Bull. Inst. Zool., Academia Sinica **18**(1): 11-20 (1979)

THE OCCURRENCE AND SEASONAL VARIATIONS OF Na, K, Ca, Mg AND HEAVY METALS IN TAIWAN'S OYSTERS AND CLAMS

SHUN-YAO HSU, GUOO-SHYNG WANG

Taiwan Provincial College of Marine Science and Technology, Keelung, Taiwan, Republic of China

and

SEN-SHYONG JENG

Kaohsiung Institute College of Marine Technology, Kaohsiung, Taiwan, Republic of China

(Received February 9, 1979)

Shun-Yao Hsu, Guoo-Shyng Wang and Sen-Shyong Jeng (1979) The occurrence and seasonal variations of Na, K, Ca, Mg and heavy metals in Taiwan's oysters and clams. *Bull. Inst. Zool., Academia Sinica* **18**(1): 11-20. For the purpose of finding out the chemical properties of oysters and clams cultured in Taiwan, the contents of the major elements, Na, K, Ca, Mg and heavy metals, Cd, Cu, Fe, Hg, Ni, Pb and Zn in these shellfishes were investigated. Shucked oysters and marketed clams were collected from 7 stations along the west coast of Taiwan from April 1976 to February 1977. Na and K were measured with a flame photometer, and all other elements were determined with an atomic absorption spectrophotometer. The mean concentrations of Na, K, Ca and Mg were found to be 233, 187, 34.3 and 35.4 mg/100 g in the fresh tissue of oysters, while in the fresh tissue of clams, they were 349, 235, 37.5 and 35.3 mg/100 g, respectively. The one that had the most interesting seasonal variation among these major elements was Na in oysters. It was found that the seasonal changes of Na and glycogen in oysters were almost identical. Hence, it is supposed that sodium might have deep connection with spawning of oysters. The heavy metal concentration in Taiwan's oysters and clams could be divided into two groups. The group which had higher concentration consisted of Zn, Fe and Cu, the mean concentrations in oysters being 120.4, 86.1 and 20.4 ppm, and in clams being 14.9, 136.1 and 5.7 ppm. The other group which had lower concentration consisted of Pb, Ni, Cd and Hg, the mean concentrations in oysters being 1.29, 0.55, 0.11 and 0.01 ppm, and in clams being 1.53, 1.09, 0.09 and 0.02 ppm, respectively. These contents of heavy metals were not higher than the "normal" levels and should not constitute a hazard for consumers. Among the heavy metals investigated, Fe, Cu, Pb and Ni all showed noticeable seasonal changes both in oysters and clams, and the highest contents occurred from May to September. It is speculated that such seasonal changes arise from the fact that there are more available food and more land drainage in summer along the west coast of Taiwan.

It is well known that Na, K, Ca and Mg are the major elements of many organisms. However, there is little information on the occurrence and seasonal variation of these elements in shellfishes. In order to find out the chemical properties of the oysters *Crassostrea gigas* and hard clams *Meretrix lusoria* cultured in Taiwan, these major elements were studied. Although the heavy metal concentrations of the oysters of Taiwan have been reported by Jeng and Huang[5], the seasonal variation of these

Reprint request send to S. S. Jeng.

heavy metals is still not clear. In this investigation, the occurrence and seasonal variation of Cd, Cu, Fe, Hg, Ni, Pb and Zn were also studied.

MATERIALS AND METHODS

Sample and preliminary treatment

Shucked oysters and marketed clams were collected from 7 sampling stations along the west coast of Taiwan from April 1976 to February 1977. The sampling stations were the same as those reported before[8]. Shellfishes collected for proximate composition analysis were also used for major element and heavy metal studies, *i. e.*, the shellfishes were minced and lyophilized, then the dried samples were used for analyses of protein, glycogen and ash; Na, K, Ca and Mg; and Cd, Cu, Fe, Hg, Ni, Pb and Zn.

Analyses of major elements and heavy metals

All samples were first digested by H_2SO_4-HNO_3[1], then determined by the following methods:

Na and K: measured with a flame photometer.

