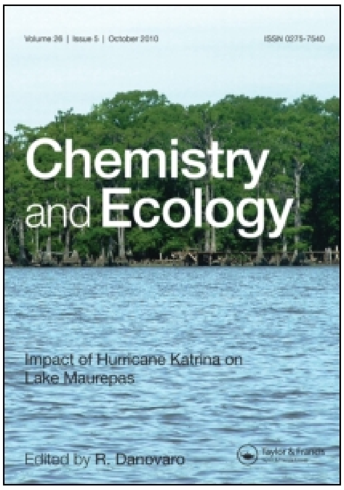

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

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To cite this Article Chu, Kevin , Pan, Tzu-Ming , Tseng, Rong-Jeng and Chen, Liang-Hsien(1995) 'A Marine Pollution Study of Northeast Coastal Water Off Taiwan Island', Chemistry and Ecology, 10: 1, 167 — 180
To link to this Article: DOI: 10.1080/02757549508035339
URL: http://dx.doi.org/10.1080/02757549508035339

Chemistry and Ecology, 1995, Vol. 10, pp. 167–180
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A MARINE POLLUTION STUDY OF NORTHEAST COASTAL WATER OFF TAIWAN ISLAND

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(*Received 19 January 1994; in final form 24 February 1994*)

The coastal water of northeast Taiwan island, called 'Yin-Yang Hai' for its distinct yellow colour compared with blue offshore water, was investigated from 1989 to 1990 by the authors. Biological study showed the dominant species of plankton to be Copepoda, Cladocera, planktonic eggs and Diatoma. Dominant species of benthos were young crabs, Amphipoda and Annelida, with Amphipoda usually occurring in heavily polluted areas. Heavy metal data showed that the concentration of copper was high. The copper and iron concentration in algae of the intertidal zone was also high. The concentrations of iron and copper in inshore water were also higher than in offshore water. By comparison of the pH and salinity distribution of this area, we conclude that this coastal water has been polluted by acid waste water from coastal industry. The suspended solids concentration in sea water is high. Flocculation occurring at the boundary of fresh and saline water might be a reason for the distinct yellow colour of the water of this area. Further study is required.

KEY WORDS: pollution, acidic mining discharge, heavy metals, zooplankton, benthos

INTRODUCTION

Shuei-Nan Don is a U-shaped bay, located to the east of Kee Lung (25.1° N, 121.8° E). It has acquired a reputation as 'Yin-Yang-Hai'*. The Taiwan Metal Mineral Company located nearby, now no longer operating, for many years discharged waste water directly into the bay. In addition, acidic mineral waste water of the King-Kwa-Shi mining area flows into Lian-Don brook which discharges to the bay. Owing to the ebb and flood of the sea (current velocity about 2 knots in a east direction at flood and 1.5 knots to the northwest at ebb), the water inside the bay does not exchange effectively with the sea outside, resulting in a phenomenon of yellow water inside the bay and blue in the sea outside.

The King-Kwa-Shi area is adjacent to Shuei-Nan-Don. Its mining activity can be traced back to the Ching Dynasty (before 1911) and reached its zenith during the Japanese occupation period. From 1973 to 1989, literature records show that the total mining discharge at Shuei-Nan-Don Bay caused the accumulation of sediments and a reduction of depth of about 3 m (Guan *et al.*, 1973; Poo *et al.*, 1991). The ecological structure of this sea-shore must have been changed by this long-term environmental influence and there are almost no benthic organisms inhabiting the intertidal zone of the bay (Chu *et al.*, 1989).

* Yin and Yang, two Chinese characters, are two relative attributes. Because of the relative condition and the obviously different colour of the sea and enclaved bay, it received this name.

The environmental impact of metal mining activities has received world-wide attention (Dills and Rogers, 1974). In recent years, coastal pollution has caused contamination of marine ecosystems and has also damaged natural biological processes. If the waste water discharged at Shuei-Nan-Don sea-shore contains heavy metals, these can easily adhere to suspended particles flowing to ocean. They can accumulate along the food chain or sink to the bottom of the sea to form sediment and there influence the benthic environment.

Biological evaluation of organism and ecosystems has shown elsewhere an ecological alteration in species and communities affected by mining waste water, a result of both inorganic and organic components (Castilla and Neallar, 1978; Lathrop and Waynes, 1986; Lenihan, 1992). This study is investigating and analyzing the hydrology, nutrients, heavy metals, plankton, coastal epizoa, benthos and the heavy metal content of algae of Shai-Nan-Don sea-shore to determine the environmental impacts of the waste water.

METHODS

Sampling Times and Locations

We divided the period from November 1989 to June 1990 into four occasions for sampling. On the northeastern sea-shore of Taiwan, we set up six stations offshore (N1 to N6), and in the in-shore intertidal zone, we set up eight stations (St 1 to St 8) (Figure 1). Since, in northeastern Taiwan, the increasing northeasterly seasonal wind from September can influence the sampling, we divided each sampling into two parts, offshore and intertidal zone.

Investigation Methods

Hydrology

Hydrological investigations included sea water transparency (Secchi disc, to 25 cm) and the measurement of coastal current flow.

Water quality

The temperature and acidity of sea water were determined by portable pH/temperature meter (Model TS-1, Suntex Co., R.O.C.), salinity by portable conductivity meter (Model SC-120, Suntex Co., R.O.C.), and dissolved oxygen by DO meter (Model SD-70, Suntex Co., R.O.C.). The concentrations of nitrite, nitrate, phosphate, and silicate in sea water (the samples used were natural sea water) were determined by the methods of Strickland and Parsons (1972). Heavy metals (copper, zinc, nickel, chromium, lead, cadmium, iron and manganese) in sea water, sediment and algae were analyzed by atomic absorption spectrophotometer (Model Z-8100, Hitachi Co., Japan) with the methods described by Bettinelli (1986) and Hsu (1983).

