Heavy Metal Contents in Purpleback Squid (*Sthenoteuthis oualaniensis*) from the Bay of Bengal

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Abstract

Oceanic purpleback squid (*Sthenoteuthis oualaniensis*) were sampled at nine locations in the Bay of Bengal by the fishery research vessel M.V. SEAFDEC, of the Southeast Asian Fisheries Development Center (SEAFDEC). The squid were captured by jigging machines, and samples were kept frozen until analysis of heavy metal. Three individual squid were randomly chosen from each location and the edible parts of the squid (mantle, arm and tentacle) were separated from the visceral mass. The samples were homogenized and a portion from each individual was digested in a microwave digester. Hg concentration in the digested solution was determined by cold vapor atomic fluorescence spectrophotometer. Cd, Cu, Zn and Pb concentrations in the digested solution was determined by atomic absorption spectrophotometer. Results from this study show that purpleback squid from the Bay of Bengal accumulate high concentrations of Cd, Cu and Zn. Levels of heavy metals were similar across all sampling stations. These metals accumulate mainly in the visceral mass, which includes the ink sac, digestive gland, gills, and gonads, whereas accumulation in the edible part (mantle, arm and tentacle) is significantly lower. Cd was the only heavy metal in mantle tissue found to exceed safety standards. The concentrations of Cd and Cu in visceral mass were also higher than safety standards. The concentrations of Hg, Pb and Zn in both mantle and visceral mass were lower than safety standards. Our sampling indicates that purpleback squid is not safe for human consumption based on the degree of Cd contamination. Close monitoring is necessary in order to follow changes in Cd contamination. Further study to investigate sources of the heavy metals, especially Cd, may provide a better view on contaminant sources.

Key words: heavy metal, purpleback squid, *Sthenoteuthis oualaniensis*, Bay of Bengal

Introduction

The Ecosystem-Based Fishery Management in the Bay of Bengal, a collaborative survey project of the BIMSTEC member countries (Bangladesh, India, Myanmar, Sri Lanka, Nepal and Thailand) carried out a 58-day survey trip in the Bay of Bengal from 25 October to 21 December 2007. The objectives were to assess the potential of fishery resources, collect biological data (species composition, distribution and catchability) of fishes and oceanic squids as well as study the physico-chemical and hydrological aspects of the survey area.

Purpleback squid (*Sthenoteuthis oualaniensis*) is an oceanic squid widely distributed in the equatorial and tropical waters of the Indo-Pacific Ocean. The squid is characterized by a wide ecological amplitude, complex intraspecific structure, high fecundity, short life cycle, high natural mortality, high growth rate and significant production (Nesis, 1977). It is very abundant and recognized as one of the main squid resources in the South China Sea and especially the northwestern Indian Ocean (Chesalin, 1997; Chesalin and Zuyev, 2002). Similar to all other squid, purpleback squid is carnivorous, feeding mainly on crustaceans, small fish, and other cephalopods (Collins *et al*., 1994; Collins and Pierce, 1996; Quetglas *et al*., 1999). Xinjun *et al*. (2007) found that stomach contents of purpleback squid from the northwestern Indian Ocean contained three major diet groups: fish, cephalopods and crustaceans, mainly *Cypselurus* spp. and *S. oualaniensis*. More than 60% of the stomachs of squid larger than 400 mm ML had evidence of cannibalism.

Squid are themselves important prey items for large fish, sea birds, and marine mammals (Pierce and Santos, 1996; Santos *et al*., 2001). Squid (and other cephalopods) are very efficient accumulators of various trace elements (Martin and Flegal, 1975; Miramand and Bentley, 1992; Bustamante *et al*., 2002). Toxic metals such as cadmium and mercury are bioaccumulated and retained in squid (Bustamante *et al*., 1998, 2006) and consequently passed on to predators, thus potentially increasing the contaminant load in higher trophic levels, including humans (Bustamante *et al*., 1998; Lahaye *et al*., 2005; Storelli *et al*., 2005, 2006).

