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Pb, Cd and Hg Contents of Bivalves Collected During the Different Seasons of the Year

E. S. Luis, A. H. Balagot, A. C. Villaflor,
F. C. Sanchez & E. N. Develles

Food Research Program,
National Institute of Science and Technology,
DOST Science Complex, Bicutan, Taguig, M. M., Philippines

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ABSTRACT

Levels of lead, cadmium and mercury were determined in talaba *(*Ostrea malabonensis, *F.),* tahong *(*Perna viridis, *L.),* halaan *(*Arca *spp.) and* tulya *(*Corbicula manilensis, *P.) including the seawater where the saltwater bivalves were harvested. The bivalves were sampled during the dry (March–June), wet (July–October) and cold (November–February) seasons of the years 1983–1985. The heavy metals were determined by atomic absorption spectroscopy. The solutions for Pb and Cd determination were prepared by dry ashing at 400°C with the use of 20%* H_2SO_4 *as ashing aid followed by wet oxidation of the residue with sulfuric acid and 30%* H_2O_2*. Samples for total mercury determination were prepared by solubilization at 50°C with concentrated* H_2SO_4*, oxidized with 6%* $KMnO_4$ *solution and reduced with stannous chloride solution.*

*The average concentration of Pb, Cd and Hg in the bivalves (*talaba, tahong, halaan *and* tulya*) ranged from 0·64 to 2·24 ppm, 0·06 to 0·66 ppm and 0·62 to 11·68 ppb, respectively. However, the variations due to sample and season of the Pb and Cd contents in the bivalves were found insignificant. In contrast, the Hg content of the bivalves varied significantly with the sample and the season. The same trends were also noted in the Pb, Cd and Hg content in the seawater which ranged from 0·66 to 1·16 ppm, 0·07 to 0·10 ppm and 1·8 to 2·6 ppb, respectively.*

The saltwater bivalves exhibited low bio-accumulation factors for the three metals studied. Overall, the findings demonstrated that the four bivalves are safe for human consumption and that the ecosystems where they were harvested do not pose any hazard to man or to marine life. However, caution should be taken if these bivalves are to be considered for feeding children. For

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example, the FAO/WHO recommendation for Pb is 5 μg/kg body weight/day for adults. However, children have about five times the gastrointestinal absorption rate of adults and consumption of these bivalves by children may predispose them to Pb exposure.

INTRODUCTION

A surveillance study on lead (Pb), cadmium (Cd) and mercury (Hg) in bivalves harvested from fresh water and seawater provided needed data for safeguarding the health of the nation. *Talaba* (*Ostrea malabonensis*, F.), *tahong* (*Perna viridis*, L.), *halaan* (*Arca* spp.) and *tulya* (*Corbicula manilensis*, P.) are among the bivalves that are commonly eaten by the Filipinos. The first three grow in seawater and the last in fresh water. The feeding habits of these bivalves, i.e. filter feeding, predispose them to accumulate heavy metals in their system. Bivalves that are harvested from polluted seashores, lakes or rivers are highly likely to contain heavy metals.

The hazard of the presence of heavy metals in food has long been recognized (Davis, 1966; Underwood, 1971, 1973; Birke *et al.*, 1972; Sommers, 1974; Neathery & Miller, 1975). The metals which are known to be toxic can be manifested at various stages in the food chain commencing from the raw produce up to the finished product. In the marine food chain, metals such as mercury, lead, cadmium, chromium, cobalt and arsenic have been widely investigated (Klein & Goldberg, 1970; Won, 1973; Kapauan, 1973; Childs & Gaffke, 1974; Gomez & Markakis, 1974; Williams, *et al.*, 1976; Zook, *et al.*, 1976; Domingo, L. E. & Luis, E. S. (unpublished); Mabesa *et al.*, 1985).