Zooplankton

Zooplankton was sampled by towing a NORPAC standard plankton net (mouth diameter 45 cm, net length 180 cm, mesh 0.33×0.33 mm) equipped with a mouth-mounted digital flowmeter (Model 438-110, Hydro-Bios Apparate bau Gmbh, Germany) behind a boat sailing parallel to the coast from west to east. Tows were made sailing for 5–10 minutes at a horizontal speed of 0.5–1.0 knots so as to keep the upper edge of the net mouth about 0.3 m below the water surface.

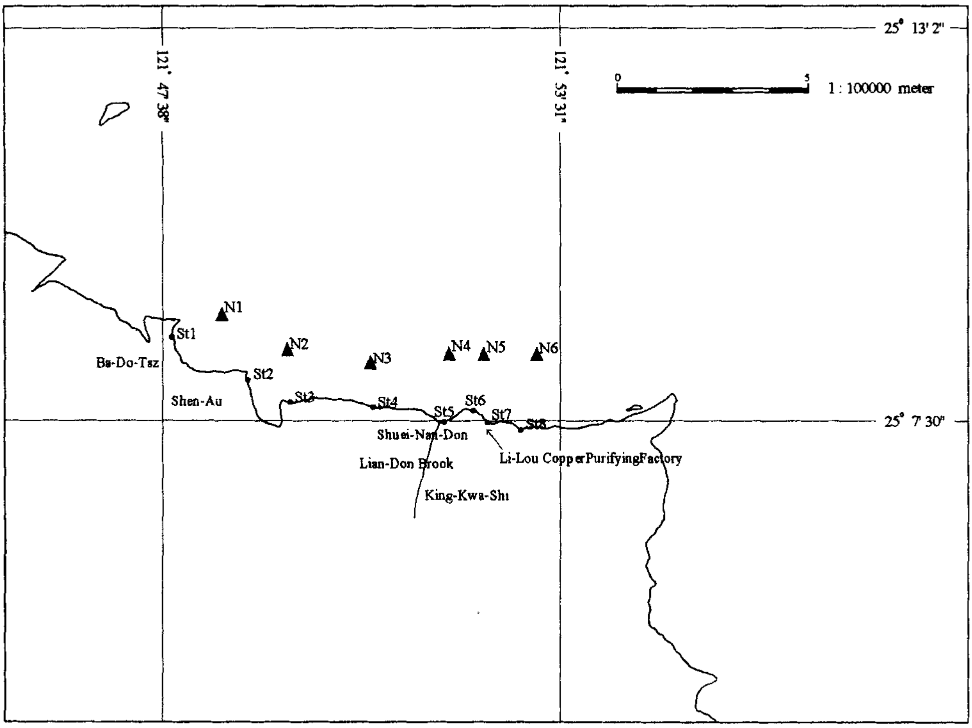

Figure 1 The stations in coastal water of northeast Taiwan.

Benthic animals

Benthic animals were sampled on four occasions in the sea-shore area between Ba-Do-Tsz and the Li-Lou Copper Purifying Factory. In the intertidal zone, qualitative samples of the benthos were collected on the rocky beach; this sample was taken by hand. Small quantitative samples were obtained in an area of $0.5 \times 0.5\ m^2$ at each of the intertidal stations. For sampling off-shore, samples were taken on board by a 10 min haul with a $50 \times 20\ cm^2$ rectangular dredge; net bag length 80 cm with 3 mm diam mesh, so that a small size sample of amphipods was obtained. The benthic fauna from the dredge samples was elutriated and screened through a 5 mm pore sieve followed by a 1mm pore sieve. Samples were preserved in 5% neutral formalin. Total community diversity was estimated using the Shannon-Wiener index, based on information theory (Ludwig and Reynolds, 1988). In this index, species diversity is:

$$H' = -\sum_{i=1}^{S} Pi * \ln Pi\ ,$$

where Pi = ni/N, ni is the number of individuals of the species, N the total number of individuals and S the total number of species. Literature suggests that such indices can be used to assess environmental quality (Wilhm and Dorris, 1968; Sanders, 1968; Headrich, 1975; Washington, 1984).

RESULTS

Hydrological Investigations

The values of water transparency showed that station N4 had the lowest level of the six sites offshore (Table I). The tidal current in the vicinity of the Shuei-Nan-Don was measured at a velocity of about two knots in an easterly direction at flood and at 1.5 knots to the northwest at ebb.

Table I The transparency of sea water (Secchi disc depth, m) of northeast near-shore coastal water of Taiwan

Station	Dec. 1989	Jan. 1990	March 1990	May 1990
N 1	5.0	3.1	6.5	5.5
N 2	6.2	4.1	6.5	4.5
N 3	7.5	4.3	8.0	4.5
N 4	0.5	0.3	0.3	0.5
N 5	3.0	5.0	5.0	6.5
N 6	4.1	4.5	6.0	5.0

Water Quality

The temperatures of sea water in November, December and January were not significantly different (average value about 20°C), but were higher in May (about 25°C). The salinities at all inshore stations were all about 34‰ except at St 7. The low salinity of St 7 (16.3‰) was due to the river discharge nearby. The pH values of the sea water were in the range of 3.54 to 8.44 (Table II). pH values less than 7.0 were observed at St 5 and 7. Station 7 (Li-Lou Copper Purifying Factory) had the lowest value (3.54) at the first sampling. The dissolved oxygen concentration of sea water ranged from 5.41 to 7.02 ppm. The values in January were higher than those of November and December, and those of March higher than those of May.