The purpleback squid population in the Bay of Bengal has been recognized as a potential fishery resource for human consumption. Hence, information on heavy metal concentrations in this squid is important for future policy regarding exploitation of this species. The aims of this study were to determine and compare heavy metal concentrations in the edible portion (mantle, arm and tentacle) and visceral mass of purpleback squid (*Sthenoteuthis oualaniensis*) from nine sampling stations in the Bay of Bengal.

Materials and Methods

Samples of purpleback squid were caught by two Japanese automatic squid jigging machines which were fixed and operated at the starboard side of the fishery research vessel M.V. SEAFDEC, of the Southeast Asian Fisheries Development Center (SEAFDEC). The squid were attracted by 500 kilowatt light from 15 halogen lamps fixed along the starboard side of the ship at a height of 10 m from the surface of water. The lights were switched on 60 minutes before the start of sampling. Collection occurred from 20.00-24.00 PM. for every sampling event. Seven of the sampling stations (1, 3, 7, 8, 9, 10 and 12) were located within area C, or the eastern part of the Bay of Bengal (Fig. 1). Two other sampling stations (14 and 16) were located at the northern part of the Bay (area A; Fig. 1). A list of sampling stations and their positions can be found in Table 1.

Mantle length and body weight of each individual caught were measured and recorded. Sex of the squids was determined by the presence or absence of a hectocotylus (modified ventral arm of the male). Each squid was placed in a plastic zip-log bag and kept frozen until analysis.

Prior to heavy metal analysis the samples of purpleback squid were thawed at room temperature. Three individuals from each sampling station were randomly chosen for the analysis, except for station 3, in which only one squid was available. The edible body parts (mantle, arm and tentacle) and visceral mass of each squid were separated. The samples were cut and homogenized in a blender. A 1.0-1.5 g portion of each homogenized sample was carefully weighed in a Teflon vessel. Hydrogen peroxide and sub-boiled distilled nitric acid was added to the vessels. The vessels were then closed tightly and placed in a microwave digester (CEM; Mar5x). Afterwards, the samples were cooled down and diluted with deionized water. Mercury (Hg) concentration in the digested sample was determined by Cold Vapor Atomic Fluorescence Spectrometer (PSAnalytical; Merlin) whereas Cd, Pb, and Cu were determined by Graphite Furnace Atomic Absorption Spectrophotometer (Unicam;

Solars). Zinc concentration was determined by Flame Atomic Absorption Spectrophotometer (Varian; SpectrAA-50).

To validate the analytical technique, a certified reference material for trace metals, DORM-3 (National Research Council, Canada), was digested and heavy metal levels were determined in the same manner as for our samples. Limit of detection of each heavy metal was calculated from three standard deviations of eight method blanks.