Ca, Mg and Fe: measured with a Varian Model 1000 atomic absorption spectrophotometer

TABLE 1

Sodium, potassium, calcium and magnesium concentrations (mg/100 g fresh tissue) in Taiwan's oysters

Date	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	Mean ± SD
				Na				
1976 Apr. 22	194	103	104	154	355	64	269	178±104
Jun. 28	384	790	449	795	820	343	723	615±213
Sep. 1	117	397	313	356	137	72	472	266±156
Oct. 31	137	44	212	125	93	55	108	111±56
Dec. 30	75	59	126	266	62	102	46	105±76
1977 Feb. 28	108	124	235	136	92	64	104	123±54
				K				
1976 Apr. 22	186	114	134	210	227	92	160	160±50
Jun. 28	195	328	204	360	254	203	275	260±65
Sep. 1	147	421	334	390	298	165	352	301±107
Oct. 31	139	55	141	85	96	76	106	100±32
Dec. 30	167	79	209	306	154	179	83	168±78
1977 Feb. 28	123	127	203	162	115	103	137	139±34
				Ca				
1976 Apr. 22	61.1	80.1	40.1	96.3	92.6	27.3	57.1	64.9±26.1
Jun. 28	14.8	51.9	16.4	43.7	43.3	5.2	8.1	26.2±19.4
Sep. 1	11.5	75.2	66.0	100.1	173.4	11.1	53.8	70.2±56.0
Oct. 31	4.0	0.9	36.4	3.7	5.1	11.8	12.1	10.6±12.1
Dce. 30	1.2	1.1	40.0	17.8	1.0	2.3	1.0	9.2±14.9
1977 Feb. 28	1.7	31.5	57.4	37.3	8.1	13.0	20.3	24.2±19.3
				Mg				
1976 Apr. 22	46.5	29.7	31.4	50.4	72.0	23.4	62.5	45.1±18.0
Jun. 28	29.4	58.8	25.9	47.3	35.0	18.4	35.9	35.8±13.6
Sep. 1	29.0	100.5	70.3	81.6	50.7	19.1	95.6	63.8±31.7
Oct. 31	31.3	9.9	51.3	25.9	14.1	27.0	39.6	28.4±14.2
Dec. 30	27.1	18.0	38.9	61.2	22.2	34.3	14.1	30.8±16.0
1977 Feb. 28	6.9	7.9	13.7	9.5	6.6	1.5	7.3	7.6±3.6

TABLE 2
Sodium, potassium, calcium and magnesium concentrations (mg/100 g fresh tissue) in Taiwan's clams

Date	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	Mean ± SD
				Na				
1976 Apr. 22	776	355	430	591	469	563	638	546±141
Jun. 28	473	250	250	268	193	160	189	255±104
Sep. 1	499	430	375	478	465	259	499	429±87
Oct. 31	227	247	250	244	271	226	275	249±19
Dec. 30	268	345	365	337	369	384	397	352±42
1977 Feb. 28	423	354	415	341	83	112	107	262±154
				K				
1976 Apr. 22	241	185	204	201	191	225	192	206±20
Jun. 28	324	278	278	319	244	200	214	65±48
Sep. 1	332	345	301	297	345	209	291	303±47
Oct. 31	105	126	117	129	121	127	129	122±9
Dec. 30	289	276	256	292	279	289	282	280±12
1977 Feb. 28	293	187	230	238	247	201	227	232±34
				Ca				
1976 Apr. 22	105.6	92.4	136.4	227.8	191.7	369.9	232.6	193.8±95.8
Jun. 28	3.6	9.7	9.7	16.1	7.9	7.6	11.7	9.5±3.9
Sep. 1	9.2	20.1	16.6	11.6	14.6	11.4	10.3	13.4±3.9
Oct. 31	0.4	0.3	1.0	0.6	3.0	1.2	0.6	1.0±0.9
Dec. 30	2.9	2.5	3.2	3.9	3.5	4.8	2.0	3.3±0.9
1977 Feb. 28	3.4	3.9	3.6	5.9	5.4	2.4	3.3	4.0±1.2
				Mg				
1976 Apr. 22	105.8	23.9	58.4	87.9	34.3	85.6	81.2	68.2±30
Jun. 28	33.5	29.9	29.9	26.9	29.5	20.0	32.0	28.8±4.4
Sep. 1	78.7	74.0	67.4	69.3	17.0	42.7	9.6	51.2±28.4
Oct. 31	25.3	18.1	44.7	18.2	29.1	32.6	37.8	29.4±9.9
Dec. 30	58.2	73.0	90.1	55.8	84.6	82.4	82.9	75.3±13.5
1977 Feb. 28	19.3	16.6	18.0	15.8	21.3	19.1	20.3	18.6±2.0

TABLE 3
Mean concentrations ±SD (mg/100 g fresh tissue) of sodium, potassium, calcium and magnesium in Taiwan's oysters and clams (The range of concentration is shown in parenthesis)

	Na	K	Ca	Mg
Oyster	233±197 (44-820)	188±77 (55-421)	34.3±26.8 (0.9-173.4)	35.4±18.7 (1.5-100.5)
Clam	349±120 (83-776)	235±65 (105-345)	37.5±76.7 (0.3-369.9)	45.3±23.2 (15.8-105.8)

(AAS). The contents of Fe in the shellfishes were checked by the method of Barkan and Walker[2], and it was found that the result was very similar to that determined with AAS.