The nutrient content of sea water in the intertidal zone is shown in Table III. The nutrient content in November was higher than that in January. The values at St 7 were very high, perhaps due to the addition of mineral waste water. The values at St 5 near Lian-Don River in March 1990 were higher than those at the other stations. The nutrient concentrations in May were almost always higher than those in March. This may be due to runoff from the land during this period.

The heavy metal concentrations of sea water in the intertidal zone are shown in Table IV. Copper, zinc and cadmium were present mostly in soluble form, chromium and manganese as particulates. The concentrations of copper, zinc, nickel, lead and iron at St 5 and St 7 were significantly higher than at other stations. The total metal concentrations in March were higher than those in May. This may be the result of seasonal dilution of sea water by rain. The heavy metal concentrations of sea water in the coastal area are shown in Table V. The values at stations N4 and N5 were always highest; the reason is that these stations are near the Lian-Don River. Figures 2 and 3 show the difference in concentrations of copper and iron between the inshore intertidal zone and the offshore coastal zone. The concentrations of copper and iron in algae (Enteromorpha) are shown in Figures 4 and 5. The pattern of distribution with time of heavy metals in algae is much the same as that of sea water, but the

Table II The pH values of sea water of northeast coastal water of Taiwan

Station	Nov./Dec. 1989	Jan. 1990	March 1990	May 1990
St 1	8.44	8.33	8.11	8.20
St 2	8.31	8.25	8.34	8.02
St 3	8.37	8.29	8.02	8.08
St 4	8.41	8.22	8.26	7.96
St 5	7.68	7.33	7.67	5.02
St 6	8.28	8.27	8.03	8.0
St 7	3.54	7.86	7.87	8.05
St 8	8.18	8.54	7.98	8.10
N 1S	8.36	8.40	8.06	7.02
N 1D	8.33	8.42	8.04	5.59
N 2S	8.28	8.34	8.02	5.41
N 2D	8.30	8.37	7.99	5.41
N 3S	8.37	8.40	8.21	5.99
N 3D	8.35	8.42	8.12	6.23
N 4S	8.05	6.46	8.17	6.04
N 4D	8.20	8.27	8.19	6.05
N 5S	7.84	8.22	7.93	5.45
N 5D	8.27	8.38	7.98	5.71
N 6S	8.16	8.29	8.01	5.76
N 6D	8.28	8.39	8.00	5.42

St 1–8 are in-shore, intertidal stations.
N 1–6 are near-shore stations, S:surface, D = depth(5m) samples.

values are much larger. The pattern of distribution of heavy metals in sediment (Table VI) is also similar.

Zooplankton Offshore Sites (N1 to N6)

During the period of investigation (Figure 6), we found a gradually decreasing abundance of zooplankton from east to west around Yin-Yang-Hai sea-shore. It was also less in winter months and greatly increased from April.

Benthic Animals

In four samples taken in the intertidal zone (Table VII), stations 1, 2, 3 and 4 appeared to have greater abundance and diversity of benthic animals. At St 6 and St 8, the frequency of occurrence was lower than at St 1–4. Station 5 is near the Yin-Yang-Hai coast, and pyrite present in the rocks has a characteristic pyrite-yellow colour. No benthos is found there. Station 7 near the Li-Lou Copper Purifing Factory also had no benthic fauna. Does this phenomenon result from geographical and environmental influences? Intertidal zone station 1 showed the highest diversity for the first sampling, while the second and third sampling were lower, and fourth higher again. These changes accompany the effect of northeastern seasonal wind, and abundance of organisms and species also differed greatly between stations.

In off-shore benthos sampling (Table VIII), station N1 had a higher diversity and no obviously dominant species and the benthic community appears stable. At Shuci-Nan-Don sea-shore N4, the first sample had a Shannon's Index H′ = 1.53, and for the fourth sample H′ = 1.75. The change in Shannon's Index is not large, but Amphipoda appeared as the dominant species, and exceed more than half of the population (53.5% to 55.1%).

Table III The nutrient content (μM) of sea water of northeast coastal water of Taiwan