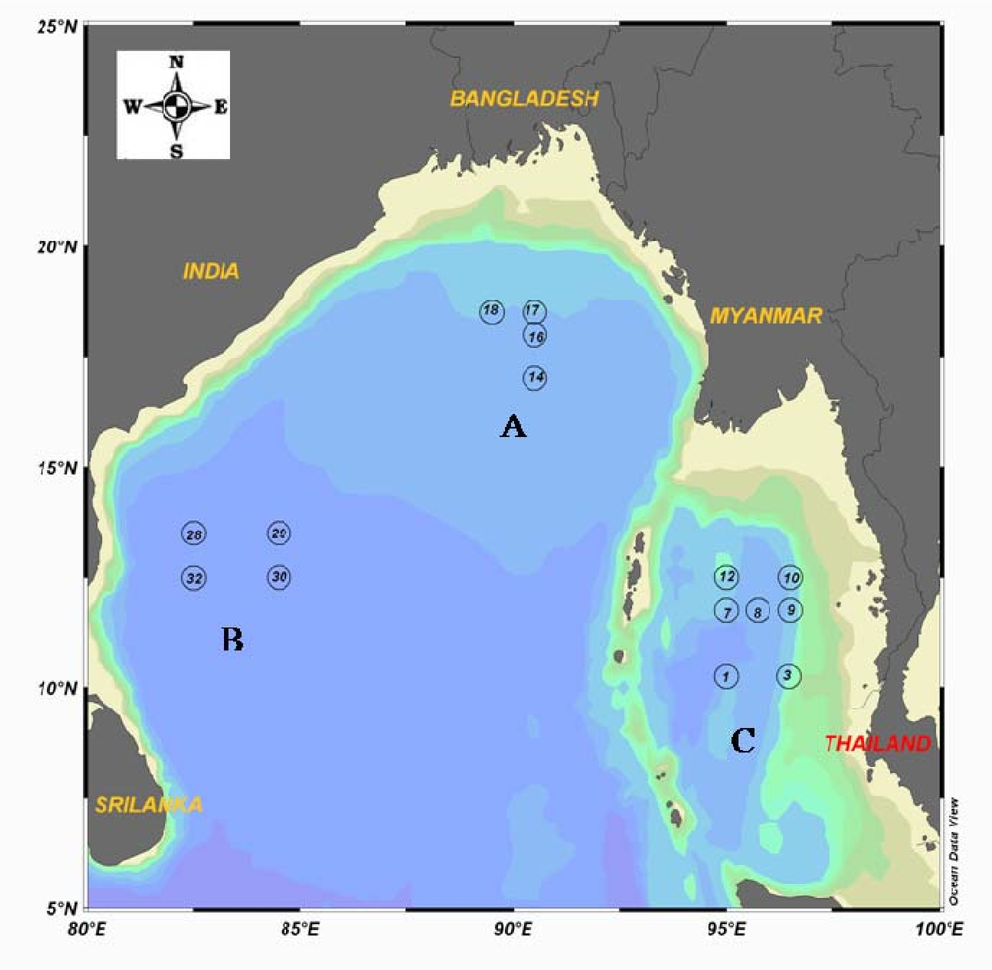

Figure 1 Map depicting the stations of automatic squid jigging in each area.

Table 1 Dates of jigging operation, positions of sampling stations and depth of sampling stations.

Area	Jigggin operation no.	Survey st. no.	Date	Position latitude (N)	Position longitude (E)	Sea depth
C	1	01	06/11/2007	10°18.20′	95°01.00′	2,628
	2	03	07/11/2007	10°14.40′	96°32.80′	538
	3	07	10/11/2007	11°04.90′	95°36.30′	513
	4	08	11/11/2007	11°54.50′	95°06.70′	2,884
	5	09	12/11/2007	11°45.60′	96°32.40′	883
	6	10	13/11/2007	12°04.50′	96°23.40′	1,128
	7	12	15/11/2007	12°29.50′	94°54.50′	1,418
A	8	14	17/11/2007	16°49.50′	90°20.90′	2,353
	9	16	18/11/2007	18°01.40′	90°35.70′	2,136

Results and Discussion

Validity of Methods

Table 2 shows determined values, certified value and % recovery of Hg, Cd, Cu, Pb, and Zn of certified reference material (DORM-3; National Research Council, Canada) and limit of detection of each heavy metal. The recovery levels of all heavy metals from this study were within an acceptable range (96-103%).

Table 2 Determined value, certified value and percent (%) recovery of heavy metal contents of the DORM-3 (n=4) as validation for analytical technique.

Metals/description	Hg (ug/g)	Cd (ug/g)	Cu (ug/g)	Pb(ug/g)	Zn (ug/g)
Determined value	0.415±0.011	0.292±0.024	16.03±0.34	0.405±0.025	49.51±0.39
Certified value	0.409	0.290	15.5	0.395	51.3
% recovery	101.58±2.78	100.59±8.16	103.43±2.19	102.74±6.56	96.50±0.768
Detection limit[b]	0.001	0.003	0.030	0.012	0.090

Heavy Metal Contents in Squid

Heavy metal concentrations in the edible portion (mantle, arm and tentacle) and visceral mass of purpleback squid (*Sthenoteuthis oualaniensis*) from each station in the Bay of Bengal are shown in table 3. Mean concentrations±standard deviation of Hg, Cd, Pb, Zn and Cu in the edible parts of purpleback squid from all sampling stations were 39.92±34.10 (ng/g), 3.759±4.856, 0.035±0.029, 16.54±2.32 and 10.99±8.60 (µg/g), respectively. Mean concentrations ± standard deviation of Hg, Cd, Pb, Zn and Cu in the visceral mass of purpleback squid from all sampling stations were 34.26±25.32 (ng/g), 17.47±5.70, 0.062±0.020, 43.82±9.86 and 73.68±47.07 (µg/g), respectively.

