TRACING METHOD OF NATURAL SEDIMENTS BY NEUTRON ACTIVATION

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(Received January 1991)

ABSTRACT

A new method of NAA for sediment movement study is presented in this paper. Through analyzing the natural sediment, the information about natural tracing agents has been obtained, which can show the direction of sediment movement and relative discharge of sediment transportation. Test results in some areas, such as Shantou Harbour and Hangzhou Bay, are in good agreement with those from normal hydrologic measurements and some results are not obtainable with the latter. The NAA is economical, practical and reliable, and should be widely used in engineering practice.

Keywords: Tracing method Natural sediment Neutron activation NAA

I . INTRODUCTION

In coastal engineering, the source, transportation and deposition of sediment are the main problems to be solved. Because of the generality, researchers and engineers have shown a great interest in the above problems for many years and they have carried out extensive studies in theory and practice and obtained a lot of useful data. But much more information in sediment transportation is needed[1]. There are some problems which can't be solved with physical models, and need to be studied with the method of tracing, e.g. mineral tracing, tracing of fluorscencer, tracing of radioactive isotopes as well as NAA. The :e tracing methods have their advantages and defects in practice. Take the tracing of radioactive isotopes for example, it can be divided into natural and artificial radioisotope tracing, the former only works on the condition that there exists a natural tracer in the sediment in the field, and this tracing method was used by Kamel et al.[2] and Sakoakini[3]; the latter has been used less since 1970 because of the harmful radiation and environmental pollution.

Researchers began to use NAA to study sediment movement around 1970s and the method was successfully used by U.S.Army Corps of Engineers in North San Francisco Bay in 1974[4]. Its main advantages are its harmlessness, long tracing time and reliable data; defects are extensive field work and expensiveness, so it can't be used widely. To make full sue of the advantages and avoid the defects of NAA, an economical, pracical and reliable method- NAA for natural sediment- has been developed through a series of laboratory and field tests.

Ⅱ. PRINCIPLE OF THE METHOD

The sediment in rivers is the product of weathering of surface rocks in various valleys. Because the components of the rocks in different valleys are not the same, the contents of various elements in the sediment in rivers are different. Besides, different climate, different distribution of rainfall and different vegetation bring about different discharges of sediment from different rivers. After a river reaches the sea, the convection, turbulence and diffusion of currents mix up the sediment thus the sediment shows the characteristics of the sediments from different sources. Different hydraulic conditions bring about different characteristics of sediment even in the same river. The study of the process of sediment transportation is on the basis of variation of the characteristic values of the moving sediment.

Through neutron activation analysis of natural sediment, dozens of kinds of elements can be obtained (most of them can be used as natural tracing agents). The data of sediment movement can be obtained through analyzing the compositions and the characteristic values of sediment. The method, also named "the method of natural tracing agent", has been adopted in the experiments at Shantou Harbour, Hangzhou Bay and the reach of Grand Canal at Changzhou of Jiangsu Province, and the results are satisfactory.

Ⅲ. FIELD TEST

1. Sediment movement in Shantou Harbour

With the economic development and development of foreign trade, Shantou Harbour is in need of expansion. But the shallow channel outside this harbour is a barrier to the expansion. In Aug.1977, the channel was dredged to the depth of − 5.5m, but the measurement in May, 1978 showed that the channel returned to the previous depth due to sedimentation. A lot of studies on the source of sediment and regularity of erosion and deposition in the channel was done, and some useful results were obtained. The NAA was used in the area for the first time[5].

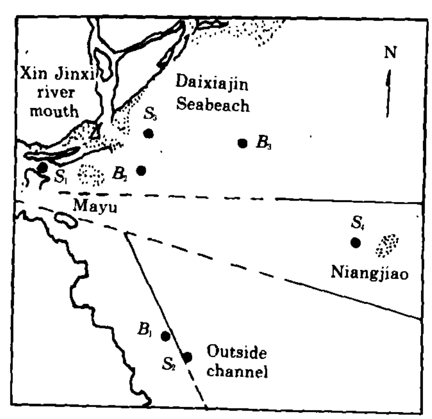

Fig.1 Point of sampling in Shantou harbour

In Mar.1985, three bed- load samples $B_1 - B_3$ and four suspended load samples $S_1 - S_4$ were taken in the field. The locations of sampling are shown in Fig.1. The NAA for the seven samples were carried out, and the results are listed in Table 1.