Station	PO_4-P A	PO_4-P B	PO_4-P C	PO_4-P D	SiO_4-Si A	SiO_4-Si B	SiO_4-Si C	SiO_4-Si D	NO_2-N A	NO_2-N B	NO_2-N C	NO_2-N D	NO_3-N A	NO_3-N B	NO_3-N C	NO_3-N D
St 1	0.37	0.34	0.24	0.34	10.4	9.8	14.9	19.7	0.47	0.31	0.19	0.27	0.71	1.13	1.12	2.13
St 2	0.62	0.47	0.37	0.52	16.3	12.3	19.2	9.7	0.53	0.47	0.48	0.36	0.98	1.17	0.91	1.07
St 3	0.73	0.23	0.42	0.37	8.3	9.9	11.5	14.7	0.25	0.29	0.35	0.39	0.64	1.42	0.77	2.67
St 4	0.58	0.69	0.49	0.52	13.5	15.3	8.4	20.9	0.42	0.54	0.31	0.42	1.03	0.97	1.47	1.96
St 5	0.87	0.74	0.83	0.68	9.8	18.4	37.3	39.6	0.37	0.37	0.41	0.49	2.10	2.36	2.90	2.49
St 6	0.47	0.41	0.27	0.41	17.3	8.7	24.8	9.2	0.29	0.29	0.17	0.19	1.88	1.79	1.94	1.71
St 7	0.58	0.83	0.51	0.37	7.3	19.8	14.6	17.0	0.28	0.31	0.13	0.28	1.62	2.07	0.74	2.06
St 8	0.79	0.24	0.48	0.47	14.7	11.7	19.2	11.7	0.13	0.19	0.46	0.23	2.39	1.88	3.73	3.18
N 1S	0.18	0.15	0.21	0.23	32.1	9.3	23.2	21.3	0.21	0.08	0.19	0.11	1.14	2.07	1.01	1.87
N 1D	0.17	0.21	0.15	0.30	21.4	12.5	20.2	20.5	0.50	0.12	0.45	0.16	1.09	1.67	1.21	2.57
N 2S	0.12	0.23	0.24	0.35	29.4	14.5	23.7	9.3	0.42	0.13	0.28	0.23	0.83	0.98	1.72	2.34
N 2D	0.27	0.19	0.27	0.26	18.5	11.2	12.5	18.2	0.36	0.35	0.41	0.32	0.76	1.07	0.92	0.89
N 3S	0.11	0.15	0.19	0.11	21.5	8.5	21.4	13.5	0.38	0.25	0.24	0.25	1.57	1.10	0.87	1.23
N 3D	0.09	0.37	0.10	0.24	27.4	17.6	16.7	20.6	0.49	0.13	0.42	0.31	1.03	2.06	1.64	1.06
N 4S	0.09	0.11	0.49	0.64	14.9	11.3	41.3	31.2	0.18	0.17	0.58	0.37	1.79	0.74	2.97	3.34
N 4D	0.16	0.13	0.11	0.41	16.9	22.4	26.3	32.6	0.18	0.27	0.15	0.26	2.10	1.44	3.06	2.91
N 5S	0.18	0.13	0.25	0.17	20.9	6.8	11.9	8.9	0.29	0.23	0.21	0.28	0.89	1.19	1.15	1.19
N 5D	0.13	0.52	0.18	0.39	8.4	15.3	7.4	15.6	0.56	0.18	0.50	0.21	0.66	0.89	2.01	0.82
N 6S	0.14	0.29	0.24	0.41	19.0	19.7	10.5	19.9	0.41	0.20	0.41	0.19	1.66	1.36	1.52	1.97
N 6D	0.22	0.33	0.41	0.23	12.5	14.8	12.3	11.9	0.33	0.26	0.30	0.26	0.94	0.97	0.74	1.29

A: Samples on Nov. 22, 1989 or Dec. 5, 1989.
B: Samples on Jan. 12, 1990 or Jan. 18, 1990.
C: Samples on March 15, 1990 or March 24, 1990.
D: Samples on May 12, 1990 or May 16, 1990.
Stations were the same as Table II.
Detection limit < 0.01 ppb

Table IV The heavy metal content ($\mu g l^{-1}$) of sea water of northeast intertidal coastal water of Taiwan

Station	Cu				Zn				Ni				Cr				Pb				Cd				Fe			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1	4.0	7.3	8.5	2.7	2.0	0.4	21.7	31.3	1.8	1.9	3.6	1.2	1.3	0.7	1.2	0.3	0.4	0.1	1.2	1.2	1.2	2.4	0.3	1.0	470	nd	104	36
2	4.0	8.9	5.1	6.6	1.8	1.1	10.9	64.2	4.4	1.5	0.9	2.0	1.9	1.2	0.4	0.1	0.3	0.4	1.0	3.0	0.8	1.8	0.6	0.7	750	210	40	14
3	3.3	3.5	6.3	2.6	2.2	0.5	18.5	16.4	1.9	0.6	1.2	1.6	1.1	0.1	0.2	0.2	0.2	0.1	1.2	2.7	0.8	0.9	0.9	0.4	410	40	29	18
4	10.3	14.1	1.4	5.1	0.8	6.7	9.1	16.1	0.7	1.8	0.4	1.2	0.8	0.6	0.2	0.2	0.5	nd	1.0	2.3	0.4	1.3	0.1	0.1	110	400	154	33
5	355.1	157.6	534.6	19.4	10.3	3.4	10.9	90.8	9.4	14.9	16.8	1.7	2.6	3.1	0.3	0.2	0.9	0.2	2.0	2.7	0.6	1.3	0.7	0.2	1720	1520	388	293
6	19.0	34.5	45.1	7.8	0.8	1.4	27.5	18.1	1.6	3.1	2.1	1.5	2.7	0.6	0.3	0.2	0.1	0.1	1.1	2.4	0.8	1.0	0.3	0.1	400	420	38	30
7	469.1	437.3	279.9	42.8	12.3	12.9	92.5	20.1	5.9	22.7	9.9	1.2	1.2	1.8	0.1	0.2	6.5	6.0	2.1	2.5	0.5	1.3	1.0	0.3	1980	1470	287	53
8	17.7	21.9	21.6	22.2	1.6	1.9	9.3	32.1	2.0	1.5	0.8	1.9	1.4	1.7	0.2	0.2	0.6	0.4	1.2	2.4	1.1	0.9	0.3	0.2	780	880	228	68

Sampling times were the same as Table III.
Detection limit < 0.01 ppb, nd = not detected

Table V The heavy metal content ($\mu g l^{-1}$) of sea water of northeast intertidal coastal water of Taiwan