The capability of bivalves or molluscs to undergo bioaccumulation of heavy metals from their habitat has heightened the need to investigate these food sources in terms of their ability to accumulate specific heavy metals from a defined environment and the need for various methods of reducing body tissue burdens, e.g. depuration (Fowler, *et al.*, 1975; Richardson, *et al.*, 1975; Pentreath, 1976; Ray & Tripp, 1976; George & Coombs, 1977; Janssen & Scholz, 1979; Lakshmanan & Nambisan, 1979; Watling, 1983; Ray, 1984; Teskeredzie, 1984; Rosell, 1985). Further, the aforementioned capability of molluscs to accumulate metals had made possible the use of these animals as biological indicators of metal pollution in lakes, rivers and seashores (Darracott & Watling, 1975; Philipps, 1977; Leonzio, *et al.*, 1981; Prina *et al.*, 1982; Cooper *et al.*, 1983; Shaikh & Smith, 1984).

It had also been established that metals such as mercury, cadmium and lead can elicit physiological abnormalities in marine organisms (Valee & Ulmer, 1972). The lethal toxicity of these heavy metals in molluscs was found

TABLE 1
Pb, Cd and Hg Contents of Bivalves as Reported in Published Literature

Sample	*Place*	*Metal content (ppm)*			*Reference*
		Pb	*Cd*	*Hg (Total)*	
Short-neck clam	Tokyo Bay	0·18	0·09	0·034	Yasuno *et al.* (1977)
Short-neck clam	Tokyo Bay	0·20	0·06	0·055	Hori *et al.* (1978)
Blue mussel	Sweden			0·046	Ohlin & Voz (1978)
Oyster	Port Davey, SW-Tasmania	0·2–2·0	0·15–0·25		Thomson (1979)
Mussel		0·3–4·1	0·16–0·22		
Short-neck clam	Tokyo Bay	0·13	0·04	0·10	Hori *et al.* (1980)
Oyster	New Zealand				Winchester & Keating (1980)
Farmed			20		
Wild			46		
Clam (*M. mercenaria*)	Buzzards Bay Massachusetts	1·86	1·16		Genest & Hatch (1981)
Mussel (*M. edudis*)	Corio Bay, Vic. Australia	1·2–9·7	9·8–5·3		Smith *et al.* (1981)
Mussel (*M. edudis*)	Southeastern Australia	1·68–4·15	0·39–0·63		Wootton & Lye (1982)
Oyster (*C. virginica*)	St. Louis Bay Mississippi	<0·5	1·61	0·074	Lytle & Lytle (1982)
Clam (*R. cuneata*)			<0·05		
Oyster (*C. magaritacea*)	Southern African Coast	0·01–0·53	<0·1–2·6		Watling & Watling (1982)
Mollusc					
(*C. conchoiepos*)	Region V, Chile		0·110	trace	Chiang & Nunez (1983)
(*M. donacium*)	Region V, Chile		0·45	trace	
Mussel[a]	Adriatic Sea Italy	0·45–2·03	0·065–0·56		Crisetig *et al.* (1984)
Oyster (*S. Curculata*)	Dampier, West Australia	1·7			Talbot (1985)
Mussel (*D. viridis*)	Batan, Aklan Philippines	nd	nd	10[b]	Rosell (1985)

[a] μg/kg, wet wt. basis.
[b] ppb, wet wt. basis.
nd = non-detectable.

to vary with the species (Ekanath & Menon, 1983) and is greatly influenced by the form of the metal, environmental factors, and state of the marine organism (Bryan, 1976).

In view of the above, many reports have been published on the metal contents of bivalves or shells popularly consumed around the world. Examples of data reported for Pb, Cd and Hg are shown in Table 1. The values presented are assumed to be on a dry weight basis unless specified.

The study was conducted with the following specific objectives:

(1) To determine the levels of toxic heavy metals (Pb, Cd and Hg) present in *talaba*, *halaan*, *tahong* and *tulya*.

(2) To establish the background levels and/or degree of metal pollution

in the eco-system from where the *talaba*, *halaan* and *tahong* were harvested.

(3) To investigate the influence of area and season (dry, cold and wet season) on the accumulation of metals by bivalves.

MATERIALS AND METHODS

Sample preparation

Seawater bivalves such as *talaba* (oyster), *tahong* (green mussels) and *halaan* were either purchased directly from the culture farms in Bacoor and Binakayan, Cavite or from the Baclaran and Paco public market.