Panutrakul (unpublished data) determined heavy metal concentrations in mantle tissue of marbled octopus (*Octopus aegina*) and pharaoh cuttlefish (*Sepia pharaonis*) collected from the upper Gulf of Thailand. For octopus, concentrations of Hg, Cd, Pb, Zn and Cu were 12.12±5.59 (ng/g), 0.020±0.037, 0.126±0.169, 19.88±4.42 and 11.48±5.10 (µg/g), respectively. For cuttlefish, concentrations of the same group of metals were 15.39±8.03 (ng/g), 0.055±0.072, 0.061±0.029, 13.5±2.47, 5.76±1.69 (µg/g), respectively. Mean concentrations of Hg, Pb, Zn and Cu in edible tissue of purpleback squid from the Bay of Bengal were similar to concentrations found in octopus and cuttlefish in Thailand. However, Cd concentrations in purpleback squid were much higher than in the other two species.

Pierce *et al*. (2008) measured Hg and Cd concentrations in tissues of two loliginid (*Alloteuthis* sp. and *Loligo forbesi*) and two ommastrephid (*Todarodes sagittatus* and *Todaropsis eblanae*) squid species collected in UK waters during 2004-2005. They found concentrations of Hg and Cd in muscle tissue of the squid to be in the range of 17-80 ng/g and 0.021-0.256 µg/g, respectively. However, the authors also reported that the digestive gland is the main storage organ of Cd in these squid species. Hg and Cd concentrations in the digestive gland of these squid varied from 17-110 (ng/g) and 0.16-3.31 (µg/g), respectively. In comparing results from this study with those of Pierce *et al.* (2008) we found that squid from UK waters show slightly higher Hg concentration in both muscle and digestive gland than our samples from the Bay of Bengal. Meanwhile, Cd concentrations in both muscle and digestive gland of squid from UK waters were lower than our samples.

Bioconcentration and bioaccumulation experiments of Cd by oval squid (*Sepioteuthis lessoniana*) run by Koyama *et al*. (2000) showed that oval squid can take Cd up via diffusion of Cd ions from the water and from their diet. After 14 days of exposure to 0.2 mg Cd/l seawater, the mean Cd concentrations in the liver, gill, digestive tract, mantle, ink sac and the remaining parts of the squid were 49.3, 19.2, 7.08, 0.79, 1.35 and 1.62 µg/g wet weight, respectively. In another experiment, squid were reared in 0.12 mg Cd/l seawater, and also fed a diet of fish raised in the same seawater. The mean Cd concentrations in the liver, gill, digestive tract, mantle, ink sac and remaining parts of the squid were 58.8, 19.4, 13.0, 1.10, 3.30 and 1.13 µg/g wet weight, respectively. Their results showed that oval squid can bioconcentrate and bioaccumulate waterborne and dietary Cd in a short period of time. Cd tends to accumulate primarily in liver whereas Cd concentration in the mantle is lower than in the other tissues.