Station	Cu				Zn				Ni				Cr				Pb				Cd				Fe			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
N 1S	3.0	4.3	15.7	6.2	1.4	1.5	90.0	18.5	5.1	2.0	1.4	3.0	1.1	1.0	0.2	0.2	0.4	0.3	2.8	1.3	0.6	0.6	0.1	0.8	310	190	127	14
N 1D	3.7	9.3	3.2	3.0	1.3	0.2	89.5	16.6	3.4	0.4	2.0	0.7	0.9	0.4	0.3	0.2	0.7	nd	2.0	1.0	1.1	0.4	0.7	0.1	30	20	17	14
N 2S	31.4	6.1	9.3	8.1	4.1	3.6	57.7	16.2	5.0	3.1	0.9	1.5	0.8	1.4	0.1	0.2	2.5	0.3	2.5	1.0	0.3	0.3	0.1	0.5	800	170	58	35
N 2D	7.8	3.5	7.7	2.2	5.8	0.8	50.3	13.8	1.6	1.3	0.9	1.9	0.5	0.8	0.1	0.4	1.0	nd	1.5	1.0	0.4	0.1	0.2	0.2	30	20	13	26
N 3S	5.9	3.0	3.6	8.0	0.7	1.9	43.8	14.3	0.8	4.5	1.0	3.9	0.5	2.3	0.4	0.3	0.1	0.1	2.1	1.0	0.1	0.2	0.1	0.3	190	230	23	31
N 3D	5.3	2.7	1.7	4.0	1.8	0.4	33.6	12.9	0.4	0.2	0.9	1.5	0.1	0.6	0.1	0.3	0.3	nd	1.2	0.9	0.3	nd	0.6	0.1	10	20	12	28
N 4S	235.9	55.5	570.7	136.1	2.2	2.2	96.4	23.0	8.2	4.1	5.4	2.9	2.7	0.2	0.3	0.2	1.1	0.1	2.2	1.2	0.9	0.3	0.4	0.1	910	940	608	297
N 4D	11.4	15.4	4.5	11.1	1.3	0.3	26.4	31.9	6.1	1.2	1.1	1.2	1.8	0.9	0.2	0.2	0.6	nd	1.6	1.1	0.3	0.1	0.1	0.1	310	10	79	119
N 5S	355.8	218.8	52.7	116.4	8.4	2.9	41.9	77.2	9.8	17.3	2.0	6.1	0.9	2.0	0.3	0.2	1.7	0.7	2.3	1.6	1.4	1.4	0.1	0.5	820	330	140	286
N 5D	31.8	7.2	7.2	9.7	3.8	0.3	12.0	26.1	5.6	0.6	0.9	1.1	1.5	0.8	0.1	0.3	0.9	nd	0.9	0.9	0.3	nd	0.7	0.1	620	20	57	78
N 6S	34.7	6.8	6.8	14.4	7.8	2.5	89.8	24.7	1.0	1.2	4.1	1.6	0.8	0.8	0.2	0.1	0.6	1.7	2.8	0.8	1.0	0.2	0.1	0.1	750	30	23	27
N 6D	3.7	2.0	3.9	9.2	2.5	0.3	23.2	49.9	1.0	0.7	0.6	0.8	1.1	0.5	0.2	0.3	0.4	nd	1.4	1.1	0.2	nd	0.2	0.1	320	10	29	58

Stations were the same as Table II.
Sampling times were the same as Table III.
nd: not detected ($< 0.01\ \mu g l^{-1}$)

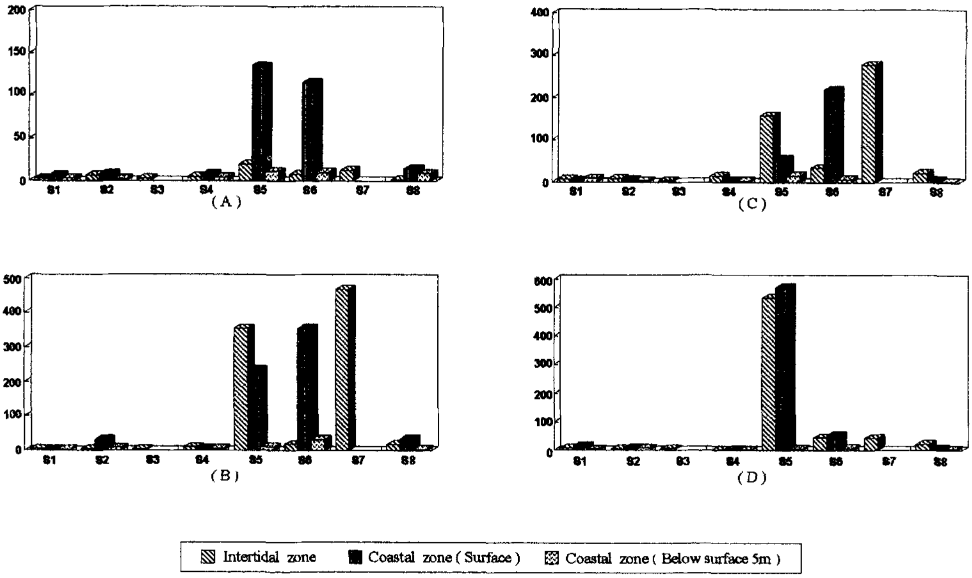

Figure 2 The heavy metal content of iron in sea water of coastal water of northeast Taiwan. (A) in Jan. 1990, (B) in March 1990, (C) in Nov. 1989, (D) in Dec. 1989. Concentrations (vertical scale) are $\mu g l^{-1}$.

