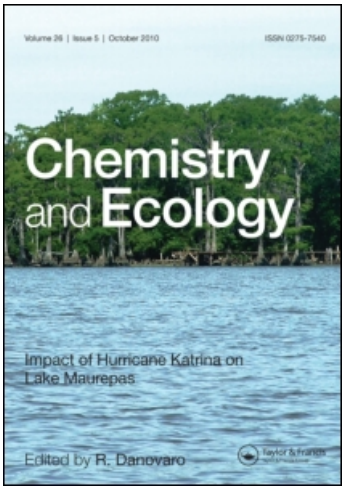

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Wen-Lung Wu[a]
[a] Institute of Zoology, Academia Sinica, Taipei, Taiwan, R.O.C.

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ARSENIC IN TWO TAIWANESE BIVALVES, *CRASSOSTREA GIGAS* (THUMBERG) AND *MERETRIX LUSORIA* RÖDING

WEN-LUNG WU

Institute of Zoology, Academia Sinica, Taipei, Taiwan 115, R.O.C.

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Arsenic, one of the most toxic elements, is present naturally in marine organisms at much higher concentrations than in terrestrial organisms. The arsenic contents in two marine bivalves, *Crassostrea gigas* (Thumberg) and *Meretrix lusoria* Röding, from Taiwan were investigated. The total arsenic content of *C. gigas* (33.7–60.5 μg g^{-1}) is higher than that of *M. lusoria* (30.2–34.6 μg g^{-1}). These two bivalves from Lu-kang contain more arsenic in soft tissues than specimens from other areas (significant at 1%, t-test). On the other hand, samples from Pen-hu contain less arsenic than those from other areas (significant at 5%). The arsenic contents of other Indo-Pacific bivalves are also given for comparison.

KEY WORDS: Arsenic, bivalves, Taiwan.

INTRODUCTION

Arsenic is found in the environment as the sulphides realgar and orpiment, in the mineral arsenopyrites (FeSAs), as arsenides and sulpharsenides of metals, as the oxide, and as arsenates (Phillips, 1990). Arsenous oxide (As_2O_3) is the most important arsenic compound employed by industry: it is present in paints, glass, alloys, medicinal formulations, electronic components and wood preservatives (Lederer and Fensterheim, 1983), and is also used as a food additive and in pesticides.

About 30,000 tonnes of arsenic are released annually into the environment from both industrial and agricultural sources (Ferguson and Gavis, 1972; Andreae and Froelich, 1984; Johnson, 1987; Reierson, 1988). The aquatic environment is important in the global cycling of arsenic (Ferguson and Gavis, 1972; Wood, 1974), and arsenic concentrations in the biota of aquatic ecosystems are much higher than those found in organisms inhabiting the terrestrial environments (Lunde, 1977). It is, in any event, of significant toxicity to aquatic biota in its inorganic forms. Inorganic arsenic is also of very significant acute toxicity to mammals, including man. Several lesser symptoms of arsenic toxicity also exist, such as damage to the mucous membranes, development of cardiac abnormalities, and peripheral nervous system disturbances.

Crassostrea gigas and *Meretrix lusoria* are the most important edible aquatic bivalves in Taiwan (Wu, 1980). There are no other reports concerning the arsenic content of aquatic organisms from Taiwan. This paper will focus on the arsenic

content in these two important Taiwanese species and will compare the findings for other bivalves in the Indo-Pacific region.