Zn: measured with AAS[1].

Cu, Pb and Cd: the digested samples were further extracted with APDC-MIBK[5], then measured with AAS.

Hg: determined by flameless atomic absorption spectrophotometry with a Colemen MAS mercury analyzer.

RESULTS AND DISSCUSSION

Concentrations of Na, K, Ca and Mg

The concentrations of Na, K, Ca and Mg in the oysters and clams are shown in Tables 1 and 2, respectively. When the concentrations of these major elements were observed with reference to the sizes of oysters and clams, it was found that there was no significant relation between the concentration and the size. In addition to this, there was also no significant difference in concentration among samples from different stations. Table 3 summarizes the mean concentration and range of Na, K, Ca and Mg in the oysters and clams. It could be seen from Table 3 that the occurrence of these elements was in the order of Na, K, Ca and Mg and the magnitudes of contents in oysters and clams were very similar, especially Ca and Mg which had almost the same mean concentrations.

Seasonal variation of Na, K, Ca and Mg

Since the patterns of seasonal variation of the major elements from different sampling stations were similar, the average values of the 7 sampling stations were calculated. The seasonal variations of the average values are shown in Fig. 1.

In Fig. 1, K and Mg show almost identical patterns in oysters and clams. This may suggest that with oysters and clams, the seasonal variations of K and Mg may be mainly caused by environmental factors rather than physiological effect.

It was found in Fig. 1 that Na and Ca showed quite different seasonal changes between oysters and clams. The contents of Na in clams and Ca in oysters were somewhat constant through the year. However, oysters showed remarkable seasonal changes of Na, and clams had noticeable changes of Ca. Although the reason of high Ca content in clams in May is not clear, the seasonal variation of Na in oysters may have very close relation with spawning. Fig. 2 shows the seasonal variations of sodium and glycogen[8] in oysters. Surprisingly enough, the seasonal changes of these two components were almost identical. As mentioned before[8],

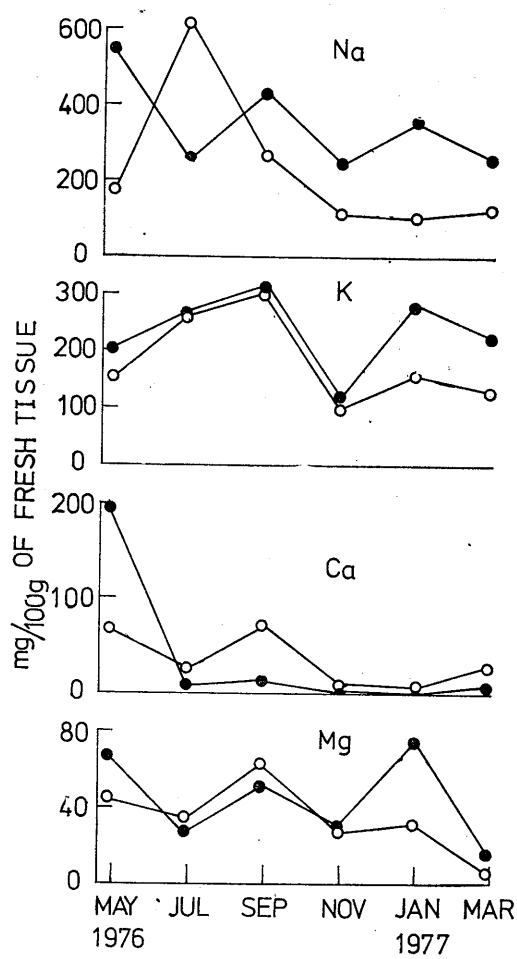

Fig. 1. Seasonal changes in contents of Na, K, Ca and Mg in Taiwan's oysters (○) and clams (●).

the change of glycogen in oysters has significant relationship with spawning. Therefore, the results in Fig. 2 strongly suggest that sodium might also have close connection with spawning of oysters.