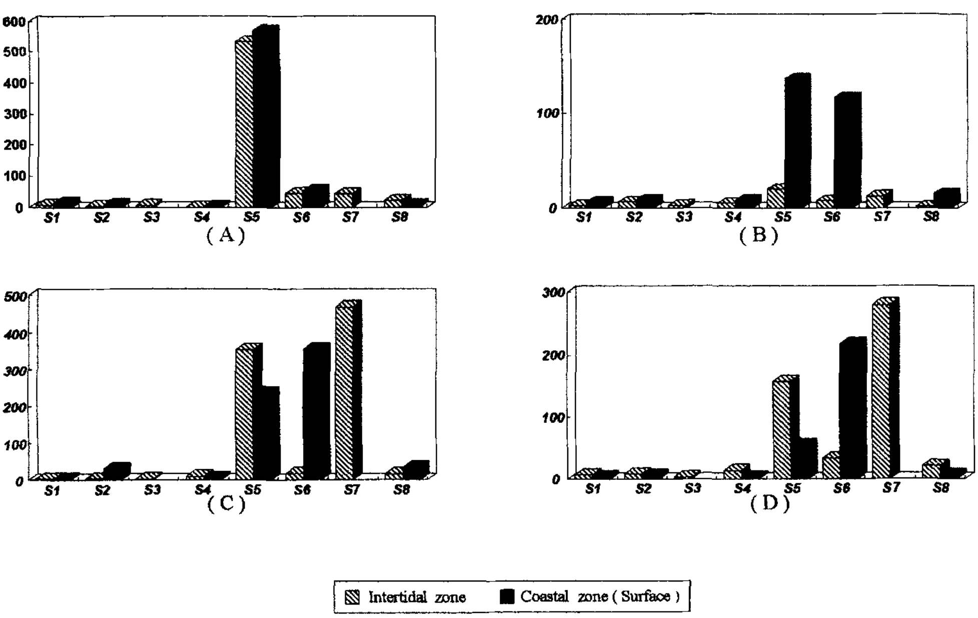

Figure 3 The heavy metal content of copper in sea water of coastal water of northeast Taiwan. (A) in Jan. 1990, (B) in March 1990, (C) in Nov. 1989, (D) in Dec. 1989. Concentrations (vertical scale) are $\mu g l^{-1}$.

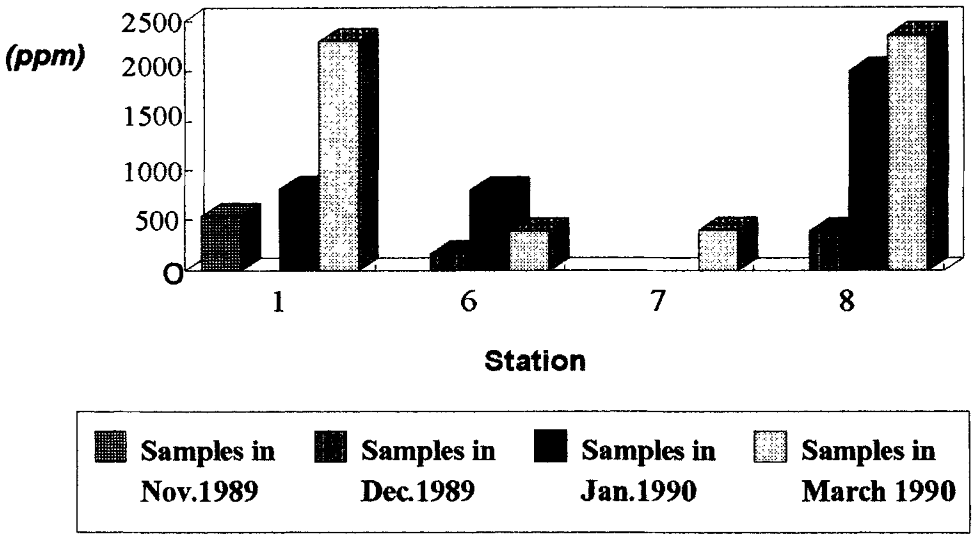

Figure 4 The copper content of algae (Enteromorpha) sampled in coast water of northeast Taiwan.

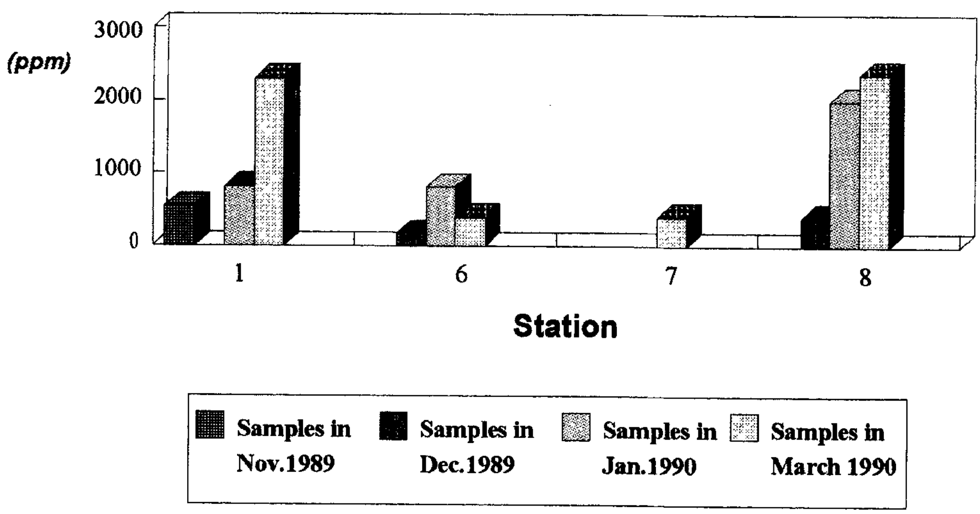

Figure 5 The iron content of algae (Enteromorpha) sampled in coast water of northeast Taiwan.

DISCUSSION AND CONCLUSIONS

The pH values of stations St 5, St 7, N4 and N5 were lower than those of other stations. The concentrations of phosphate, copper, zinc and iron at these stations were higher than at other stations. This may be the result of mining waste water discharged to the sea (Tan, 1990).

