

Temporal and Spatial Variations of Heavy Metal Concentrations in Sediments of the Tainan Coastal Area, Anping Harbor and Tainan Canal, Southwestern Taiwan



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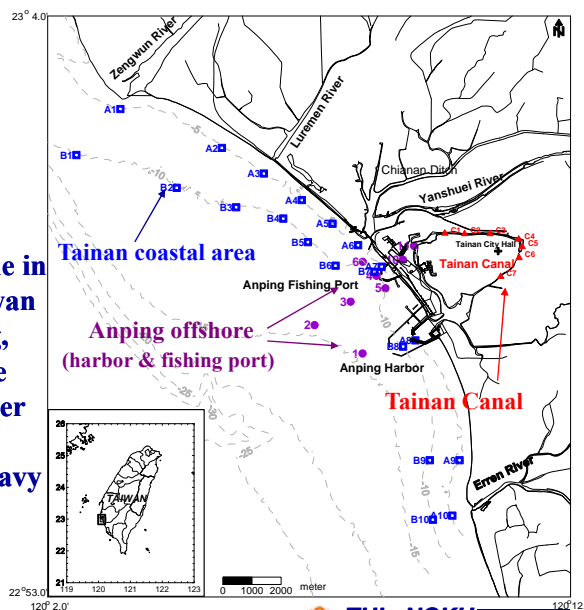
Introduction

- Trace metal pollution is a world-wide problem
- Heavy metal concentrations in coastal sediments can vary widely and difficult to evaluate without normalization
- The knowledge of trace metals contamination in the Tainan coastal sediments and city canal is still limited



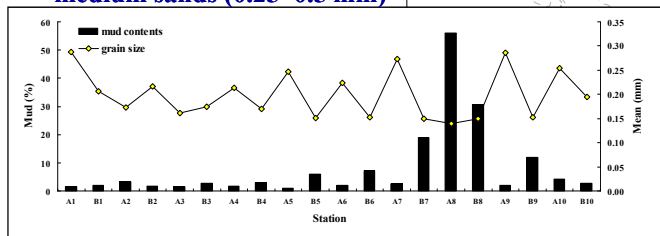
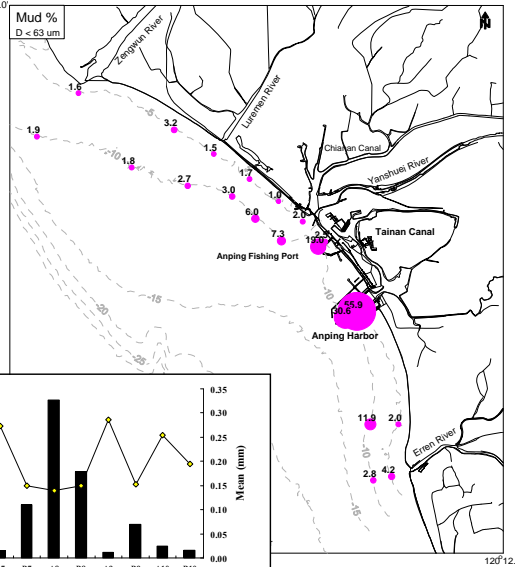
Study Area

- ✓ Tainan coastal area
- ✓ Anping offshore
(Anping Harbor and Fishing Port)
- ✓ Tainan Canal
- Along a straight coastline in the west next to the Taiwan Strait nearly 20 km long, and in the south with the Erren River on the border which has degraded this river to a foul flow of heavy metal pollutants.



Results

- mud contents (< 63µm)
- mean grain size (mm)
- ✓ Smaller mean grain size and elevated mud content were observed close to the Anping Harbor and Port
- ✓ Most sediments within 10-m bathymetry are classified as medium sands (0.25~0.5 mm)



Trace metal concentrations

- ✓ The highest metal concentrations, except for Hg, were found near the entrance of Anping Harbor (B8).
- ✓ For Hg the highest concentration was found near the mouth of Luremen River (A3 and B3).

Trace metal concentrations (mg/kg dry wt.), mud contents (%) and mean grain size (mm) in sediments collected from the Tainan coastal area on 4 April 2004.