The location and schedule of sampling were as follows:

Sample	*Dry Season* (*March–June*)	*Wet Season* (*July–Oct.*)	*Cold Season* (*Nov.–Feb.*)
Talaba	BFAR Culture Farm (Binakayan)	BFAR Culture Farm (Binakayan)	BFAR Culture Farm (Binakayan)
Tahong	Private Culture Farm (Bacoor)	Private Culture Farm (Bacoor)	Private Culture Farm (Bacoor)
Halaan	Baclaran Public Market	Paco Public Market	Paco Public Market
Tulya	Baclaran Public Market	Baclaran Public Market	Baclaran Public Market
Seawater	BFAR	BFAR	BFAR

Freshly harvested or purchased *talaba* or *tahong* samples were immediately cleaned by brushing with plastic brushes under running water. The cleaned bivalves were allowed to drain to remove excess water for at least 10 min. The *tulya* and *halaan* which were bought from the market were rinsed in running water and also allowed to drain for at least 10 min.

The *talaba* meat was obtained from the clean bivalve by prying the shell lids with a pointed metal, i.e. icepick or screw driver. The clean *tulya*, *halaan* and *tahong* were cooked separately in boiling kettles for at least 15 min or until the bivalves opened. The juices that came out from the bivalves that opened on cooking were collected and the total volume noted. All the bivalve's meat or juice were immediately prepared and sampled for analysis or stored in the freezer for future analysis.

Quantitative assay

Lead and cadmium

Lead and cadmium were determined by atomic absorption spectrophotometry. The solution for Pb and Cd determination for both the meat and juices of

Weigh 50 g sample in 250 ml beaker

↓

Oven dry at 100°C overnight

↓

Transfer to muffle furnace which is initially set at 150°C

↓

After 1 h, increase in increments of 5°C until 400°C is reached

↓

Heat for 18 h in furnace

↓

Remove from furnace and cool in a desiccator

↓

Add 5 ml of distilled water and 1 ml conc. H_2SO_4

↓

Further add 5 ml distilled water and 1 ml conc. H_2SO_4

↓

Add 5 ml 30% H_2O_2 and cover with a watch glass

↓

Heat on a hot plate to evaporate water

↓

Continue heating until H_2SO_4 fumes appear

↓

Cool then add 5 drops 30% H_2O_2

↓

Heat until H_2SO_4 fumes appear

↓

Repeat process until digestion solution becomes colorless; increasing volume of 30% H_2O_2 until a total volume of 83·3 ml 30% H_2O_2 is consumed

↓

Evaporate H_2SO_4 to near dryness

↓

Cool then add 10 ml conc. HCl

↓

Heat to near dryness

↓

Add 10 ml of 2M HCl

↓

Heat for 2 minutes

↓

Remove beaker from hot plate

↓

Filter using Whatman No. 42

↓

Wash residue three times with hot 2M HCl

↓

Cool and dilute to 50 ml with further 2M HCl

↓

Store in polyethylene bottles

↓

AAS Determination

Fig. 1. Schematic diagram of digestion procedure for Pb and Cd determination in the bivalves.

the bivalves were prepared by ashing at 400°C with the use of 20% H_2SO_4 as ashing aid. The digestion was completed by wet oxidation of the residue with sulfuric acid and 30% H_2O_2 (Noller & Bloom, 1978).

The solutions for Pb and Cd determination in seawater were prepared by the 'Nitric Acid Digestion' described in the *Standard Methods for Examination of Water and Wastewater*, (15th edn), 1980.

Schematic diagrams of the digestion procedures adopted are shown in Figs 1 and 2.

Mercury

Mercury was determined as total mercury with the use of a Perkin-Elmer Mercury Analyzer Model MAS-50A. Solutions for total mercury determination in bivalves were prepared by solubilization at 50°C with concentrated H_2SO_4, oxidized with 6% $KMnO_4$ solution and reduced with stannous chloride solution (Thorpe, 1971). The samples of seawater were digested at 95°C for 2 h with concentrated HNO_3 in the presence of 5%

Mix sample
↓
Transfer 100 ml to beaker
↓
Add 5 ml conc. HNO_3 and cover with a watch glass
↓
Place beaker on a hot plate; bring to a slow boil
↓
Evaporate until 15–20 ml remain
↓
Add 5 ml conc. HNO_3
↓
HEAT
↓
Repeat process until a light-colored solution is obtained
↓
Add 2 ml conc. HNO_3 and warm to dissolve residue
↓
Wash down the beaker walls and watch glass with distilled water
↓
Filter the sample to remove silicate and other insoluble material
↓
Transfer filtrate to 100 ml volumetric flask and dilute to the mark
↓
Mix thoroughly
↓
Store in polyethylene bottles
↓
AAS Determination

Fig. 2. Nitric acid digestion of seawater for Pb and Cd determination.