Concentration of heavy metals

The heavy metal concentration in the oysters and clams of Taiwan could be divided into two groups. One group consisted of Fe, Zn and Cu which were in 10–100 ppm levels as shown in Tables 4 and 5, and the other group consisted of Pb, Ni, Cd and Hg which were in 1 ppm or less than 1 ppm levels as shown in Tables 6 and 7.

Just as the major elements, the heavy metal concentrations in Taiwan's oysters and clams had no significant relation with size or sampling stations. The mean concentrations and ranges of the heavy metals in the oysters and clams are shown in Table 8.

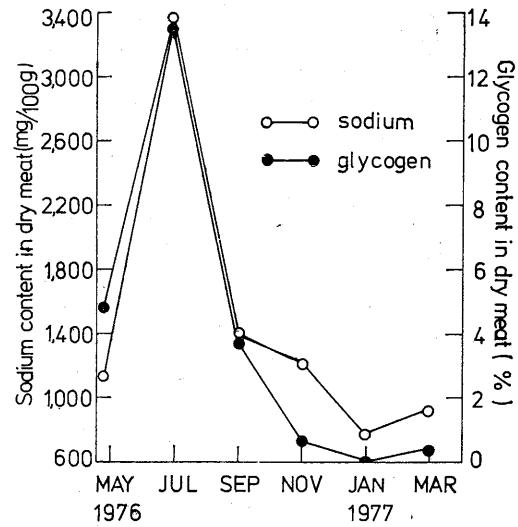

Fig. 2. Seasonal changes in contents of sodium and glycogen in Taiwan's oysters.

TABLE 4

Iron, zinc and copper concentrations (μg/g fresh tissue) in Taiwan's oysters

	Date	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	Mean ± SD
					Fe				
1976	Apr. 22	198.9	174.5	53.2	134.8	49.8	28.2	257.0	128.1±87.1
	Jun. 28	58.8	88.2	61.7	249.9	78.6	69.6	181.8	112.7±73.8
	Sep. 1	59.4	157.1	151.9	211.4	145.7	49.6	241.6	145.2±71.1
	Oct. 31	25.3	75.0	13.6	22.2	53.1	22.8	37.5	35.6±21.6
	Dec. 30	3.6	130.2	51.2	37.4	82.8	110.6	25.4	63.0±46.4
1977	Feb. 28	29.0	25.6	30.4	31.1	29.7	28.7	51.6	32.3±8.7
					Zn				
1976	Apr. 22	225.9	253.2	201.6	210.2	166.0	61.5	88.0	172.3±72.0
	Jun. 28	160.4	222.2	169.1	108.6	116.3	33.6	89.1	128.5±61.3
	Sep. 1	31.2	124.6	168.9	65.6	110.7	96.2	81.4	96.9±44.1
	Oct. 31	116.9	101.7	85.5	22.0	25.3	30.0	29.3	58.7±41.0
	Dec. 30	126.8	132.3	131.7	283.4	66.2	64.3	33.4	119.7±82.2
1977	Feb. 28	131.1	157.6	244.5	143.7	132.5	92.5	133.1	147.9±47.0
					Cu				
1976	Apr. 22	35.0	19.9	50.6	50.6	52.5	19.9	62.5	41.6±16.8
	Jun. 28	12.0	24.8	23.0	36.6	36.7	6.8	39.4	25.5±12.8
	Sep. 1	2.0	12.9	18.3	9.2	11.3	22.3	15.0	13.0±6.5
	Oct. 31	4.2	7.0	16.0	4.8	6.1	9.5	8.2	8.0±4.0
	Dec. 30	22.6	8.9	21.9	24.1	22.3	18.3	12.3	18.6±5.8
1977	Feb. 28	13.6	7.8	18.4	22.2	16.0	15.9	18.4	16.0±4.5

TABLE 5
Iron, zinc and copper concentrations (μg/g fresh tissue) in Taiwan's clams