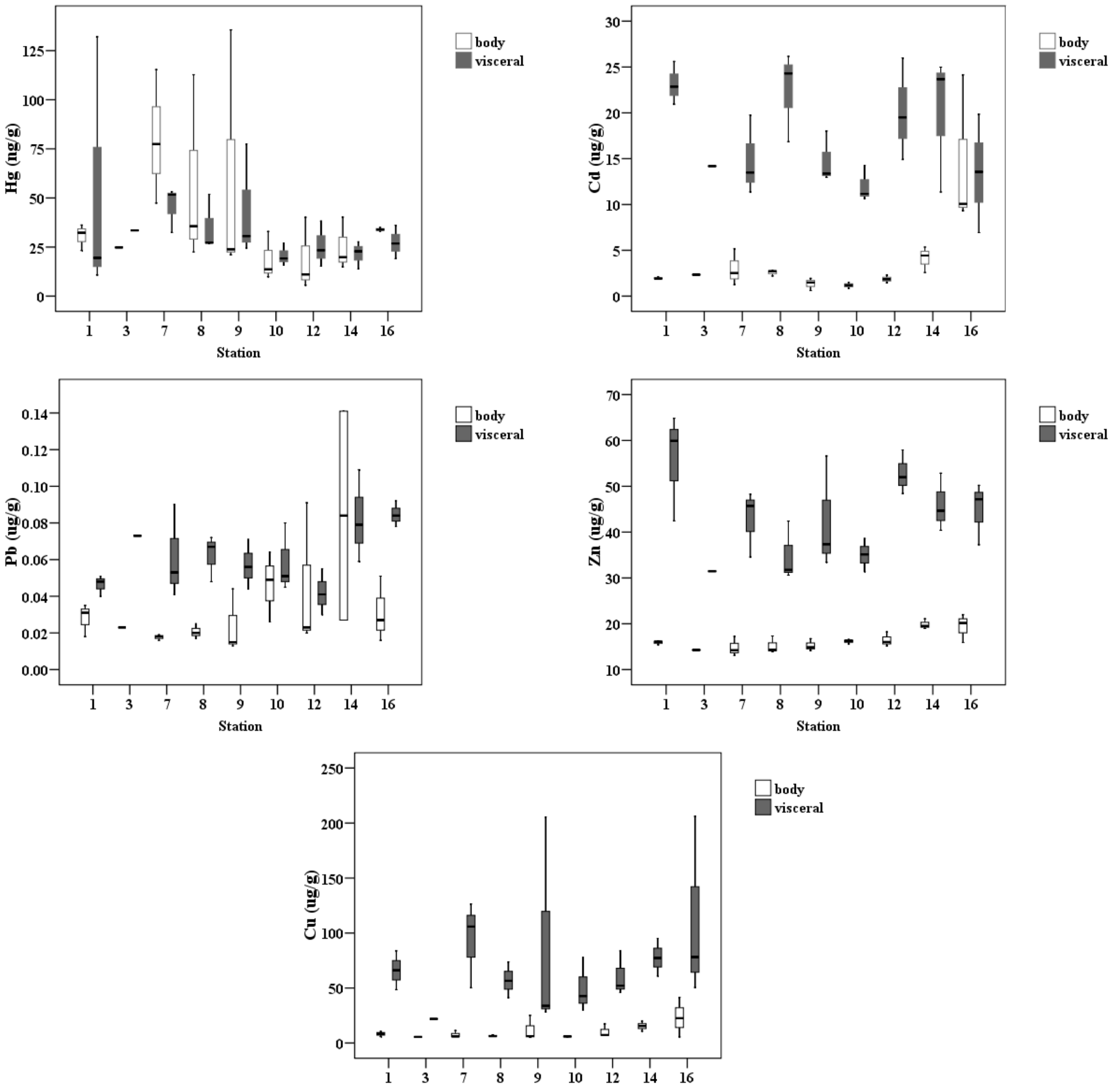

Figure 2 Box plot of heavy metal concentrations in edible parts (mantle, arm and tentacle) and visceral mass of purpleback squid (*Sthenoteuthis oualaniensis*) collected from the Bay of Bengal.

Table 3 Heavy metal concentrations in edible body parts (mantle, arm and tentacle) and visceral mass of purpleback squid (*Sthenoteuthis oualaniensis*) collected from the Bay of Bengal.