$KMnO_4$ and 5% potassium persulfate solutions and reduced with 10% $SnCl_2$ in 5% H_2SO_4 (APHA-AWWA-WPCF, 1980).

RESULTS AND DISCUSSION

Lead content

The average total Pb contents of *talaba*, *tahong*, *halaan*, *tulya* and the seawater during the dry, wet and cold seasons in 1983–1985 are shown in Table 2. The values shown represent the average of sampling and analysis for two consecutive years. The total metal contents for *tahong*, *halaan* and *tulya* were the sum of those contained in the meat and the juice collected after cooking.

The Pb content in the bivalves was highest in the *halaan* during the dry season (2·24 ppm), in *tahong* and *halaan* during the wet season (1·21 ppm) and in *tahong* during the cold season (1·24 ppm). It could be noted that only *halaan* during the dry season exceeded the statutory limit for Pb set by the FAO, 2 ppm.

Talaba and *tahong* were harvested from clustered strings hanging in the seawater around 500 m from the shore. On the other hand, *halaan*, although bought from public markets, were reported to have been picked along the seashore where they are often buried in the sand. Likewise, the *tulya* was bought from public markets; however, they were known also to be picked along the shore of Laguna Lake buried in the sand. The similar habitation of *halaan* and *tulya* can partially explain their having higher Pb contents during the dry season.

The Pb content of *talaba* and *tahong* remained more or less constant throughout the year. The Pb content in *halaan* decreased from dry to wet

TABLE 2
The Average Total Pb Content in Bivalves and Seawater during the Dry, Wet and Cold Season, 1983–1984

Sample	*ppm total Pb (wet weight basis)*		
	Dry season	*Wet season*	*Cold season*
Talaba	0·68	0·64	0·64
Tahong	1·22	1·21	1·24
Halaan	2·24	1·21	1·09
Tulya	1·64	0·64	0·65
Seawater	0·66	1·16	1·06

TABLE 3
Analysis of Variance on the Total Pb Content

Source	*Degree of freedom*	*Sum of squares*	*Mean square*	*F ratio*
Total	29	12·36		
Sample	4	2·49	0·62	1·40
Season	2	0·75	0·38	0·84
Sam X Sea	8	2·45	0·31	0·68
Error	15	6·68	0·45	

F0·05 (4, 15) = 3·06.
F0·05 (2, 15) = 3·68.

then cold season. *Tulya* had a pronounced decrease in Pb content only from dry to wet season. The Pb content of the seawater had an increase–decrease pattern in going from dry, wet to cold season.

Two way analysis of variance revealed that the variations noted above were insignificant at the 5% confidence level (Table 3).

Comparison of the results obtained in the present study with those reported in the literature (Table 1), on the Pb content of bivalves, would show that higher Pb values were obtained by previous authors with some exceeding the 2 ppm level set by the FAO. For example, the highest Pb content was obtained in mussels, 9·7 ppm, from Corio Bay, Victoria, Australia (Smith *et al.*, 1981). However, the mussels from Southeastern Australia had a higher limit of 4·15 ppm Pb (Wootton & Lye, 1982). Clams and oysters were also reported to contain Pb but at a lower level. Pb was found non-detectable in *tahong* or Philippine mussel harvested from Batan, Aklan (Rosell, 1985).

The reported background level of Pb in seawater is 4 ppb (Parker, 1972). The seawater in Batan, Aklan, collected on 13 September 1982 and 30 January 1983 had Pb levels of 600 ppb and 200 ppb, respectively (Rosell, 1985). Based on the average values, the range obtained in the present study was 660 to 1,160 ppb during the 1983–1984 sampling periods. These differences could be due to the degree of pollution experienced by the areas from where the seawater was obtained. Logically, the seashore in Cavite, which is a part of Manila Bay, would be more polluted than the seashore in Batan, Aklan, mainly due to the greater industrial activity in the area.

