Environmental Quality Assessment of Seawater and Sediment in Futou Bay, Southeast China

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Keywords: Seawater, sediment, environmental quality, Futou Bay

Abstract: In December 2014, the quality of seawater and sediments in Futou Bay was investigated. The results showed that the main pollutants in seawater were dissolved inorganic nitrogen (DIN), and its concentration ranged from 0.294 to 0.369 mg/L. The active phosphate (PO_4-P) concentration met the second class of Seawater Quality Standard. Other parameters were all within the first class of Seawater Quality Standard. The waters in study area have reached the eutrophication state, and nitrogen (N) is a limiting factor. The parameters in the sediments all met the first class of Sediment Quality Standard. Correlation analysis showed that increased nitrate nitrogen (NO_3-N) will reduce dissolved oxygen (DO) in the sea. Oil in seawater, mercury and arsenic in sediments may not come from terrestrial.

1 INTRODUCTION

Futou Bay is located in the southeast of Fujian province between Liuao peninsula and Gulei peninsula. The bay is 10 km wide from east to west, 16 km long from north to south, and has an area of about 160 km^2. The coastal area is rich in aquatic products. The northern part of the Futou Bay is a tourist and entertainment area. The southern waters are close to Gulei industrial and urban construction area, where some industrial projects have started. To date, there have been no reports of environmental quality in seawater and sediment of Futou Bay. A systematic survey of the physical and chemical characteristics of water bodies and sediments has been conducted in December 2014, to assess the environmental quality. This provide the technical support required for environmental protection, sustainable development and utilization.

2 SAMPLING, ANALYSIS AND EVALUATION METHODS

2.1 Sample Collection

In December 2014, the surface water samples of 12 stations were collected in Futou Bay. Surface sediment samples were collected at stations 1, 5, 6, 7, 9 and 12. The sample stations are shown in figure 1.

The collection and preservation of seawater samples were carried out in accordance with Marine monitoring specifications (Ma et al., 2007a). The surface sediments were collected with a grab bucket dredger. A plastic spoon was used to extract the undisturbed surface mud sample. Sediment samples for analysis of sulfide components were sealed in brown glass bottle, and preserved below 4 ºC. Sediment samples for analysis of trace metals and organic carbon were sealed in vinyl bags, and preserved under 0 ~ 4 ºC. After drying, samples were crushed by agate mortar, sieved via 160 mesh sieve, mixed and stored for trace metal analysis.

Chen, S., Wang, W. and Li, Q.
Environmental Quality Assessment of Seawater and Sediment in Futou Bay, Southeast China.
In *Proceedings of the International Workshop on Environment and Geoscience (IWEG 2018)*, pages 110-114
ISBN: 978-989-758-342-1

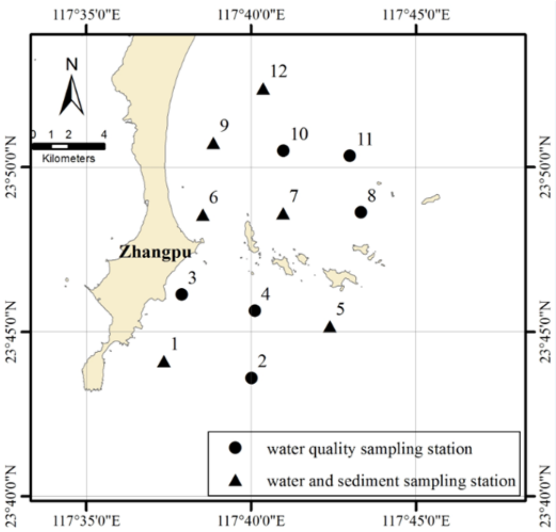

Figure 1: Sampling station map of Futou Bay.

2.2 Sample Analysis

Sea water and sediment quality were analyzed according to Marine monitoring specifications (Ma et al., 2007a; Ma et al., 2007b). Seawater quality parameters include pH, salinity, dissolved oxygen (DO), chemical oxygen demand (COD), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), ammonia nitrogen (NH_3-N), active phosphate (PO_4-P), oil and suspended particulate matter (SPM). The surface sediment quality parameters include copper (Cu), lead (Pb), zinc (Zn), mercury (Hg), arsenic (As), organic carbon and sulfide.

