samples analysed	Min. value of results (ppm) – wet weight basis	Max. value of results (ppm) – wet weight basis	Average value of results (ppm) – wet weight basis	Average Recovery (%)	Remarks
		Common name	Scientific name						
2004	Cadmium	Longtail tuna	*Thunnus tonggol*	n=7	ND	ND	ND	100.8%	*ND-not detected
		Barred Spanish mackerel	*Scomberomorus commerson*	n=7	ND	ND	ND		
		Sea cucumber	-	n=6	ND	0.044	0.010		
		Mitre squid	*Loligo chinensis*	n=7	0.096	0.246	0.166		
		Blood cockle	*Anadara granosa*	n=7	0.136	0.794	0.542		

Table 4. Results for Lead.

Year of analysis & Sampling location	Analyte	Fish sample analysed		No. of samples analysed	Min. value of results (ppm) – wet weight basis	Max. value of results (ppm) – wet weight basis	Average value of results (ppm) – wet weight basis	Average Recovery (%)	Remarks
		Common name	Scientific name						
2004	Lead	Barred Spanish mackerel	*Scomberomorus commerson*	n=7	ND	ND	ND	94.0%	*ND-not detected
		Longtail tuna	*Thunnus tonggol*	n=7	ND	ND	ND		
		Mitre squid	*Loligo chinensis*	n=7	ND	ND	ND		
		Sea cucumber	-	n=7	ND	0.207	0.041		
		Blood cockle	*Anadara granosa*	n=7	0.096	0.336	0.212		

c. **Corrective Actions**

Not applicable.

5. Problems and Challenges Encountered

In this survey, only six types of species were analysed and a total of forty-two fish samples were collected. Thus, the samples collected may not be truly representative of the catches, which landed in Singapore.

6. Recommendations and Suggestions for Future Follow up Action

The use of quicker digestion methods, for example, use of microwave digestion, could be explored to reduce sample preparation time.