Station	Hg (ng/g)		Cd (µg/g)		Pb (µg/g)		Zn (µg/g)		Cu (µg/g)	
	Body	Visceral	Body	Visceral	Body	Visceral	Body	Visceral	Body	Visceral
1	30.58±6.66	54.09±67.66	1.975±0.095	23.136±2.345	0.028±0.009	0.046±0.005	15.92±0.43	55.74±11.76	8.28±5.54	66.12±17.63
3	24.77	33.50	2.336	14.186	0.023	0.073	14.27	31.46	5.54	21.97
7	80.07±34.06	45.74±11.59	2.980±1.999	14.87±4.36	0.018±0.002	0.061±0.026	14.85±2.13	42.84±7.29	7.76±3.12	94.15±39.42
8	56.9±48.75	35.31±14.32	2.570±0.326	22.44±4.92	0.021±0.004	0.062±0.013	15.19±1.87	34.93±6.50	6.65±0.70	57.21±16.24
9	60.17±65.31	44.19±29.00	1.348±0.686	14.78±2.81	0.024±0.017	0.057±0.014	15.27±1.336	42.46±12.41	12.17±11.26	89.21±100.76
10	18.82±12.36	20.69±5.70	1.180±0.332	12.02±1.95	0.046±0.019	0.058±0.019	16.15±0.049	35.04±3.61	5.77±0.37	49.99±24.76
12	18.90±18.58	25.59±11.62	1.865±0.413	20.13±5.57	0.045±0.040	0.042±0.013	16.48±1.57	52.78±4.80	10.54±5.97	60.63±20.32
14	24.99±13.42	21.44±7.01	4.117±1.410	20.01±7.52	0.084±0.080	0.082±0.025	19.86±1.10	45.98±6.33	15.35±4.50	77.80±17.12
16	33.96±0.90	27.32±8.53	14.511±8.347	13.45±6.46	0.031±0.018	0.085±0.007	19.35±3.12	44.87±6.78	23.23±17.95	111.60±83.01

Table 3 Heavy metal concentrations in edible body parts (mantle, arm and tentacle) and visceral mass of purpleback squid (*Sthenoteuthis oualaniensis*) collected from the Bay of Bengal.

Station	Hg (ng/g)		Cd (µg/g)		Pb (µg/g)		Zn (µg/g)		Cu (µg/g)	
	Body	Visceral	Body	Visceral	Body	Visceral	Body	Visceral	Body	Visceral
1	30.58±6.66	54.09±67.66	1.975±0.095	23.136±2.345	0.028±0.009	0.046±0.005	15.92±0.43	55.74±11.76	8.28±5.54	66.12±17.63
3	24.77	33.50	2.336	14.186	0.023	0.073	14.27	31.46	5.54	21.97
7	80.07±34.06	45.74±11.59	2.980±1.999	14.87±4.36	0.018±0.002	0.061±0.026	14.85±2.13	42.84±7.29	7.76±3.12	94.15±39.42
8	56.9±48.75	35.31±14.32	2.570±0.326	22.44±4.92	0.021±0.004	0.062±0.013	15.19±1.87	34.93±6.50	6.65±0.70	57.21±16.24
9	60.17±65.31	44.19±29.00	1.348±0.686	14.78±2.81	0.024±0.017	0.057±0.014	15.27±1.336	42.46±12.41	12.17±11.26	89.21±100.76
10	18.82±12.36	20.69±5.70	1.180±0.332	12.02±1.95	0.046±0.019	0.058±0.019	16.15±0.049	35.04±3.61	5.77±0.37	49.99±24.76
12	18.90±18.58	25.59±11.62	1.865±0.413	20.13±5.57	0.045±0.040	0.042±0.013	16.48±1.57	52.78±4.80	10.54±5.97	60.63±20.32
14	24.99±13.42	21.44±7.01	4.117±1.410	20.01±7.52	0.084±0.080	0.082±0.025	19.86±1.10	45.98±6.33	15.35±4.50	77.80±17.12
16	33.96±0.90	27.32±8.53	14.511±8.347	13.45±6.46	0.031±0.018	0.085±0.007	19.35±3.12	44.87±6.78	23.23±17.95	111.60±83.01

The Ecosystem-Based Fishery Management in the Bay of Bengal

Differences in Heavy Metal Concentrations between Body Parts and among Sampling Location

Two-way analysis of variance was used to test the effects of body part and sampling station on Hg, Cd, Pb, Zn and Cu concentrations of purpleback squid (Table 4). Body part and sampling location were significant factors for Cd, and Zn concentrations. Cd concentration in visceral mass of squid in every station, except station 16, was significantly higher (p<.01) than the edible portion (mantle, arm and tentacle) (Fig. 2). Zn concentrations in visceral mass of squid in every station was significantly higher (p<.01) than the edible portion. However, the difference found for station 1 was larger than in the other stations (Fig. 2). Body part was the only significant factor for Pb and Cu concentrations. Mean concentrations of these two metals in visceral mass of squid were significantly higher (p<.01) than the edible portion for every station. Hg concentrations were similar for both body parts and similar among stations (Table 4). Generally speaking, there were no significant differences of heavy metals among sampling stations. Cd, Pb, Zn and Cu show higher accumulation levels in visceral mass compared to the edible portion. No significant correlations between heavy metal concentration in edible tissues and either mantle length or total body weight were found.