The possible bioaccumulation of Pb could be addressed only to *talaba* and *tahong* as these bivalves thrive in seawater and were harvested from the same area. No water samples were taken from Laguna Lake. On average, the accumulation factors during the dry season for *tahong* and *talaba* were 0·85 and 0·03, respectively. If it is assumed that the *halaan was* harvested from the same general area, it would have an accumulation factor of 2·39 during the dry season. In the wet and cold season, almost no accumulation occurred.

Bioaccumulation of Pb conducted in a simulated environment with the addition of known amounts of the metal showed that bivalves can accumulate Pb from 13 to 45-fold which was largely dependent on the species (Watling, 1983). Thus, it can be averred that the level of Pb along the shoreline of Cavite has not yet reached a saturation point where bioaccumulation of the metal by bivalves can be considered as hazardous to man as well as to marine life.

Cadmium content

The average total Cd contents of the four bivalves studied including the seawater during the dry, wet and cold season in 1983–1985 are shown in Table 4. The same experimental setting was followed as in the lead content. On average the Cd contents present in the bivalves were low, ranging from 0·06 to 0·66 ppm in *tulya* and *tahong*, respectively. As in the case of Pb, the Cd content of *talaba* remained more or less constant all year round; the same trend was also exhibited by *halaan*. Cd content of *tahong* (0·66 ppm) was highest during the wet season. *Tulya* exhibited a similar pattern of changes in Cd content as in Pb content. However, in contrast to the Pb content, the Cd content of seawater remained more or less constant. Further, *talaba* and *tahong* had accumulation factors of 2·5 and 7·25, respectively, during the wet season. Reported bioaccumulation of Cd in marine animals ranges from 2·4 to 11 (Watling, 1983).

The background level of Cd in seawater was found to be 0·03 to 0·06 ppb (Parker, 1972). However, for seawater samples collected on 13 September 1982 and 30 January 1983, the Cd levels from Batan, Aklan, were both 40 ppb (Rosell, 1985). In the present study, the Cd levels of the seawater from Cavite ranged from 70 to 100 ppb.

TABLE 4

The Average Total Cd Content in Bivalves and Seawater during the Dry, Wet and Cold Season, 1983–1985

Sample	*ppm total Cd (wet weight basis)*		
	Dry season	*Wet season*	*Cold season*
Talaba	0·23	0·28	0·26
Tahong	0·12	0·66	0·15
Halaan	0·12	0·12	0·17
Tulya	0·13	0·06	0·06
Seawater	0·10	0·08	0·07

TABLE 5
Analysis of Variance on the Total Cd Content

Source	*Degree of freedom*	*Sum of squares*	*Mean square*	*F ratio*
Total	29	1·12		
Sample	4	0·26	0·06	1·98
Season	2	0·06	0·03	0·96
Sam X Sea	8	0·31	0·04	1·20
Error	15	0·49	0·03	

F0·05 (4, 15) = 3·06.
F0·05 (2, 15) = 3·68.

Also, as in the case of Pb content in the bivalves and seawater, variations of Cd due to the sample and the season were found insignificant (Table 5).

It can also be claimed from the above results that the level of Cd along the shoreline of Cavite has not yet reach a saturation point where bioaccumulation of the metal by bivalves can endanger the safety of man.

Mercury content

The average total mercury content of the bivalves and seawater during the dry, wet and cold season in 1983–1985 are shown in Table 6.

The Hg content of the bivalves was highest in *halaan* for both dry and wet season, 9·87 ppb and 11·68 ppb, respectively. Like the Pb content, *tahong* (9·24 ppb) exhibited the highest Hg content during the cold season. The Hg content of *talaba*, *tahong* and *tulya* had a decrease–increase pattern in going from dry, wet to cold season. A pronounced decrease in Hg content was observed only from dry to wet season. However, Hg content of *halaan* had a contrasting pattern of increase–decrease from dry, wet to cold season.