Date	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	Mean ± SD
				Fe				
1976 Apr. 22	337.6	83.3	304.7	45.3	135.2	40.4	56.7	143.3±125.9
Jun. 28	243.3	200.2	257.3	353.3	165.5	181.4	118.7	217.1±76.1
Sep. 1	195.6	239.1	123.4	170.8	174.2	163.8	257.4	189.2±46.0
Oct. 31	103.4	130.9	65.0	92.4	51.7	18.4	127.7	84.2±41.4
Dec. 30	136.5	67.5	94.7	193.9	97.2	122.9	135.5	121.2±40.6
1977 Feb. 28	38.2	46.6	88.0	77.0	64.3	38.4	78.6	61.6±20.6
				Zn				
1976 Apr. 22	18.8	13.9	28.6	15.6	11.5	13.3	11.3	16.1±6.1
Jun. 28	20.7	18.2	20.7	17.7	16.6	12.6	14.5	17.3±3.0
Sep. 1	19.2	19.2	28.5	13.9	19.5	16.7	15.0	18.9±4.8
Oct. 31	11.8	9.8	11.5	7.8	7.8	8.9	9.0	9.5±1.6
Dec. 30	11.9	16.7	11.5	12.9	11.3	14.6	11.6	12.9±2.0
1977 Feb. 28	14.2	14.5	17.0	17.0	13.3	13.8	14.5	14.9±1.5
				Cu				
1976 Apr. 22	15.7	13.6	15.2	15.1	23.6	19.2	9.0	15.9±4.6
Jun. 28	8.5	3.4	3.4	5.6	2.1	3.7	2.9	4.3±2.2
Sep. 1	2.0	1.9	3.1	2.0	2.4	4.1	2.0	2.5±0.8
Oct. 31	1.4	1.3	1.5	2.4	1.1	1.5	1.4	1.5±0.4
Dec. 30	5.4	9.2	4.0	3.8	7.6	7.7	4.2	6.0±2.2
1977 Feb. 28	3.0	3.5	2.0	2.0	3.2	4.8	3.6	3.2±1.0

TABLE 6
Lead, nickel, cadmium and mercury concentrations (μg/g fresh tissue) in Taiwan's oysters

Date	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	Mean ± S.D
				Pb				
1976 Apr. 22	1.75	0.21	0.68	<0.01	2.34	<0.01	<0.01	<0.71
Jun. 28	4.12	7.72	4.58	1.63	5.26	4.42	6.17	4.84±1.88
Sep. 1	0.70	<1.90	<0.01	<0.01	<1.62	1.12	<1.65	<0.99
Oct. 31	0.43	0.12	0.20	0.22	0.34	0.26	0.08	0.24±0.12
Dec. 30	0.43	0.14	0.44	0.35	0.68	0.16	0.22	0.35±0.19
1977 Feb. 28	0.43	0.60	0.96	0.14	0.07	0.10	0.19	0.36±0.33
				Ni				
1976 Apr. 22	0.19	0.10	<0.01	0.05	0.31	<0.01	0.14	<0.11
Jun. 28	1.10	1.70	1.20	1.80	0.90	1.00	1.40	1.30±0.35
Sep. 1	0.18	0.69	0.71	0.73	0.44	0.15	0.65	0.51±0.25
Oct. 31	0.51	0.31	0.65	0.32	0.35	0.35	0.45	0.42±0.13
Dec. 30	0.32	0.66	0.75	0.37	0.26	0.20	0.24	0.40±0.22
1977 Feb. 28	1.13	0.68	1.19	0.31	0.18	0.15	0.33	0.57±0.44

TABLE 6 (Continued)

Date			St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	Mean ± SD
						Cd				
1976	Apr.	22	0.05	0.16	<0.01	0.15	0.16	<0.01	<0.01	<0.07
	Jun.	28	0.08	0.13	0.07	0.20	0.18	0.11	0.23	0.14±0.06
	Sep.	1	0.04	0.13	0.12	0.24	0.16	0.12	0.19	0.14±0.06
	Oct.	31	0.03	0.03	0.11	0.17	0.15	0.14	0.18	0.12±0.06
	Dec.	30	0.11	0.05	0.09	0.11	0.11	0.01	0.12	0.09±0.04
1977	Feb.	28	0.07	0.01	0.05	0.03	0.06	0.23	0.07	0.07±0.07
						Hg				
1976	Apr.	22	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
	Jun.	28	0.02	<0.01	<0.01	0.01	0.01	0.01	0.02	<0.01
	Sep.	1	0.01	<0.01	<0.01	<0.01	0.03	0.01	0.06	<0.02
	Oct.	31	0.02	0.01	0.02	0.01	0.01	<0.01	<0.01	<0.01
	Dec.	30	0.02	0.01	0.08	0.02	0.03	<0.01	<0.01	<0.03
1977	Feb.	28	<0.01	<0.01	<0.01	0.01	0.02	<0.01	<0.01	<0.01