Table 4 Comparisons of Hg, Cd, Pb, Zn and Cu concentrations in purpleback squid (*Sthenoteuthis oualaniensis*) collected from the Bay of Bengal by sampling station and by body part (edible vs. visceral mass).

Metals	Source	df	F	P
	Station	8	1.465	ns
Hg	Part	1	0.256	ns
	Station * Part	8	0.477	ns
	Station	8	36.144	ns
Cd	Part	1	2034.466	**
	Station * Part	8	65.623	**
	Station	8	2.017	ns
Pb	Part	1	15.568	**
	Station * Part	8	1.148	ns
	Station	8	2.958	*
Zn	Part	1	233.191	**
	Station * Part	8	2.276	*
	Station	8	0.830	ns
Cu	Part	1	29.543	**
	Station * Part	8	0.401	ns

Ns = p>0.05; * p < 0.05; ** p < 0.01; *** p < 0.001

Pierce *et al.* (2008) showed that Cd concentration in digestive gland of two loliginid (*Alloteuthis* sp. and *Loligo forbesi*) and two ommastrephid (*Todarodes sagittatus* and *Todaropsis eblanae*) squid species collected from research cruise and fishery (market) samples in UK waters during 2004-2005 is higher than in muscle. Seixas *et al.* (2005) also found that concentration of Hg in digestive gland of common octopus (*Octopus vulgaris*) is higher than in the other tissue. Experimental work of Koyama *et al*. (2000) shows that oval squid (*Sepioteuthis lessoniana*) can bioconcentrate and bioaccumulate Cd from water and dietary. They also show that liver is the main storage organ for Cd in the oval squid (Koyama *et al*., 2000). Concentrations of Cd, Zn and Cu in digestive gland of cephalopods from the various works has been summarized and reported in table 5 (notice: concentrations of the heavy metals are reported based on dry weight whereas results from this work is based on wet weight).

Hence, results from this study and those previously reported suggest that internal organs, especially digestive gland and liver, are the main storage organs for most heavy metals. Cd, Cu and Zn are the three metals that have been found highly accumulated in digestive gland and liver of cephalopods. The high contamination levels of Cd, Cu and Zn found in Japanese common squid waste (Omid and Hiroyuki, 2005) resulted from highly contaminated visceral mass which is the major component of squid waste.

Sources of Cd and Other Metals Residue in Squid

It has long been recognized that squid and other cephalopods can accumulate high levels of cadmium and other metals. Squid also play a major role in transferring these metals through the food chain (Martin & Flegal, 1975; Smith *et al.* 1984; Miramand & Guary 1980; Finger & Smith 1987; Miramand & Bentley 1992; Bustamante 1998; and Bustamante *et al.*, 1998a). However, the sources of Cd and other metal residues in squid and other cephalopods has never been clear. Squid and most other cephalopods are characterized by high growth rate, high mortality rate, high fecundity and short life. Xinjun *et al.* (2007) reported that most purpleback squid from the northwestern Indian Ocean have a life span of 0.5-1.0 year. Thus, high levels of heavy metals in these organisms are not a result of long term accumulation.

Koyama *et al*. (2000) concluded from their experimental work that accumulation of Cd in oval squid (*Sepioteuthis lessoniana*) can occur via diffusion from seawater into the body and by ingestion. Xinjun *et al*. (2007) found that stomach contents of purpleback squid from the northwestern Indian Ocean contained three major diet groups: fish, cephalopods and crustaceans, mainly *Cypselurus spp.* and *S. oualaniensis*. More than 60% of the stomachs had evidence of cannibalism for the squid larger than 400 mm ML.

Data on dissolved heavy metals in the Bay of Bengal are rare. Therefore, it is difficult to make any conclusion on the sources of the heavy metals in purpleback squid. Since purpleback squid is carnivorous and even cannibalistic (Xinjun *et al*. 2007), it appears that residues of these heavy metals come at least in part via ingestion.