Table 1

Result of neutron activation analysis for samples from Shanton Harbour (ppm)

No.	Elements	S_1	S_2	S_3	S_4	B_1	B_2	B_3
1	Fe	51180	51100	52200	52200	22432	34800	39947
2	Ca	6192	6053	6442	6314	5114	8087	7008
3	Ba	452	422	475	481	340	387	370
4	Ce	179	172	150	179	75.3	136	140
5	Rb	171	172	167	168	134	157	166
6	La	102	98.9	87.7	104	43.2	73.8	76.3
7	Zr	88.4	98.3	102	88.6			
8	Cr	64.5	62.3	79.3	65.0	35.2	46.8	52.4
9	Nd	55.8	61.1	44.1	48.1	46.6	75.8	69.6
10	Th	38.7	39.4	33.7	39.4	23.6	36.8	29.8
11	Ni	37.3	31.5	49.7	26.3	26.4	32.8	23.6
12	Sc	18.3	18.3	19.0	18.5	7.78	11.9	14.3
13	Br	18.3	60.6	47.0	30.5	18.7	34.9	41.4
14	Co	15.0	14.9	16.0	15.6	5.84	7.9	10.7
15	Sm	14.1	13.2	11.7	14.0	5.93	10.2	10.6
16	Cs	9.92	10.1	10.0	10.2	4.12	5.61	7.10
17	U	7.07	7.92	5.23	6.10	6.71	11.7	6.81
18	Hf	4.78	4.75	4.22	4.41	13.8	28.9	9.2
19	Yb	4.60	4.17	3.57	4.47	2.79	6.09	3.05
20	Ta	2.72	2.34	1.99	2.53	1.90	3.29	2.43
21	Eu	2.26	2.32	1.88	2.22	0.95	1.39	1.61
22	Tb	1.82	1.42	1.27	1.35	0.75	1.31	1.16
23	Sb	1.12	1.23	1.00	2.71	0.96	0.77	0.87
24	Lu	0.86	0.80	0.67	0.82	0.64	1.29	0.70

Table 2

Comparison of element contents in samples

No.	Elements	B_2/B_1	B_3/B_1	B_3/B_2	S_1/S_2	S_3/S_2	S_4/S_2	S_3/S_1	S_4/S_1	S_3/S_4
1	Fe	1.55	1.78	1.15	1.01	1.02	1.02	1.01	1.01	1.00
2	Ca	1.58	1.37	0.87	1.02	1.06	1.04	1.04	1.02	1.02
3	Ba	1.14	1.09	0.96	1.07	1.13	1.14	1.05	1.06	0.99
4	Ce	1.81	1.86	1.03	1.04	0.87	1.04	0.84	1.00	0.84
5	Rb	1.17	1.24	1.06	1.00	0.97	0.98	0.98	0.98	0.99
6	La	1.71	1.77	1.03	1.07	0.89	1.05	0.86	1.02	0.84
7	Zr				0.90	1.04	0.90	1.15	1.00	1.15
8	Cr	1.33	1.49	1.12	1.04	1.27	1.04	1.23	1.01	1.22
9	Nd	1.63	1.49	0.92	0.91	0.72	0.79	0.70	0.86	0.92
10	Th	1.56	1.26	0.81	0.98	0.86	1.00	0.87	1.02	0.86
11	Ni	1.24	0.89	0.72	1.18	1.58	0.84	1.33	0.71	1.89
12	Sc	1.53	1.84	1.20	1.00	1.04	1.01	1.04	1.01	1.03
13	Br	1.87	2.21	1.19	0.30	0.78	0.50	2.57	1.67	1.54
14	Co	1.35	1.87	1.35	1.01	1.07	1.05	1.07	1.04	1.03
15	Sm	1.72	1.79	1.04	1.07	0.89	1.06	0.83	0.99	0.84
16	Cs	1.37	1.72	1.25	0.98	0.99	1.00	1.01	1.03	0.98
17	U	1.74	1.01	0.58	0.89	0.66	0.77	0.74	0.87	0.86
18	Hf	2.09	0.67	0.32	1.01	0.89	0.93	0.88	0.92	0.56
19	Yb	2.18	1.09	0.50	1.10	0.86	1.07	0.78	0.97	0.80
20	Ta	1.73	1.28	0.74	1.16	0.85	1.08	0.72	0.93	0.79
21	Eu	1.46	1.69	1.16	0.97	0.81	0.96	0.83	0.98	0.85
22	Tb	1.66	1.47	0.89	1.28	0.89	0.95	0.70	0.74	0.94
23	Sb	0.80	0.91	1.34	0.91	0.81	2.20	0.89	2.42	0.37
24	Lu	2.02	1.09	0.54	1.08	0.84	1.03	0.78	0.95	0.82
Average		1.61	1.52	1.16/1.55*	1.08	1.19*	1.12	1.23*	1.18	1.28*