The transparency values were lowest at station N4, indicating that the sea water there contains more particulates and soluble materials. The permanent suspension

Table VI The heavy metal content (ppm)* of sediment of northeast inshore coastal water of Taiwan

Station	Date	Cu	Zn	Ni	Cr	Pb	Cd	Fe	Mn
N 1	A	936.4	196.8	13.5	68.0	82.8	nd	210.4	204.0
N 3	A	65.9	46.8	2.0	6.5	11.0	nd	102.7	141.0
N 4	A	610.4	233.5	14.8	52.3	78.3	nd	298.9	175.3
N 2	B	34.1	69.5	18.8	22.0	14.3	nd	267.5	244.0
N 4	C	589.1	235.0	17.5	48.3	64.3	nd	189.3	143.8
N 2	D	67.6	162.8	14.0	17.5	14.8	nd	250.9	227.5
N 4	D	49.1	44.8	1.3	10.0	10.5	nd	233.4	63.3

*wet-weight basis
Sampling times were the same as Table III.
nd: not detected (< 0.01 ppb)

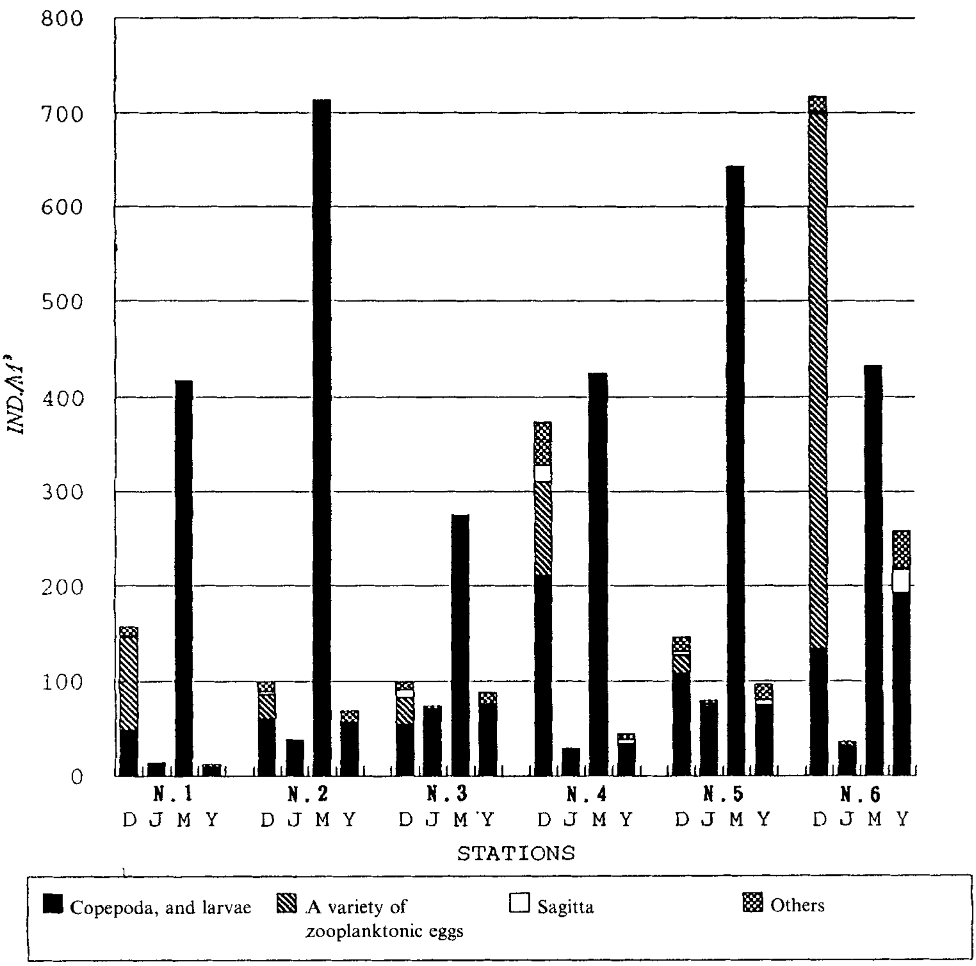

Figure 6 The abundance (individuals·m^{-3}) and dominant zooplankton in the 6 sampling stations off north-eastern Taiwan found on 4 occasions. D: December 5th, 1989, J: January 18, 1990, M: March 23, 1990, Y: May 16, 1990.

Table VII The species number (S) and abundance (A) of benthos (0.5 × 0.5 m^2) at 8 stations in the intertidal zone of northeast Taiwan

Station	Dec. 1989	Jan. 1990	March 1990	May 1990
1	8 (S)*	10 (S)	10 (S)	8 (S)
	39 (A)*	252 (A)	538 (A)	98 (A)
2	–	8 (S)	6 (S)	3 (S)
		144 (A)	69 (A)	20 (A)
3	–	1 (S)	3 (S)	8 (S)
		11 (A)	12 (A)	73 (A)
4	–	1 (S)	–	3 (S)
		5 (A)		216 (A)
5	–	–	–	–
6	5 (S)	–	1 (S)	2 (S)
	24 (A)	1 (A)	55 (A)	
7	–	–	–	–
8	2 (S)	–	4 (S)	1 (S)
	9 (A)		88 (A)	1 (A)

Table VIII Benthic macrofaunal analysis at 3 stations in the near-shore region of northeast coast

Station		Dec. 1989	Jan. 1990	March 1990	May 1990
	Total No.	7	18	3	3
N1	No of individuals	7	66	3	3
	% Amphipoda	0	0	0	0
	Diversity (H')	1.97	2.56	1.10	1.10
	Total No.			21	23
N2	No of individuals	–	–	261	104
	% Amphipoda			6.5	20.2
	Diversity (H')			2.07	2.18
	Total No.	9			19
N4	No of individuals	48	–	–	200
	% Amphipoda	55.1			53.5
	Diversity (H')	1.53			1.75

H′ : Shannon-Wiener index

of solids in the bay and adjacent beach seriously affects marine ecosystems, causing reduction in light penetration and lower phytoplankton abundance inside the bay compared to other areas (Poo and Juang, 1991). From these four samples we found that a variety of zooplankton eggs emerge mostly in December. Copepoda appear in great abundance after January; in March, a single species comprises more than 90% of the community, so diversity is low. As for each station's change between sample dates, except at station N4 which had a large difference of average abundance, the other stations were steady. Thus, the zooplankton of the coastal zone investigated suffered no obvious influence except from Yin-Yang-Hai nearby.