TABLE 7

Lead, nickel, cadmium and mercury concentrations (μg/g fresh tissue) in Taiwan's clams

Date			St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	Mean ± SD
						Pb				
1976	Apr.	22	2.46	<0.01	<0.01	<0.01	2.18	2.61	<0.01	<1.04
	Jun.	28	6.07	6.17	7.29	6.47	4.84	3.49	4.89	5.62±1.27
	Sep.	1	<1.57	<1.73	<1.47	<1.43	<1.46	<0.01	<0.01	<1.09
	Oct.	31	0.30	0.18	0.44	0.42	0.38	0.36	0.36	0.35±0.09
	Dec.	30	0.35	0.22	0.66	0.73	0.24	0.48	0.48	0.45±0.20
1977	Feb.	28	0.36	0.29	0.94	0.28	0.20	0.01	0.31	0.34±0.29
						Ni				
1976	Apr.	22	0.92	<0.01	0.79	<0.01	0.41	0.52	<0.01	<0.38
	Jun.	28	2.70	1.40	2.20	2.00	1.70	2.30	1.80	2.01±0.43
	Sep.	1	0.65	1.09	1.81	0.78	1.33	1.10	0.93	1.10±0.39
	Oct.	31	0.60	0.94	1.12	0.91	0.67	0.58	0.66	0.78±0.21
	Dec.	30	1.65	2.20	1.49	1.56	1.55	2.20	1.37	1.72±0.34
1977	Feb.	28	0.93	0.91	1.61	1.46	1.44	2.04	2.99	1.62±0.72
						Cd				
1976	Apr.	22	0.21	<0.01	0.25	<0.01	0.19	0.19	<0.01	<0.12
	Jun.	28	0.13	0.02	0.09	0.12	0.09	0.18	0.08	0.10±0.05
	Sep.	1	0.06	0.07	0.06	0.04	0.05	0.08	0.06	0.06±0.01
	Oct.	31	0.04	0.04	0.05	0.05	0.04	0.06	0.06	0.05±0.01
	Dec.	30	0.05	0.02	0.05	0.08	0.06	0.08	0.07	0.06±0.02
1977	Feb.	28	0.13	0.09	0.09	0.08	0.09	0.13	0.09	0.10±0.02
						Hg				
1976	Apr.	22	0.01	0.02	<0.01	<0.01	<0.01	0.01	0.01	<0.01
	Jun.	28	0.01	0.01	0.01	0.02	0.03	0.01	0.01	0.02
	Sep.	1	<0.01	0.02	0.02	<0.01	0.02	0.04	0.02	<0.02
	Oct.	31	0.03	0.02	0.01	0.04	0.02	<0.01	<0.01	<0.02
	Dec.	30	<0.01	0.01	0.02	0.03	<0.01	<0.01	<0.01	<0.01
1977	Feb.	28	<0.01	0.02	0.02	0.03	0.05	<0.01	0.04	<0.02

TABLE 8
Mean concentrations ±SD (μg/g fresh tissue) of heavy metals in oysters and clams of Taiwan (The range of concentration is shown in parenthesis)

	Cd	Cu	Fe	Hg	Ni	Pb	Zn
Oyster	0.11±0.03 (<0.01-0.24)	20.4±11.9 (2.0-62.5)	86.1±48.9 (3.6-257.0)	<0.02 (<0.01-0.08)	0.55±0.40 (<0.01-1.80)	1.25±1.78 (<0.01-7.72)	120.6±39.7 (22.0-283.4)
Clam	0.08±0.03 (<0.01-0.25)	5.7±5.3 (1.1-23.6)	136.1±59.8 (18.4-353.3)	<0.02 (<0.01-0.04)	1.27±0.62 (<0.01-2.99)	1.48±2.06 (<0.01-7.29)	14.9±3.4 (9.0-28.6)

Table 8 indicates that the mean concentrations of Cd, Hg and Pb were almost the same in the oysters and clams, and the concentrations of Fe and Ni were not too different. The great difference of concentration between oysters and clams occurred in Cu and Zn. Oysters had about 4 times as much of Cu, and 8 times as much of Zn as clams. Since the concentrations of Zn and Cu in the oyster of Taiwan are quite low as compared with the values of oysters in other parts of the world, it could be said that the higher concentration of Zn and Cu in the oysters may primarily come from physiological requirement.