The contents of 23 elements in 3 bed- load samples and those of 24 elements in 4 suspended load samples are compared in Table 2. After statistical analysis according to the data of Table 2, we can say that the bed- loads at the Xing Jingxi Estuary head in SE direction first, then mix with the bed- loads coming from Diaxiajing Shoal and finally enter the channel. The suspended loads in the channel come from two directions, from Mayu and from Niangjiao.

The optimized fitting of the data with computer[7] shows that the ratio of the suspended load to bed- load No.1 is about 37%. The analysis of the data with fuzzy theory also shows that the ratio is about 35%[6]. The results obtained with heavy mineral analysis by Qingdao Oceanographic Institute[8], South China Oceanographic Institute and Science and Technology Institute, Guangzhou Bureau of Navigation are in agreement with the results in this paper.

2. Bed—load movement along north bank of Hangzhou bay

The development of Shanghai Harbour needs the study of the bed- load movement along the north bank of Hangzhou Bay[9]. 27 bed- load samples along the bank were taken in Nov.1987, and the locations of sampling are shown in Fig.2

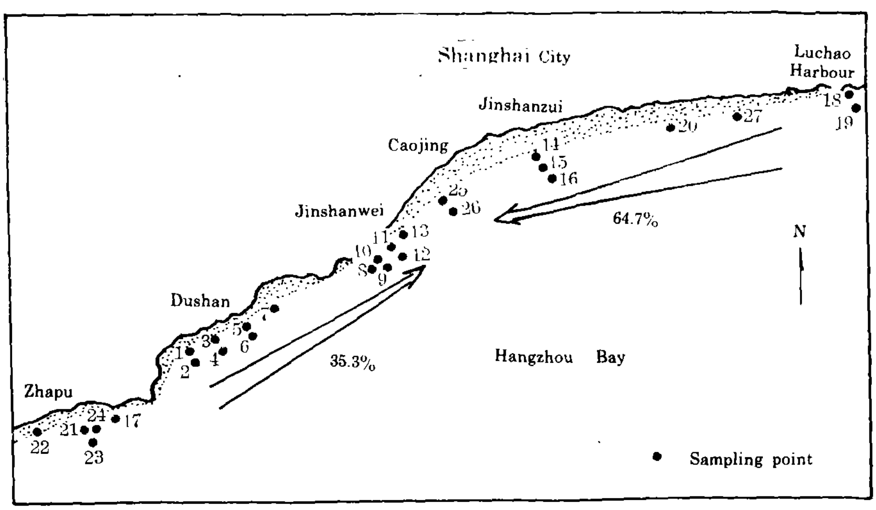

Fig.2 Direction of bed—load movement and relative discharges along the north bank of Hangzhou bay

All the samples were measured and the contents of 25 elements in each sample were obtained. The results are listed in Table 3, which shows clearly the situation of sediment movement. Furthermore, a method for estimating the relative discharge of sediment transportation, i. e. the ratio- area ($R-A$) method is developed.

$$R=\frac{1}{n}\ \Sigma_{n=1}^{n} r_n \qquad (n\geqslant 14,\ r_n>1)$$

where n is number of elements; r_n is ratio of contents of the same element content in two samples. The A means the area between two isobaths and two lines passing the

Table 3

Number and sum of the ratios of contents of same element in two sample larger than 1