MATERIALS AND METHODS

Crassostrea gigas and *Meretrix lusoria* were collected from four locations in Taiwan (Fig. 1). At least 10 to 30 live samples of each species were dissected and separated into gill, mantle, adductor muscles, visceral mass (Tab. I) and shell. The dissected tissues were dried in an oven at 60°C for three days. To 0.5 g of dry sample, 14N nitric acid was added and the sample then digested at 240°C for four hours. The acidified samples were then added to 10% potassium iodide and concentrated hydrochloric acid. Inorganic arsenic content of the solutions were analyzed in triplicate

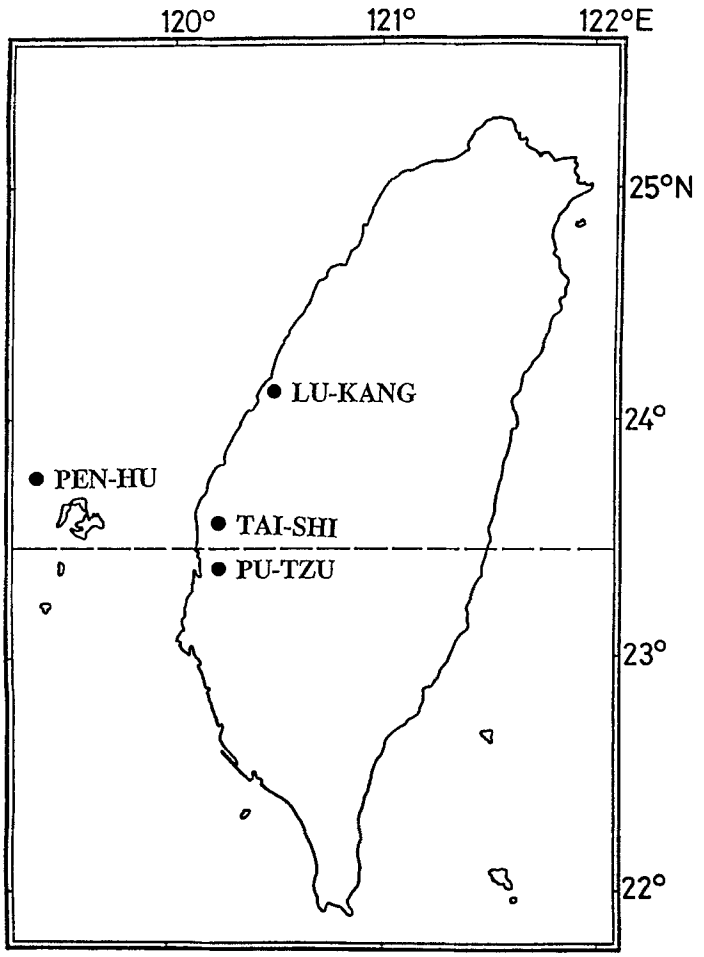

Figure 1 The Sampling locations (solid circles) from Taiwan.

Table I Weight and percentage of soft tissues from *Crassostrea gigas* and *Meretrix lusoria*.

Tissues	*Crassostrea gigas*		*Meretrix lusoria*	
	Weight (g)	*Percentage(%)*	*Weight (g)*	*Percentage (%)*
Gill	0.4922* (0.2379)	14.18	1.1405 (0.4915)	18.32
Mantle	0.8336 (0.3783)	24.02	1.2947 (0.9045)	20.80
Adductor muscles	0.9989 (0.4021)	28.80	1.0490 (0.7336)	16.85
Visceral mass	1.1452 (0.6775)	33.00	2.7396 (1.4849)	44.03
Total	3.4699	100.00	6.2238	100.00

*: Data shown as mean (standard deviation).

by atomic absorption spectrophotometry (Hitachi 8000, Hitachi Ltd., Tokyo, Japan).

RESULTS AND DISCUSSION

Inorganic Arsenic Contents

The inorganic arsenic contents from different soft tissues in *C. gigas* are summarized in Table II. In general, the inorganic arsenic content of the visceral mass is higher than those of other soft tissues such as gill, mantle and adductor muscles. The inorganic arsenic content of shells is higher than that of all soft tissues, except for samples collected from Pen-Hu (Tab. II).

Table II Inorganic arsenic contents ($\mu g\ kg^{-1}$ wet-weight) in *Crassostrea gigas*.