Station	Zn	Pb	Cu	Ni	Cr	Hg	Mud contents	Mean grain size
^a A1	49.2	17.0	2.14	20.1	15.4	0.039	1.55	0.287
^b B1	47.6	22.6	<1.32	21.2	14.2	<0.031	1.87	0.206
A2	55.4	17.0	2.14	20.1	12.9	<0.031	3.18	0.173
B2	54.4	22.6	<1.32	21.2	12.9	<0.031	1.79	0.216
A3	55.6	11.5	<1.32	20.1	14.2	0.051	1.48	0.161
B3	58.4	11.5	<1.32	22.3	12.9	0.051	2.74	0.174
A4	57.9	22.5	3.08	21.2	16.6	<0.031	1.69	0.214
B4	54.8	11.5	<1.32	20.1	14.2	0.044	2.95	0.17
A5	59.7	22.5	3.08	24.5	17.9	<0.031	1.02	0.247
B5	62.2	17.1	4.05	22.4	16.7	0.042	5.95	0.151
A6	64.6	11.5	<1.32	22.3	14.1	<0.031	1.97	0.224
B6	66.7	17.1	4.05	22.4	18.0	<0.031	7.28	0.153
A7	66.3	17.1	<1.32	20.1	14.2	<0.031	2.53	0.273
B7	99.8	17.2	7.90	24.8	23.1	<0.031	19.0	0.15
A8 ^c	72.4	17.3	10.8	24.8	19.4	<0.031	55.9	0.139
B8 ^c	113	28.9	28.5	28.6	33.7	0.044	30.6	0.149
A9	82.7	22.6	19.2	24.5	11.7	<0.031	1.95	0.286
B9	48.7	11.5	5.92	13.5	9.19	<0.031	11.9	0.153
A10	85.4	22.7	11.7	25.8	15.5	<0.031	4.15	0.287
B10	64.8	17.1	5.93	19.0	11.7	<0.031	2.82	0.206

Tainan coast

^aStations are located at bathymetry of 5 m, and ^b10 m of the Tainan coastal area, ^cin the Anping Harbor, southwestern

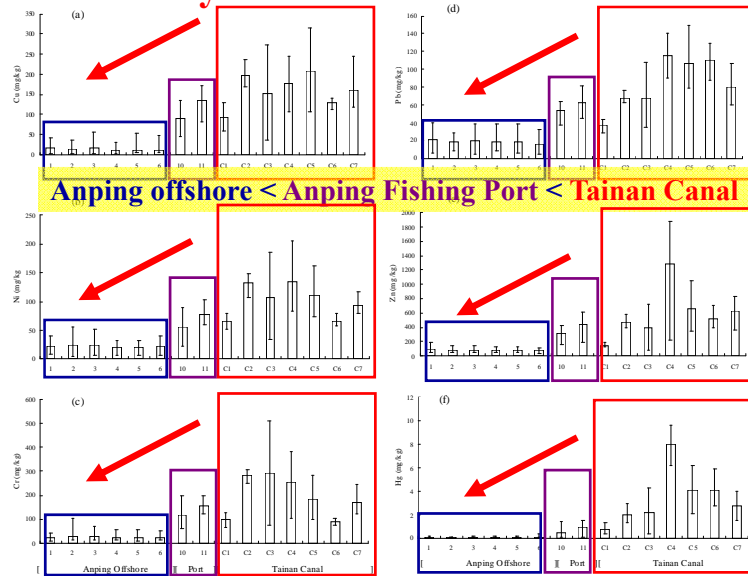
Comparison

Trace metal concentrations in sediments collected from the Anping offshore (the Anping Harbor and Fishing Port), and Tainan Canal (mg/kg dry wt.)