TABLE 6
The Average Total Hg Content in Bivalves and Seawater during the Dry, Wet and Cold Season, 1984–1985

Sample	*ppb total Hg (wet weight basis)*		
	Dry season	*Wet season*	*Cold season*
Talaba	4·45	0·62	3·12
Tahong	9·50	3·59	9·24
Halaan	9·87	11·68	7·31
Tulya	9·04	1·05	2·36
Seawater	1·80	1·80	2·6

The Hg content of the seawater remained constant for the dry and wet season, 1·8 ppb, and increased during the cold season, 2·6 ppb.

Comparison of the results obtained in the present study with those reported in Table 1 on the total Hg content of bivalves would show that higher Hg values had been reported in the literature, although not exceeding the 0·5 ppm Hg level.

The highest Hg content had been reported in clams (100 ppb) from Tokyo Bay (Horri *et al.*, 1980). Likewise, oysters from St. Louis Bay, Mississippi, and blue mussels from Sweden were also reported to contain Hg at 74 ppb (Lytle & Lytle, 1982) and 46 ppb (Ohlin & Voz, 1978), respectively. Lower levels of Hg were reported for Philippine mussels from Aklan, 10 ppb (Rosell, 1985).

The reported background level of Hg in seawater is 0·03 ppb (Parker, 1972). For seawater samples collected in Batan, Aklan, on 13 September 1982 and 30 January 1983, the Hg levels were non-detectable (Rosell, 1985). Based on the average values obtained in the present study, the Hg levels of the seawater from Cavite ranged from 1·8 ppb to 2·6 ppb. As in the Pb and Cd content of the seawater, these differences could be due to the seashore in Cavite which is a part of Manila Bay, being more polluted than in Batan, Aklan, mainly because of the greater industrial activity in the area.

On average, the bioaccumulation factors in *tahong* and *talaba* of Hg for the dry season were 4·28 and 1·47, respectively. Again, if it is assumed that the *halaan* was also harvested from the same area, it would have an accumulation factor of 4·48.

In contrast with the Pb and Cd content, the average total Hg content of the bivalves and seawater varied significantly with the sample and the season. Statistical analyses of the data obtained are shown in Table 7. The

TABLE 7
Analysis of Variance on the Total Hg Content

Source	*Degree of freedom*	*Sum of squares*	*Mean square*	*F ratio*
Total	29	428·32		
Sample	4	249·27	62·32	36·25*
Season	2	51·84	25·92	15·08*
Sam X Sea	8	101·42	12·68	7·37*
Error	15	25·79	1·72	

F 0·05 (4, 15) = 3·06.
F 0·05 (2, 15) = 3·68.
* Significant.

significant variations would imply that Hg content in the bivalve is dependent on the species and the season during which they are harvested. The results further show that pollution, by Hg, of Manila Bay has not yet reached an alarming level.

Recovery study

The sample digestion procedure adopted for the determination of Pb and Cd in the meat and juice of the bivalves combined the dry ashing and wet digestion technique (Noller & Bloom, 1978). The procedure offered a big advantage over that of either purely dry ashing or wet digestion. The initial dry ashing step ensured that most of the organic constituents were removed slowly with the minimum possibility of incurring chemical and mechanical losses. This was attained by heating the oven-dried sample in the furnace at an initial temperature of 150°C and programming to reach a final temperature of 400°C within 2 h. The final wet ashing or destruction of the residual organic matter was affected by the action of peroxymonosulphuric acid formed from hot sulfuric acid and hydrogen peroxide. This procedure was applied by the aforementioned authors over a wide range of food products, e.g. powdered milk, pet food, baby food and cow's milk including two NBS Standard Reference Materials. Other digestion methods employed for the determination of Cd and Pb require the use of an organic solvent as an isolation and/or concentration step. In the investigation conducted in this laboratory, procedures that required solvent extraction were avoided due to

TABLE 8
Mean % Recovery of Lead (Pb) in the Meat and Juice of Fresh Bivalves and the Seawater during the Dry, Wet and Cold Season of the Year, 1984 and 1985

Sample	*Mean % recovery (Pb)*		
	Dry	*Wet*	*Cold*
Meat			
Talaba	93·7	100·9	92·2
Tahong	100·6	91·3	87·2
Halaan	99·4	94·4	96·8
Tulya	96·8	88·4	95·8
Juice			
Tahong	93·5	92·8	96·7
Halaan	93·8	96·0	93·7
Tulya	89·2	88·6	99·2
Seawater	96·4	97·5	94·7