The present study of heavy metal concentration in the oysters and clams of Taiwan was compared with a similar study 6 years ago, performed by Jeng and Huang[5]. It was found that the results were quite similar. This means that the heavy metal concentrations of the oysters and clams of Taiwan are not higher than the "normal" levels and should not constitude a hazard for consumers.

Seasonal variation of heavy metals

The seasonal variation of Fe, Zn Cu and Pb, Ni, Cd Hg in the oysters and clams of Taiwan are shown in Figs. 3 and 4, respectively. Among these heavy metals, Fe, Cu, Pb and Ni showed noticeable seasonal changes both in oysters and clams. These variations may not be caused by the reproductive cycle, because with a certain heavy metal, the pattern was almost the same with oysters and clams. Most probably these variations come from environmental factors. It could be seen from Figs. 3 and 4 that high concentrations of Fe, Cu, Pb and Ni all occurred in the summer (May to September). The possible factors may include temperature, availability of food and land drainage[3]. In summer, the seawater temperature on the southwest coast of Taiwan is around 28°C, a temperature that does not differ greatly from that in winter, around 20°C[4]. It has been mentioned before[6,7], that there is a great deal

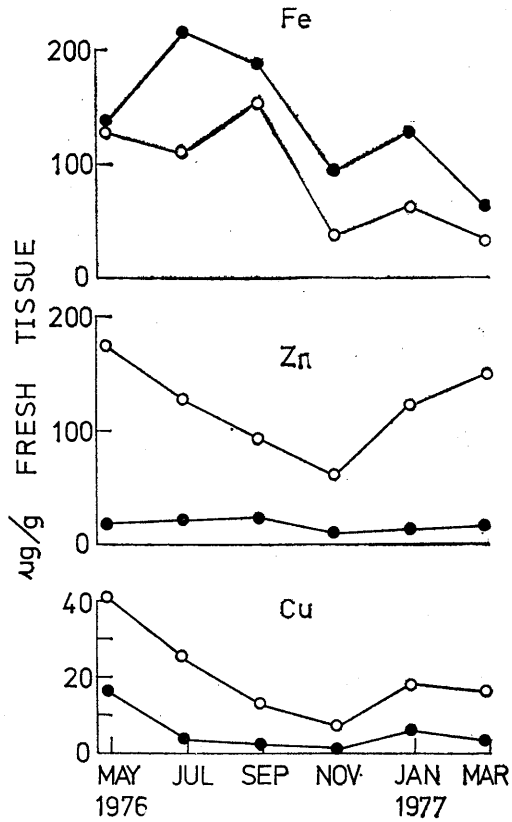

Fig. 3. Seasonal changes in contents of Fe, Zn and Cu in Taiwan's oysters (○) and clams (●).

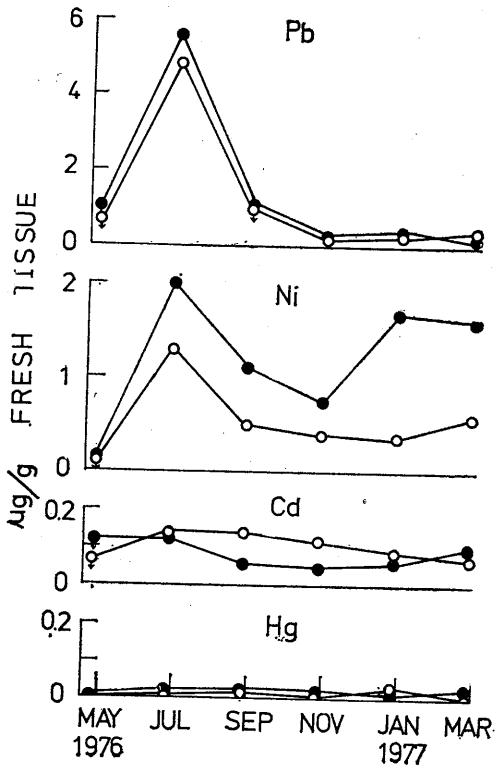

Fig. 4. Seasonal changes in contents of Pb, Ni, Cd and Hg in Taiwan's oysters (○) and clams (●).
(♀: value less than the mark)

of river water flowing into the west coast of Taiwan in summer as compared with little drainage in winter. Therefore, it is thought that the change in food and land drainge is more important than temperature. Figs. 3 and 4 indicate that the high concentrations of Fe occurred from July to September, of Cu in May, and of Pb and Ni in July. It is speculated that the difference may arise from the fact that the absorption and excretion rates of metals were different in the shellfishes.