Station		Zn	Pb	Cu	Ni	Cr	Hg	As
Harbor	1	Mean 86.3	20.7	15.2	23.0	22.7	0.058	6.95
	(20)	Range 51.4 - 190	6.12 - 40.0	4.21 - 42.8	8.08 - 39.7	9.56 - 41.1	<0.020 - 0.180	2.67 - 10.1
	2	Mean 78.1	18.6	13.0	23.9	26.2	0.043	6.69
	(20)	Range 51.1 - 138	8.34 - 28.3	4.42 - 37.2	<4.00 - 55.3	12.4 - 106	<0.020 - 0.109	2.81 - 11.5
	3	Mean 81.8	19.8	15.1	24.2	27.2	0.056	6.63
	(20)	Range 43.2 - 149	4.42 - 38.3	3.52 - 56.8	6.19 - 50.3	12.3 - 69.7	<0.020 - 0.158	2.54 - 12.4
Anping offshore	4	Mean 77.1	18.4	11.7	20.2	23.0	0.072	6.66
	(20-22)	Range 52.0 - 123	8.34 - 38.2	3.95 - 31.1	6.30 - 31.6	12.1 - 55.2	<0.020 - 0.223	3.82 - 14.4
	5	Mean 76.3	18.2	12.4	20.9	22.2	0.090	7.11
	(20-22)	Range 42.1 - 131	5.85 - 38.4	5.10 - 53.6	5.97 - 32.0	10.9 - 53.7	<0.020 - 0.220	3.54 - 13.5
	6	Mean 69.3	16.3	12.2	21.1	23.7	0.066	6.75
	(20-22)	Range 37.6 - 114	4.43 - 31.8	5.24 - 48.9	5.75 - 39.7	12.2 - 49.6	0.020 - 0.316	3.72 - 17.8
Fishing Port	10	Mean 320	53.5	89.5	55.4	117	0.439	10.6
	(8)	Range 158 - 426	37.7 - 63.6	44.2 - 135	22.7 - 89.4	62.5 - 198	0.031 - 1.39	3.90 - 17.6
	11	Mean 438	62.6	135	76.2	156	0.905	9.58
(8)	Range 187 - 609	45.5 - 81.7	80.7 - 172	59.2 - 102	124 - 197	0.105 - 1.54	4.96 - 13.8	
Tainan Canal	C1	Mean 150	37.1	91.7	66.3	98.7	0.701	8.60
	(3)	Range 130 - 187	28.6 - 43.7	60.2 - 130	52.4 - 79.7	67.1 - 126	0.358 - 1.32	7.22 - 10.8
	C2	Mean 475	68.2	198	132	285	1.94	12.3
	(3)	Range 391 - 573	62.8 - 76.5	168 - 237	107 - 147	249 - 309	1.30 - 2.96	11.0 - 13.1
	C3	Mean 384	67.2	151	107	291	2.20	9.60
	(3)	Range 85.3 - 716	34.2 - 108	36.9 - 272	34.7 - 185	74.3 - 509	0.374 - 4.24	7.00 - 12.0
	C4	Mean 1289	116	178	134	255	8.04	26.2
	(3)	Range 212 - 1877	89.9 - 140	108 - 244	82.8 - 205	102 - 383	6.18 - 9.67	25.4 - 27.3
	C5	Mean 651	106	208	110	186	4.08	14.6
	(3)	Range 349 - 1046	78.8 - 149	108 - 315	73.5 - 162	98.7 - 284	2.06 - 6.23	12.4 - 17.8
	C6	Mean 518	111	128	66.1	87.3	4.12	10.5
	(3)	Range 388 - 709	87.3 - 129	112 - 140	57.9 - 78.9	77.1 - 105	2.74 - 5.92	8.18 - 13.1
	C7	Mean 631	80.2	161	92.3	172	2.71	15.0
	(3)	Range 369 - 838	60.3 - 106	119 - 245	79.1 - 117	123 - 248	1.51 - 4.03	14.4 - 15.5

Comparison with our study area, the sediment metal concentrations follow the order:
Tainan Canal > Anping Fishing Port > Anping Harbor > Tainan coast

Sediment heavy metals



Igeo

Muller's geo-accumulation indexes

- ✓ The elevated Igeo values also indicate that the Canal sediments were either moderately or strongly contaminated with Zn and Hg.

Igeo classes of metals for each station studied in the Tainan Canal.

Metal	Zn	Pb	Cu	Ni	Cr	Hg	As
I_{geo} class^{mean}							
C1 ^a	1	1	1	0	0	1	0
C2	2	2	2	1	1	2	0
C3	2	2	2	0	1	2	0
C4	4	2	2	1	1	4	1
C5	3	2	2	0	1	3	0
C6	2	2	1	0	0	3	0
C7	3	2	2	0	1	3	0
I_{geo} class^{max}							
C1	1	1	1	0	0	2	0
C2	3	2	2	1	2	3	0
C3	3	2	2	1	2	3	0
C4	4	3	2	1	2	5	1
C5	3	3	3	1	1	4	1
C6	3	3	1	0	0	4	0
C7	3	2	2	0	1	3	1

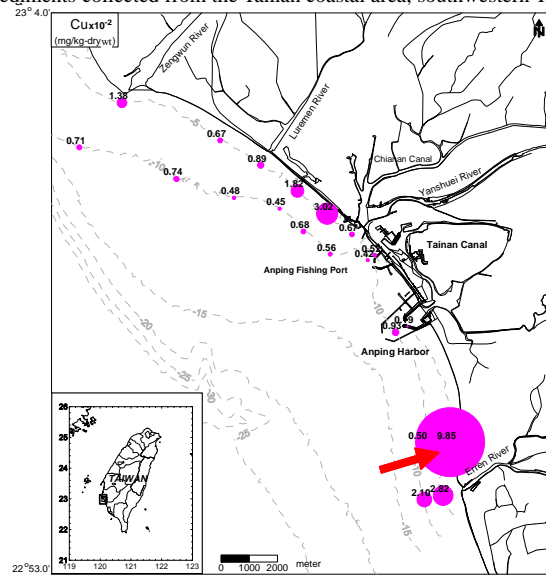
^a Station number, ^{mean} Metal mean concentrations, ^{max} Metal maximum concentrations
Geo-accumulation index (Muller, 1979)

Class: 0 = unpolluted, 1 = unpolluted to moderately polluted, 3 = moderately to strongly polluted, 4 = strongly polluted, 5 = strongly to very strongly polluted, 6 = very strongly polluted.