TABLE 9
The % Recovery of Cadmium (Cd) in the Meat and Juice of Fresh Bivalves and Seawater during the Dry, Wet and Cold Season of the Year, 1984 to 1985

Sample	*Mean % recovery (Cd)*		
	Dry	*Wet*	*Cold*
Meat			
Talaba	96·9	90·9	94·3
Tahong	97·1	93·0	93·2
Halaan	94·8	94·6	92·8
Tulya	98·0	90·6	92·2
Juice			
Tahong	96·4	93·7	97·7
Halaan	96·0	93·5	96·8
Tulya	92·9	94·0	101·0
Seawater	94·0	98·6	103·0

the previous experience that mechanical losses are easily incurred in addition to the difficulty of attaining good recovery.

The 'Nitric Acid Digestion' (APHA-AWWA-WPCF, 1980) applied in the determination of Pb and Cd in seawater was also found simple and convenient. Further, it did not require the use of organic solvents for extraction which are often expensive and hard to obtain.

TABLE 10
The % Recovery of Total Hg in the Meat and Juice of Fresh Bivalves and the Seawater during the Dry, Wet and Cold Season of the Year, 1984 and 1985

Sample	*% Recovery, Total Hg*		
	Dry	*Wet*	*Cold*
Meat			
Talaba	108·0	94·5	98·1
Tahong	97·5	94·8	94·7
Halaan	97·7	96·3	95·1
Tulya	96·6	92·6	97·3
Juice			
Tahong	100·5	100·0	100·2
Halaan	97·1	94·2	95·5
Tulya	102·5	93·8	94·9
Seawater	106	96	100·9

The applicability of the digestion procedures adopted for the determination of Pb and Cd in bivalves and seawater mentioned above was demonstrated by the good recoveries of Pb and Cd in the samples examined. As shown in Table 8, the mean per cent recovery of Pb ranged from 87·2 to 100·9%, 88·6 to 99·2% and 94·7 to 97·5% in the meat and juice of bivalves and seawater, respectively. For Cd, the corresponding per cent recovery ranged from 90·6 to 97·1%, 92·9 to 101% and 94 to 103% in the same samples, respectively (Table 9).

The digestion procedures adopted for the determination of total Hg (Thorpe, 1971 and APHA-AWWA-WPCF, 1980) also gave good recoveries (Table 10). The per cent recovery for Hg ranged from 92·6 to 108%, 93·8 to 102% and 96 to 106% in the meat and juice of bivalves and seawater, respectively.

SUMMARY AND CONCLUSION

The average concentrations of Pb, Cd and Hg in the bivalves (*talaba*, *tahong*, *halaan* and *tulya*) ranged from 0·64 to 2·24 ppm, 0·06 to 0·66 ppm and 0·62 to 11·68 ppb, respectively. However, the variations due to sample and season of the Pb and Cd contents in the bivalves were found insignificant. In contrast, the Hg content of the bivalves varied significantly with the sample and the season. The same trends were also noted in the Pb, Cd and Hg contents in the seawater which ranged from 0·66 to 1·16 ppm, 0·07 to 0·10 ppm and 1·8 to 2·6 ppb, respectively.

Bioaccumulation factors of the three metals in the different bivalves were calculated. The low average concentrations of the metals in the bivalves were consistent with the low accumulation factors obtained.

The overall findings indicated that the levels of Pb, Cd and Hg along the shoreline of Cavite have not yet reached a saturation point where bioaccumulation of the metals by bivalves can be considered as hazardous to man as well as to marine life. However, caution should be taken if these bivalves are to be considered for feeding children. For example, the FAO/WHO recommendation for Pb is 5 μg/kg body weight/day for adults. Children have about five times the gastrointestinal absorption rate of adults and consumption of these bivalves by children may predispose them to Pb exposure.

The combined dry ashing and wet digestion technique adopted for the sample preparation prior to quantification of the metals by atomic absorption was found very satisfactory. The mean per cent recoveries of Pb, Cd and Hg were all above 85%.

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