Fig. 3 indicates that oysters and clams had different seasonal concentrations of Zn. For oysters, higher concentration of Zn occurred from March to May, but clams showed almost constant concentration of Zn the whole year. As shown in Fig. 4, Cd showed no apprecible seasonal changes in the shellfishes, and in most cases Hg in the shellifishes was too low to be detected; hence, whether there are seasonal changes of Hg in the shellfishes is not clear.

Acknowledgements: This study was supported by a grant from the Joint Commission on Rural Reconstruction to S. S. Jeng. This paper is a part of the graduate work of S. Y. Hsu at the Graduate School of Marine Food Science, Taiwan Provincial College of Marine Science and Technology.

REFERENCES

1. AOAC (1970) *Methods of Analysis*, (W. Horwitz. ed.) 11th edition. Association of Official Analytical Chemists, Washington, D. C. p. 425.
2. BARKAN G. and B. S. WALKER (1940) Determination of serum iron and pseudohemoglobin iron with o-phenanthroline. *J. Biol. Chem.* **135**: 37-42.
3. BRYAN G. W. (1973) The occurrence and seasonal variation of trace metal in the scallops *Pecten Maximus* (L.) and *Chlamys Opercularis* (L.). *J. Mar. Biol. Ass. U. K.* **53**: 145-166.
4. CHEN S. C. and S. J. CHEN (1978) Outline of general sea condition along Taiwan coast in 1969-1976. *China Fish. Month.* **311**: 8-25.
5. JENG S. S. and Y. W. HUANG (1973) Heavy metal contents in Taiwan's cultured fish. *Bull. Inst. Zool., Academia Sinica* **12**(2): 79-85.
6. JENG S. S. (1975) Effect of river water pollution on the mass mortalities of cultured shellfishes along the southwest coast of Taiwan. *J. Fish. Soc. Taiwan* **4**(1): 51-71.
7. JENG S. S. and S. B. WANG (1976) Water quality in rivers of central Taiwan and its effect on fish. *J. Fish. Soc. Taiwan* **5**(1): 43-60.
8. JENG S. S., S. Y. HSU and G. S. WANG (1979) Chemical composition of Taiwan's oysters and clams. *Bull. Inst. Zool., Academia Sinica* **18**(1): 1-10.

臺灣牡蠣與文蛤之鈉鉀鈣鎂及重金屬含量與季節性之變化

許順堯　王果行　鄭森雄

爲了解臺灣牡蠣與文蛤之化學特性，乃調查此等貝類主要元素鈉、鉀、鈣、鎂，及重金屬鎘、銅、鐵、汞、鎳、鉛、鋅之含量。由 1976 年 4 月至 1977 年 2 月，每隔 2 個月自臺灣西海岸 7 個採樣站，採購剛剝殼之牡蠣與剛上市之文蛤。鈉、鉀以炎光分析法分析，其他元素則以原子吸光分析法測其濃度。由實驗得知：臺灣牡蠣中，鈉、鉀、鈣、鎂之平均濃度爲 233, 187, 34.3 及 35.4 mg/100 g 新鮮組織，在文蛤中，則分別爲 349, 235, 37.5 及 35.3 mg/100 g 新鮮組織。在主要元素中，牡蠣之鈉之季節變化最有意義。因爲由實驗中發現牡蠣之鈉與肝醣之季節變化幾乎完全相同，因此，鈉可能與牡蠣之產卵有密切之關係。臺灣牡蠣與文蛤之重金屬含量可分爲二大類。第一類爲濃度較高之鋅、鐵、銅，在牡蠣中之含量爲 120.4, 86, 20.4 ppm；在文蛤中之含量爲 14.9, 137, 5.7 ppm。第二類爲濃度較低之鉛、鎳、鎘、汞，在牡蠣中之含量 1.29, 0.55, 0.11, 0.01 ppm；在文蛤中之含量爲 1.53, 1.09, 0.09, 0.02 ppm。此等重金屬之含量，並未超過其正常含量，因此，不會對消費者構成威脅。

臺灣牡蠣及文蛤之鐵、銅、鉛與鎳皆有明顯之季節變化，且以五月至九月期間含量較高。此等季節變化之原因可能由於夏季，臺灣西海岸有較多之食物及較豐富之陸上排水所致。