Location	*Soft tissues*				*Shells*	
	Gill	*Mantle*	*Adductor muscles*	*Visceral mass*	*Left*	*Right*
Lu-kang	68.35* (33.73)	120.99 (26.47)	125.18 (8.98)	201.02 (61.43)	**	**
Tai-shi	82.72 (13.36)	88.97 (23.33)	111.79 (44.00)	146.16 (49.03)	349.91 (99.43)	213.88 (97.67)
Pu-tzu	72.29 (30.61)	69.61 (22.24)	76.78 (26.95)	123.97 (41.04)	277.85 (65.75)	259.07 (79.32)
Pen-hu	62.25 (27.84)	55.39 (11.74)	48.26 (20.35)	143.29 (89.67)	77.61 (45.03)	55.58 (31.32)

*Data shown as mean (standard deviation).
**No measurements.

Table III Inorganic arsenic contents (μg kg^{-1} wet-weight) in *Meretrix lusoria.*

Location	*Soft tissues*				*Shells*	
	Gill	*Mantle*	*Adductor muscles*	*Visceral mass*	*Left*	*Right*
Lu-kang	113.5*	131.00	47.99	170.20	119.60	109.13
	(39.43)	(49.41)	(21.76)	(91.81)	(77.64)	(76.75)
Tai-shi	157.02	138.86	93.57	118.56	353.34	344.36
	(35.64)	(25.89)	(18.98)	(23.01)	(29.54)	(23.79)
Pu-tzu	168.69	162.28	78.92	150.63	326.77	321.70
	(44.68)	(33.01)	(8.98)	(26.81)	(30.98)	(48.12)

*: Data shown as mean (standard deviation).

The inorganic arsenic content of *Crassostrea gigas* collected from Lu-kang are much higher than those from other areas (Tab. II and IV), while specimens from Pen-hu contain much less. *C. gigas* is cultured off-shore of Pen-hu (Wu, 1991) where there is no pollution and less arsenic is accumulated in soft tissues and shells.

The inorganic arsenic content of different soft tissues of *Meretrix lusoria* are summarized in Table III. The inorganic arsenic content of gill tissues is higher than those of other soft tissues, except for samples from Lu-kang. In general, the inorganic arsenic content in samples from the Pu-tzu area is slightly higher than those collected from Lu-kang and Tai-shi. The content of shells is also higher than in other soft tissues, except in samples from Lu-kang (Tab. III).

Total Arsenic Contents

In a review paper on arsenic contents of aquatic organisms, Phillips (1990) suggested that arsenic contents should be cited originally on a wet weight basis, and a dry weight ratio of six used for conversion. Shiomi *et al.* (1984) reported that in

Table IV Inorganic arsenic contents (μg kg^{-1}) and total arsenic contents (μg g^{-1}) in *Crassostrea gigas.*

Location	*Wet-weight inorganic Arsenic*		*Dry-weight inorganic Arsenic*		*Total Arsenic*	
	Soft tissues	*Shell*	*Soft tissues*	*Shell*	*Soft tissues*	*Shell*
Lu-kang	141.13[1]	*	846.78[2]	*	60.48[3]	*
Tai-shi	113.52	281.90	681.12	1691.40	48.65	120.81
Pu-tzu	89.99	268.46	539.94	1610.76	38.57	115.05
Pen-hu	83.31	66.60	499.86	399.60	35.70	28.54

*: No measurement.
1: Data from Table II with conversion from Table I.
2: Data converted from wet-weight based on inorganic arsenic, wet:dry weight ratio of 6 used for conversion (Phillips, 1990).
3: Data from dry-weight inorganic arsenic, only 1.4% of the total arsenic content for conversion (Shiomi, *et al.*, 1984).

M. lusoria only 2.5% and in *C. gigas* only 1.4% of total arsenic occurs in inorganic form. The wet weight and dry weight values of inorganic and total arsenic contents in both species have been calculated on this basis and summarized in Tables IV and V. The difference between total arsenic and inorganic arsenic is considered to represent organic arsenic. The total arsenic content in soft tissues of *C. gigas* is in the range 35.7–60.5 μg g^{-1} dry weight, and of *M. lusoria* 30.2–34.6 μg g^{-1} dry weight. *Crassostrea gigas* from Lu-kang contains much higher arsenic levels than those from the other three areas where their arsenic contents are at about the same level (Tab. IV).