In the intertidal zone, four samples showed that benthic animals consisted largely of Arthropoda, especially Amphipoda, with Mollusca second, with few other groups. The fauna is influenced greatly by the northeasterly seasonal wind. From Ba-Do-Tsz to Shen-Au, stations St 1, 2, 3 had much greater numbers of species and abundance, but St 5 (Shai-Nan-Don sea-shore) had no benthic animals. This probably resulted from the acid waste water discharged off the coast. The process of sampling at four sites along the coast was difficult because of weather conditions, with strong northeasterly seasonal winds and geography. Furthermore, a bottom dredge only samples smaller sized and slower moving benthic animals, such as young crabs and annelids, thus indicating a lower abundance of benthic animals. The bigger and faster species were not sampled; this is the reason for increasing the bias of the sample.

Amphipoda was a dominant group in the Shia-Nan-Don sea-shore but was not found at N1. In an ecosystem, environmental disturbance may lead to a change in the biological community originally present and this leads to a succession phenomenon. Gray (1979) suggested that the species that occur in the most polluted areas have life-history strategies that enable them to tolerate continuous disturbance. A balanced ecosystem generally has slower growth and longer-lived species. When a disturbance occurs, a pioneer community appears with a high growth rate, short life-span and high production (Rhoads *et al.*, 1978). According to Patin (1982), Amphipoda usually occur in heavily polluted areas. These are small in size and have short life-span and we can expect Amphipoda to occur in Shai-Nan-Don area (Chen, 1992).

The mining activity has brought a long-standing impact to Shai-Nan-Don sea shore and this has greatly influenced the ecosystem. Lacking continuous background data, we do not understand what past conditions were but present conditions and future development of it deserves further study.

ACKNOWLEDGEMENTS

The work was financially supported by the Environmental Protection Administration of the R.O.C. (Grant No. EPA-79-003-32-157).

References

Bettinelli, M. (1986) Determination of trace metals in sediment standard reference materials by graphite-furnace atomic absorption spectrometry with a stabilized temperature platform. *Anal. Chem. Acta*, **185:** 109–117.

Brown, V.M. (1968) The calculation of acute toxicity of mixtures of poisons to rainbow trout. *Water Research*, **2:** 723–733.

Castilla, J.C. and E. Nealler (1978) Marine environmental impact due to mining activities of El Salvador Copper Mine, Chile. *Marine Pollution Bulletin*, **9:** 67–70.

Chen, L.H. (1992) The disturbance of sea environment and influence of benthos community in Sui-Nan-Dong. *J. Sci. Hwa Kang*, **9:** 181–203.

Chu, K., T.M. Pan, R.J. Tseng and L.H. Chen (1990) An investigation of water quality and ecology along the coast of northeastern part of Taiwan. EPA report 79.00532-157. (R.O.C.), 104pp.

Dills, G. and D.T. Roger Jr (1974) Macroinvertebrate community structure as an indicator of acid mine pollution. *Environmental Pollution*, **6:** 239–262.

Gray, J.S. (1979) Pollution-induced changes in populations. *Phil. Trans. R. Soc. Lond. B.* **286:** 545–561.

Guan, S.J. (1973) Metallic placer deposits of the Shui-Nan-Tung bay. Institute of Marine Science, Chinese Culture University Press (R.O.C.), 21pp.

Headrich, R.J. (1975) Diversity and overlap as measures of environmental quality. *Water Research*, **9:** 945–952.

Hsu, C.G. and C.J. David (1983) Digestion methods for determination of cadmium and lead in organic and silica-rich sediments. *Anal. Chem. Acta* **153:** 313–318.

Lathrop, J.E. and W.S. Davis (1986) Aquatic sediments. *J. Wat. Pollut Control Fed*, **58:** 684–699.

Lenihan, H.S. (1992) Benthic marine pollution around McMurdo Station, Antarctica: A summary of findings. *Marine Pollution Bulletin*, **25:** 318–323.

Ludwig, J.A. and J.F. Reynolds (1988) *Statistical Ecology*. Wiley, New York, 337pp.
Patin, S.A. (1982) *Pollution and the Biological Resources of the Oceans*. Butterworths, England 289pp.
Poo, W. K. and J.T. Juang (1991) The cause of the landscape of Yin-Yang sea and planning for acid mine drainage abatement. National Central University Press (R.O.C.), 81pp.
Rhoads, D.C., P.L. McCall and J.Y. Yingst (1978) Disturbance and production on the estuaries seafloor. *American Scienctist*, **66:** 577–586.
Sanders, H.L. (1968) Marine benthic diversity: a comparative study. *The American Naturalist*, **102:** 243–282.
Strickland, J.D.H. and T.R. Parsons (1972) *A Practical Handbook of Sea Water Analysis*. Fisheries Research Board of Canada, 167, 31pp.
Tan, P.H. (1990) The cause of the landscape and the sources of the pollution of Yin-Yang Sea in northeastern Taiwan. *Bull. Geogr. Soc. China* (R.O.C.) **18**, 147–165.
Washington, H.G. (1984) Diversity, biotic and similarity indices. *Water Research*, **18:** 654–694.
Wilhm, J.L. and T.C. Dorris (1968) Biological parameters for Quality Criteria. *Bioscience*, **18:** 477–480.