2.3 Evaluation Methods

2.3.1 Assessment of Sea Water and Sediment Quality

Sea water and sediment quality were assessed using the following formula:

$$P_{ij}=C_{ij}/C_j \tag{1}$$

For DO, the formula was as follows:

$$P_{iDO} = \frac{|DO_f - DO_i|}{DO_f - DO_s} \left(DO_i \geq DO_s\right)$$

$$P_{iDO} = 10 - 9 \times \frac{DO_i}{DO_s} \left(DO_i < DO_s\right) \tag{2}$$

Where, P_{ij} is the quality index of j pollutants at point i; C_{ij} is the average of the measured concentration of j pollutants at point i; C_j is the evaluation limit value of j pollutants. DO_f is the saturated dissolved oxygen concentration value, DO_i is the mean measured concentration of DO at point i; DO_s is the evaluation limit value of DO; and P_{iDO} is the quality index of DO at point i.

2.3.2 Eutrophication

The eutrophication status index (E) was used to evaluate the nutritional status of sea area (Zou et al., 1983). The following formula was used:

$$E=C_{COD}\times C_{DIN}\times C_{DRP}/4500 \tag{3}$$

Where, E was the value of eutrophication, C_{COD}, C_{DIN}, C_{DRP} were measured values of COD(mg/L), DIN(mg/L) and PO_4-P(mg/L). If E is greater than or equal to 1, it indicates that the water body has reached eutrophication level.

2.3.3 Correlation Analysis

Correlation analysis was used to analyze the correlation between seawater quality indicators and marine sediment quality indicators. A $p<0.1$ indicates that the correlation is significant (Zhang et al., 2003). The analysis was conducted in SPSS Statistics.

3 RESULTS AND DISCUSSION

3.1 Water Quality and Eutrophication Level

According to seawater quality standards (GB3097-1997) (State Environmental Protection Administration, 1997), the main pollutants in the surface seawater of the study area were DIN, and its concentration ranged from 0.294 to 0.369 mg/L, with an average value of 0.338mg/L. NO_3-N was the main form of DIN. The PO_4-P concentration lies within the second class of seawater quality standard, whereas the other indicators such as pH, DO, COD and oil lie within the first class. The results of surface water quality monitoring are given in Table 1.

Table 1: Statistical descriptive of water quality and surface sediment quality parameters.

Categories	Indicators	Units	Average±SD	Median
Water quality parameters	pH	mg/L	8.163±0.013	8.165
	S	mg/L	30.191±0.081	30.219
	DO	mg/L	8.575±0.138	8.525
	COD	mg/L	0.49±0.229	0.490
	SPM	mg/L	34.342±12.786	31.400
	PO^4-P	mg/L	0.029±0.0008	0.029
	NO^3-N	mg/L	0.317±0.019	0.318
	NO^2-N	mg/L	0.004±0.0015	0.004
	NH^4-N	mg/L	0.018±0.012	0.013
	Oil	μg/L	14.233±2.112	14.400
sediment quality parameters	Organic carbon	(%)	0.240±0.226	0.160
	Sulfide	(mg/kg)	18.800±17.395	18.800
	Cu	(mg/kg)	3.542±3.910	1.625
	Pb	(mg/kg)	14.233±6.679	11.650
	Zn	(mg/kg)	25.833±20.855	16.350
	Hg	(mg/kg)	0.079±0.037	0.068
	As	(mg/kg)	6.083±2.381	5.300

Compared with other bays in Southeast China (Yan et al., 2012; Ouyang et al., 2014; Jiang et al., 2015; Chen et al., 2010), the content of DIN and PO_4-P in the surface water of Futou Bay is higher than that in Dongshan Bay and Jiuzhen Bay, but lower than Xiamen Bay and Quanzhou Bay, as shown in Table 2.

Table 2: Comparison of DIN and DRP concentration in surface water in different bays.

c/mg•L^{-1}		Source
DIN	PO_4-P	
0.338	0.029	This research
2.070	0.047	(Yan et al., 2012)
0.370	0.039	(Ouyang et al., 2014)
0.100	0.016	(Jiang et al., 2015)
0.283	0.023	(Chen et al., 2010)

The eutrophication status index (E) ranged from 0.38 to 2.49. The E values in stations 2, 3, 5, 7, 10 and 12 were 1.13, 1.21, 1.08, 1.28, 2.49 and 1.09, respectively, indicating that the water body at these stations were in eutrophic conditions. The maximum value appeared in station 10 (E value was 2.49), suggests eutrophication is probably due to domestic and agricultural sewage input and aquaculture in coastal area.