No.	1	2	3	4	5	6	7	8	9	10	11	12	13
				13	15	18	18	20			16	18	17
1				15.52	16.79	22.11	21.58	26.30			18.53	21.87	21.84
	15			15		22	19	22				13	17
2	18.07			16.21		25.50	21.69	28.35				16.53	21.74
	22	22		20	21	22	21	23	14			22	22
3	27.80	26.44		24.64	24.88	28.93	27.88	34.05	16.07			29.80	29.52
						22	17	22				17	19
4						25.18	19.47	29.27				20.58	23.05
		15		14		21	17	20				21	19
5		18.64		16.23		24.42	20.66	27.19				24.51	24.98
								18					13
6								20.75					15.04
						17		21					18
7						19.05		25.61					20.82
8													
	18	16		17	18	20	19	20			16	21	20
9	22.66	29.39		22.15	21.69	28.42	26.41	30.80			18.93	28.10	28.64
	18	16	13	20	17	22	23	22	15		18	23	21
10	26.54	26.85	18.22	25.07	22.40	31.13	29.21	34.38	21.21		23.20	31.06	31.52
	18	20		16	17	20	19	22				20	19
11	21.58	24.36		10.94	20.01	25.26	14.69	29.87				25.84	19.29
						16	16	18					16
12						18.48	17.46	22.30					19.29
								15					
13								18.13					
	15	15	13	16	16	17	16	17	14		14	17	18
14	24.12	20.62	17.48	20.23	21.05	25.30	22.92	29.32	20.11		19.76	23.63	26.80
						19	18	23				15	21
15						22.32	20.14	27.30				18.03	24.06
		16		15		20	19	23				18	20
16		18.85		17.77		25.20	22.89	27.30				21.15	24.93
						17	14	19				13	20
17						19.44	14.66	13.44				15.48	23.49
		13				20	18	20				15	21
18		14.66				23.94	20.86	26.33				18.54	24.81
	20	18	13	18	16	21	21	24			13	21	23
19	24 17	22.30	14.42	22.35	20.52	28.06	26.56	33.30			15.09	27.00	30.53
		17		13		20	18	21				18	21
20		19.35		15.61		24.86	20.85	28.49				22.24	26.13
	[illegible]3	19	16	19	19	23	19	21	13		14	23	22
21	[illegible]7.09	13.86	17.59	24.02	22.91	30.16	25.31	31.04	15.93		16.72	29.63	30.95
22													
	19	17	13	18	18	21	19	22	15		16	20	22
23	24.28	23.17	15.01	23.66	22.48	29.45	26.43	33.26	17.41		18.84	27.15	30.34
	13	13		13		17	16	17				16	20
24	16.25	15.32		14.46		20.69	18.54	23.20				19.50	23.75
						17	14	19				14	17
25						19.75	16.30	24.30				16.67	19.99
						17	16	20					21
26						20.46	17.93	24.61					23.62
		15		14	14	23	20	20				22	22
27		17.55		16.32	15.73	26.76	23.64	27.29				25.92	26.99

Table 3 (Continued)

No.	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1		17 19.11	14 15.00	16 18.76	13 15.07				16 23.19			16 18.27	14 20.37	13 14.13
2		14 16.53		16 20.22					20 26.35			13 16.19	14 22.24	
3		20 25.16	29 22.44	22 28.73	18 22.29		19 21.97		21 32.08	13 15.55	17 24.23	21 26.67	19 30.75	19 22.29
4		13 16.44		14 18.92	13 15.70				19 25.81			13 14.23	13 21.15	
5		18 21.46	13 15.69	19 23.21	17 20.42		14 16.20		19 27.26		14 18.20	17 21.15	17 24.02	
6									17 20.93					
7									20 25.04					
8									15 18.25					
9		20 25.55	17 20.60	19 25.48	18 22.90	16 18.08	17 20.61		19 30.32		16 23.67	21 26.92	19 29.50	17 20.50
10	16 22.03	19 26.89	14 21.67	22 30.42	22 28.89	13 17.67	13 19.02	13 18.35	23 35.74	13 19.88	21 27.79	19 28.04	19 31.39	17 22.68
11		17 21.95	18 21.15	17 22.48	17 21.66	15 21.35	15 18.36		20 30.39		14 20.60	19 24.14	18 26.64	16 19.04
12									19 24.21					
13									20 23.26					
14		15 21.93	15 21.54	15 22.57	15 21.13		15 20.09	13 17.25	18 28.27		15 19.32	15 22.74	15 26.47	15 19.99
15				20 21.38	13 13.33				20 26.16			14 15.75		
16		18 20.06		19 22.10	16 17.87				21 29.03		15 19.28	18 20.90	15 20.38	
17									20 24.97			14 15.08	13 16.29	
18				15 17.02					22 28.36			17 19.09		
19		20 24.41	19 21.71	22 27.25	21 24.89		19 21.53		23 33.42		18 23.94	23 28.09	19 27.38	19 21.53
20		16 18.55		17 20.23	13 14.60				21 33.24		13 14.72	22 25.06	16 23.84	
21		20 24.26	20 23.24	21 26.06	19 23.07	17 18.83	19 23.37		21 31.64		20 25.96	23 27.56	20 28.14	20 22.79
22														
23	14 22.20	19 24.26	17 20.61	19 25.29	18 22.89	15 17.18	17 21.38	13 14.75	19 30.62		17 23.80	21 26.42	17 25.90	20 23.32
24		14 16.27		17 20.43	13 15.39		13 15.04		19 24.76			14 17.27	15 19.57	
25									21 26.24					
26		14 15.04			13 14.01			26.77	21		17.10	15		
27		20 22.42	15 16.29	21 23.83	19 22.26		14 14.96		21 30.76		14 17.69	20 22.79	16 22.46	