Table 5 Cd, Cu and Zn concentrations (µg/g dry wt) determined in the digestive gland of cephalopods from the literature.

Species	Cd	Cu	Zn	Authors
Sepia officinalis	12.67±0.35	315±3	571±47	Miramand & Bentley (1992)
Loligo opalescens	85.0±51.6	5350±3210	247±131	Martin & Flegal (1975)
L. opalescens	121.5±57.9	8370±3130	449±201	"
N. gouldi	50±25	246±298	696±295	Smith *et al.* (1984)
Ommastrephes bartrami	287±202	195±212	163±55	Martin & Flegal (1975)
Stenoteuthis oualaniensis	782±255	1720±151	513±288	"
Eledone cirrhosa	24.00±1.75	456 ±11	646±86	Miramand & Bentley (1992)
Benthoctopus thielei	215	42	416	Bustamante *et al.* (1998a)
Graneledone sp.	369	1092	102	Bustamante *et al.* (1998a)
Octopus vulgaris		2550		Ghiretti-Magaldi *et al.* (1958)
O. vulgaris	50±10	2500±700	1450±400	Miramand & Guary (1980)

Safety Issues for Human Consumption

Table 6 compares the mean concentration of heavy metals of squid with the safety limits from several countries. The Hg, Pb and Zn concentrations in both edible tissue and visceral mass were within the safety limits at every sampling station. Mean Cu concentration in visceral mass of squid were higher than the safety limits, whereas concentrations in the edible portion were below the safety limit. Mean Cd concentration in both edible tissue and visceral mass of the squid exceeded all of the proposed safety limits at every sampling station. Cadmium concentrations in visceral mass were in fact many times higher than the safety standards. Therefore, due to Cd contamination, purpleback squid from the Bay of Bengal may not be a proper food source for humans.

Conclusion

Results from this study show that purpleback squid (*Sthenoteuthis oualaniensis*), an oceanic squid widely distributed in the Indian Ocean and the Bay of Bengal, accumulate high concentrations of Cd, Cu and Zn. The levels of heavy metals in the squid from all sampling stations were within the same range. Accumulation of these metals takes part mainly in visceral mass which contains the digestive gland, gill, and gonad, whereas accumulation in the edible portion (mantle, arm and tentacle) is lower. The concentration of Hg, Pb and Zn in both edible tissue and visceral mass were lower than safety standards. The concentration of Cd and Cu in visceral mass were higher than the safety standard. Cd was the only heavy metal found in mantle tissue to exceed safety standards, and is thus the most immediate concern for human consumption of purpleback squid. Close monitoring is necessary to follow changes of contamination levels. Further investigation may also provide a better view of contaminant sources, particularly for cadmium.

Table 6 Mean concentrations ($\mu g\ g^{-1}$) of heavy metals found in the edible portion (mantle, arm and tentacle) and visceral mass of purpleback squid (*Sthenoteuthis oualaniensis*) from all sampling stations in the Bay of Bengal and recommended safety limits.[1-5]

Heavy metals	Edible part	Visceral mass	Safety limit (µg/g)	References
Hg	0.040±0.034	0.034±0.025	0.5	1, 2
Cd	3.759±4.856*	17.47±5.70*	2, 3, 0.5	1, 3, 4
Pb	0.035±0.029	0.062±0.020	0.5, 1.5, 0.5	2, 3, 5
Zn	16.54±2.32	43.82±9.86	≤100	2
Cu	10.99±8.60	73.68±47.07*	≤20	2

[1]Australia and New Zealand Food Authority Amendment No. 53. (2000).

[2]Minsitry of Public Health, Thailand (1986).

[3]US Food and Drug Administration (2001).

[4]FAO. Report of the Codex Committee on Food Additives and Contaminants. Draft Guideline level for Cadmium in Food (http://www.fao.org/docrep/meeting/005/x7137e/x7137e20.htm)

[5]FAO. Report of the Codex Committee on Food Additives and Contaminants. Draft Maximum level for Lead (http://www.fao.org/docrep/meeting/005/x7137e/x7137e1z.htm#TopOfPage)

*indicates maximum concentration was higher than safety limit for at least one of the agencies listed.

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