Shinagawa *et al.* (1983) reported that inorganic arsenic comprised less than 5.0% of the total arsenic in marine organisms, while Shiomi *et al.* (1984) reported that less than 2.5% of total arsenic occurs as inorganic arsenic. It is notable that the toxicity of arsenicals is considered to be high, in the order: inorganic arsenic (III) > inorganic arsenic (V) > organic arsenic. Since organic arsenicals showed a lower toxicity

Table V Inorganic arsenic contents (μg kg^{-1}) and total arsenic contents (μg g^{-1}) in *Meretrix lusoria.*

Location	*Wet-weight inorganic Arsenic*		*Dry-weight inorganic Arsenic*		*Total Arsenic*	
	Soft tissues	*Shells*	*Soft tissues*	*Shell*	*Soft tissues*	*Shell*
Lu-kang	139.97[1]	114.37	785.82[2]	686.22	31.43[3]	27.45
Tai-shi	125.61	348.85	753.66	2093.10	30.15	83.72
Pu-tzu	144.26	324.24	865.56	1945.44	34.62	77.82

1: Data from Table III with conversion from Table I.
2: Data converted from wet weight based on inorganic arsenic wet-weight, wet:dry weight ratio of 6 used for conversion (Phillips, 1990).
3: Data from inorganic arsenic dry-weight, only 2.5% of the total arsenic contents for conversion (Shiomi, *et al.*, 1984).

Table VI Comparison of total arsenic content (μg g^{-1} dry weight) reported from the Indo-Pacific bivalves.

Species	*Location*	*Arsenic Content*	*Authors*
Crassostrea gigas	New Zealand	10–13	Winchester and Keating, 1980
Saccostrea glomerata	New Zealand	7.2–22.0	Winchester and Keating, 1980
Tridacna maxima	GBR+	953 – 1004 (kidney)	Benson and Summons, 1981
Tridacna derasa	GBR	455 – 1025 (kidney)	Benson and Summons, 1981
Hippopus hippopus	GBR	481 – 561 (kidney)	Benson and Summons, 1981
Tapes japonica	Japan	40.8 (soft tissue)	Shiomi *et al.*, 1984
Mytilus edulis	Japan	14.4 (soft tissue)	Shiomi *et al.*, 1984
Patinopecten yessoensis	Japan	6.6 (muscle)	Shiomi *et al.*, 1984
Patinopecten yessoensis	Japan	26.4 (liver)	Shiomi *et al.*, 1984
Crassostrea gigas	Japan	25.2 (soft tissue)	Shiomi *et al.*, 1984
Meretrix lusoria	Japan	16.8 (soft tissue)	Shiomi *et al.*, 1984
Crassostrea gigas	Taiwan	35.70–60.48 (soft tissue)	This paper
Crassostrea gigas	Taiwan	28.54–120.80 (shell)	This paper
Meretrix lusoria	Taiwan	30.15–34.62 (soft tissue)	This paper
Meretrix lusoria	Taiwan	27.45–83.72 (shell)	This paper

+: Great Barrier Reef, Australia.

than inorganic ones, it is concluded that *C. gigas* and *M. lusoria* from the Taiwan area can be eaten safely as food, even though they contain high levels of total arsenic. Total arsenic contents in marine bivalves from elsewhere in the Indo-Pacific have been documented for a number of species are listed in Table VI. The attachement bivalves, such as *Tridacna* spp., contain much higher arsenic in kidney tissue (Benson and Summons, 1981). The *C. gigas* from New Zealand waters contain less arsenic (Winchester and Keating, 1980). In the present study, *C. gigas* contains slightly higher arsenic than those collected from the Japan area (Shiomi *et al.*, 1984).

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