3.2 Surface Sediment Quality

The average content of Cu, Pb, Zn, Hg and As in surface sediments of Futou Bay were 3.54, 14.2, 25.8, 0.079 and 6.1 mg/kg. The average content of organic carbon and sulfide were 0.17% and 7.6 mg/kg. These results indicate that the sediment of Futou Bay met the first class of sediment quality standard based on the Marine sediment quality standards (GB18668-2002) (Ma et al., 2007c). The results of surface sediments are presented in Table 3. DRP (dissolved reactive phosphorus) is the content of PO_4-P.

The content of Cu, Pb and Zn in the surface sediments of Futou Bay were generally lower than that of other bays in Southeast China, and the content of Hg and As were at medium level, as shown in Table 3.

Table 3: Comparison of trace metal concentration in different bays.

Research area	ω/(mg/kg)					Source
	Cu	Pb	Zn	Hg	As	
Futou Bay	3.54	14.2	25.8	0.079	6.1	This research
Quanzhou Bay	16.2	31.8	75.7	0.044	1.15	Fujian gulf Chronicles
Xiamen Bay	24.5	41.5	113.3	0.057	6.47	
Dongshan Bay	13.6	31.9	78.4	0.091	2.03	
Jiuzhen Bay	8.64	136	57.5	0.028	6.29	

Table 4: Correlation analysis of water quality parameters.

Parameters	pH	S	DO	COD	SPM	PO_4-P	NO_3-N	NO_2-N	NH_3-N	Oil
PH	1									
S		1						0.598*		
DO			1				-0.770**			
COD				1						
SPM					1					
PO_4-P						1				
NO_3-N							1			
NO_2-N								1		
NH_3-N									1	-0.689*
Oil										1

* indicates a significant correlation at the 0.05 level (bilateral), ** indicates significant correlation at 0.01 level (bilateral)

3.3 Relationship Between Water Quality And Surface Sediment Quality

In the sampling period, DO was negatively correlated with NO_3-N (Table 4), which indicated that the content of DO in sea area with high NO_3-N content was low. Oil was negatively correlated with NH_3-N, indicating that the source of oil may come from sea activities rather than land sewage. We cannot reasonably explained the relationship between salinity and NO_2-N (salinity was positively correlated with NO_2-N).

In the sampling period, Cu was positively correlated with Pb and Zn, Pb was positively correlated with Zn (Table 5), which indicated that Cu, Pb and Zn in surface sediment had similar origin.

Table 5: Correlation analysis of surface sediment quality parameters.

Parameters	Cu	Pb	Zn	Hg	As
Cu	1	0.987**	0.998**		
Pb		1	0.987**		
Zn			1		
Hg				1	
As					1

* indicates a significant correlation at the 0.05 level (bilateral), ** indicates significant correlation at 0.01 level (bilateral).

In the sampling period, DO in water was positively correlated with Hg in surface sediment, PO4-P was negatively correlated with As (Table 6), which indicated that the source of Hg and As may not come from land sewage.

Table 6: Correlation analysis of water quality parameters and surface sediment quality.

Parameters	Cu	Pb	Zn	Hg	As
pH					
S					
DO				0.891*	
COD					
SPM					
PO_4-P					-0.890*
NO_3-N					
NO_2-N					
NH_3-N					
Oil					

* indicates a significant correlation at the 0.05 level (bilateral), ** indicates significant correlation at 0.01 level (bilateral).

4 CONCLUSIONS

The main pollutant in the surface seawater of Futou Bay were DIN, and its concentration ranged from 0.294 to 0.369 mg/L. The concentration of PO_4-P met the second class of seawater quality standard, whereas other indicators such as pH, DO, COD and oil met the first class of seawater quality standard. The water body in the study area has reached eutrophication state and N was the limiting factor. Compared with other bays, the concentrations of DIN and PO_4-P were higher than that in Dongshan Bay and Jiuzhen Bay, but lower than Xiamen Bay and Quanzhou Bay.

The average concentration of Cu, Pb, Zn, Hg and As in the surface sediments of Futou Bay were 3.54, 14.2, 25.8, 0.079, and 6.1 mg/kg. The average concentration of organic carbon and sulfide were 0.17% and 7.6 mg/kg, respectively. These results indicate that the sediment of the Futou Bay lies within the first class of sediment quality standard. The content of Cu, Pb and Zn in the surface sediments of Futou Bay were generally lower than that of other bays in Southeast China, and the content of Hg and As were at medium level.

Increased NO_3-N content will reduce dissolved oxygen in the sea. Oil in seawater, Hg and As in sediment may not come from terrestrial.

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