two sampling points and perpendicular to the two isobaths. We suppose that the width of sediment transportation are same, and it was indicated by some the two isobaths. With this ratio- area method and the above- mentionaed results, the direction of sediment movement and the relative discharge of sediment transportation are obrained, as shown in Fig.2. The results obtained by Chao and Dong show good agreement with ours for the same area[10], and the latter are more detailed and specific than the former:

3. Source of sediment in Changzhou section of Grand Canal

For the development of Changzhou, the Changzhou reach of the Grand Canal was regulated and the navigation condition was improved. Recently, severe deposition has occurred, and the study on the source of deposits has been performed to provide a basis for regulating the channel. This study includes the NAA for sediment movement, hydrologic survey, routine analysis of sediment particles and topographical survey.

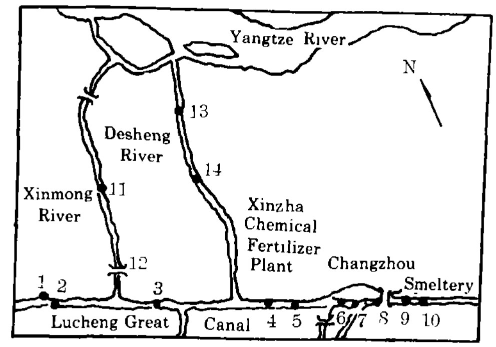

Fig.3 Points of sampling in Changzhou section of Grand Canal

15 bed- load samples were taken in Sep.1989 and the locations of sampling are shown in Fig.3. The neutron activation analysis of the samples yields[6,9] the following conclusions: (*a*) The sediment in the channel maily comes from Xinmeng River and Desheng River. both rivers connect the Changjinag River and do not provide sediment on their own. In view of flow conditions, the sediment should originate from the suspended load in the Changjiang River. The computational result shows that the relative discharge of sediment transportation in Desheng River is larger than that in Xinmeng River. (*b*) The study shows that in the vicinity of Xinzha Fertilizer Plant and in the region between Five Star Bridge and Nanyun Bridge, more severe deposition occurs, and accumulation of sediment is also found in other areas. (*c*) The sample of collapsed soil in Lucheng where severe collapse occurs indicates that the collapsed soil moves to the center of the river and has no effect on the accumulation of sediment in the channel.

Conclusions (*a*) and (*b*) are in good agreement with those from other three commonly used methods, and (*c*) can only be obtained with the NAA.

IV. CONCLUSIONS

1) The results of three field tests with NAA for sediment movement agree well with those from common methods in hydrologic survey. And some results can be obtained only with the NAA, showing that the NAA is effective and feasible.

2) Compared with the radioisotope tracing method, the NAA does not produce

radiations harmful to the health of the public and contaminate the environment. So it is an advanced and suitable method.

3) Compared with artifical tracers, the NAA for sediment movement has some advantages; (*a*) the cost of test can be reduced dramatically; (*b*) the field work can be cut down greatly; (*c*) the sampling time is seldom restricted and the field data of sediment movement in natural conditions can be obtained; and (*d*) the NAA can be used to study both suspended load and bed- load movement, and this is particularly important in studying the sediment movement near muddy coasts and other water areas in which the suspended load is dominant.

4) The NAA for sediment movement has some defects: (*a*) the method needs the instruments which are precise and valuable, and the complex technology; (*b*) the NAA can not obtain directly the data in testing field at present.

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