Normalization -Cu

- ✓ The highest normalized Cu concentration was found at the station just north of the Erren estuary.
- ✓ This area is known for past Cu pollution concern, as a consequence of the discharge of untreated effluent from the metal-scrap reprocessing industry in the Erren River.

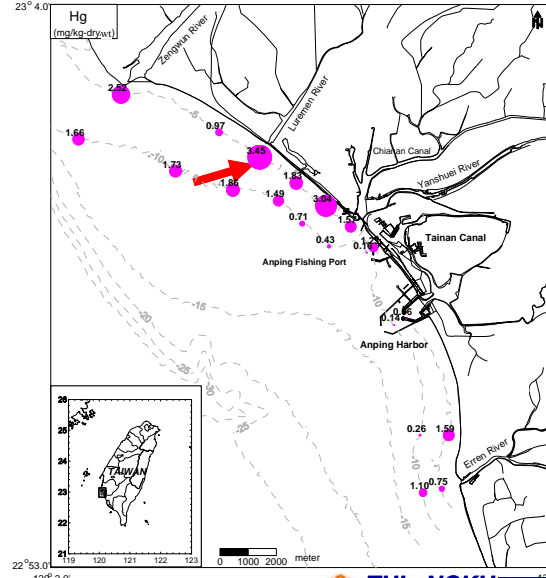
Distribution of Cu concentrations normalized by mud contents in sediments collected from the Tainan coastal area, southwestern Taiwan.



Normalization -Hg

- ✓ A slightly higher normalized Hg value was found at a station (3A) situated near Luremen estuary where a petrochemical plant is located.
- ✓ The site has been declared as a remediation site, and the target pollutants include Hg.

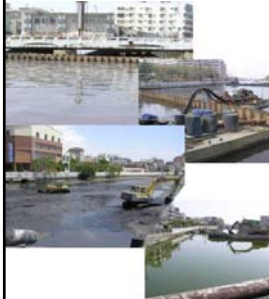
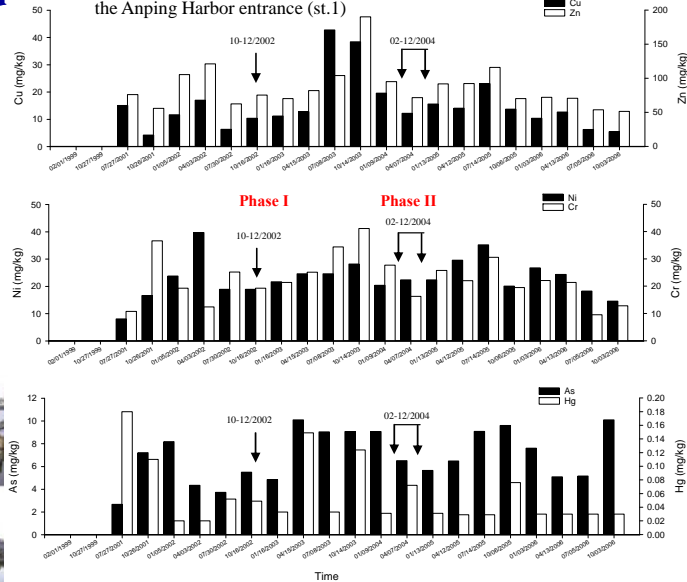
Distribution of Hg concentrations normalized by mud contents in sediments collected from the Tainan coastal area, southwestern Taiwan.



Dredging period

- ✓ No clear trends during phase I and II of dredging of the Canal, and no abnormal concentrations were observed during the dredging period.
- ✓ It indicates the metal contaminated sediments are trapped in the Canal removed via dredging.

Distribution of heavy metal concentrations in sediments collected from the Anping Harbor entrance (st.1)



Conclusions

- **Smaller mean grain size and elevated mud content are observed close to the Anping Harbor and Port.**
- ✓ Along the Tainan coast, most sediments within 10-m bathymetry are classified as medium sands.
- **High metal concentrations in the Canal sediments were found, in a consequence of severe contamination by untreated or partially treated industrial and domestic effluents in Tainan City in the past.**
- ✓ The elevated Igeo values also indicated that the Canal sediments were either moderately or strongly contaminated with Zn and Hg.
- **Polluted metals in the Canal sediments are not transported to the vicinity of Tainan coastal area, and rather are trapped in the Tainan Canal, and then via dredging machines to dredged and removal.**

Acknowledgements



Methods

- **Sampling**

- ✓ The sediment samples were collected by Birge-Ekman grab and dredger.
- ✓ All surface sediment samples were placed in clean plastic bags and immediately stored on ice.

- **Metals and sieve analysis**

- ✓ Sieve shaker analysis based on ASTM D422 method produced results of 7 size fractions.
- ✓ Digestion of sediments for trace metals analysis was by a microwave digestion technique using aqua regia
- ✓ Taiwan EPA methods (AAS: Atomic absorption spectroscopy).

