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TRACING SEDIMENT TRANSPORT AND BED REGIME IN NHATRANG BAY

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ABSTRACT Three spatial structure groups of radionuclides in U and Th series, ^{210}Pb-excess and ^{137}Cs, and ^{40}K were found based on analyzing temporal and spatial datum of their content by factor analysis with oblique rotation in Nhatrang bay.

U and Th spatial structure with their contours decreased toward the offshore, ran longshore and divided seawater of bay into two parts with strong gradient on both sides. Inside part located from center of Nhatrang bay toward the seashore with three main deposit centers of their contents higher than 23 Bq/kg.dry for ^{238}U and 40 Bq/kg.dry for ^{232}Th, indicated unstability of shoreline. Almost sediments coming from river extended toward the offshore, were stopped and transported toward southeastern. The outside part was less than above mentioned content. The boundary line between two parts superposed with the constantly limit line of turbid plume in the rainy season. Direct influence of the continental runoff was limited by the 9 Bq/kg.dry contour of ^{238}U, 19 Bq/kg.dry contour of ^{232}Th. Longshore current was a predominant process whereas lateral transport as sifting and winnowing process of finer grains in sediments of Nhatrang bay. Areas that had very low content of ^{137}Cs and ^{210} Pb-excess adjoining shoreline showed areas being eroded. Accumulation of ^{137}Cs and ^{210} Pb-excess nearby river mouth characterized for fine compositions of sediments controlled by seasonal plumes and sites further toward the south indicated finer materials transported from river and accumulated in lack of hydrodynamic process. Near shore accumulation of ^{40}K revealed the sediments there originated from bed erosion.

ÑÒNH VET DI CHUYEN CHAT ÑAY VA CHE ÑO TRAM TÍCH ÑAY BIEN, VÒNH NHA TRANG

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TOM TAT Tren cô sô phan tích dö lieu khong gian va thôi gian cua hai ñôt khao sat phong xa trong tram tích ven bô vònh Nha Trang nam 1998, ba cau truc khong gian cua cac nhom hat nhan phong xa: ho U va Th, ^{210}Pb-excess va ^{137}Cs, va ^{40}K ñöôc tìm thay bang phöông phap phan tích thanh phan chính.

Cau truc khong gian cua ho U va Th cha ra rang hoat ño phong xa giam dan ve phía bien, cac ñöông ñong ñang ve hoat ño chay doc theo bô va phan chia vung nöôc vònh Nha Trang ra lam hai phan co sö thay ñoi manh ve gradient ham löông ô hai phía. Phan ben trong, tö giöa vònh trô vao, vôi 3 vò trí tích tu chính co hoat ño phong xa lôn hôn 23 Bq/kg kho ñoi vôi ^{238}U va 40 Bq/kg kho ñoi vôi ^{232}Th cho thay ñöông bô khong on ñònh. Hau het löông tram tích van chuyen tö song ra khôi, bò chan lai va van chuyen ve phía ñong – nam. Phan ben ngoai co hoat ño be hôn hoat ño cua U va Th tren. Ranh giôi giöa hai phan nay trung vôi ranh giôi thöông thay cua plumes nöôc ñuc trong mua möa. Giôi han tac ñong tröc tiep cua

dong luc ñòa ñöôc phat hien nhô cac ñöông ñang 9 Bq/kg kho cua ^{238}U va 19 Bq/kg kho cua ^{232}Th. Tram tích ñöôc van chuyen chu yeu do dong ven bô. Trong khi ño, qua trình van chuyen ngang mang tính sang loc cac hat mòn hôn. Nhöng vung co hoat ño ^{137}Cs va ^{210}Pb-excess rat thap nam sat bô la cac vung bò xoi bô va xa hôn la nhöng khu vöc chòu sö xoi be mat. Nhöng vò trí tích tu ^{137}Cs va ^{210}Pb-excess gan cöa song mo ta thanh phan mòn cua chat tram tích chòu sö chi phoi cua cac plume mua va nhöng vò trí xa hôn ve phía nam cha ra cac loai vat lieu mòn hôn ñen tö song va tích tu trong ñieu kien che ño thuy ñong löc yeu. Hoat ño ^{40}K cao nhat gan bô tiet lo chat ñay ô ño co nguon goc tö qua trình xoi bai.

INTRODUCTION

Sediment transport phenomena are important in marine ecology and coastal engineering using zone where the river drawn sediments are settled down. Suspended sediments contain various chemical and biological pollutions (B.S. Shteinman and Y.G. Kamenir 1994, 1998), and also can act both as source and sink of nutrients, organic matters, heavy metals. Under the different conditions of hydrodynamic, suspended sediments may accumulate and be resuspended some where in coastal zone. There are different tracer methods used for studies of sediment dynamic: fluorescent, magnetic, and radio-isotopic. The use of natural and artificial radioactivity of sediments has pronounced advantages, as radioisotopes can be detected at very small concentrations, their properties are dependent on external effects. Artificial radioactive tracers are danger for human (S. Shteinman and Y.G. Kamenir 1994,1998), therefore in recent years natural and fallout radio-nuclides are used as fingerprinting tracers to reconstruct and study marine processes. The association of ^{210}Pb excess – organic matters, ^{137}Cs – clay, silt and organic matters, ^{228Th} excess – organic matters and manganese are fingerprinting properties to indicate erosion processes, the sites of high sediment accumulation, and also trace the sediment movements. ^{238}U, ^{226}Ra and ^{228}Ra are natural radionuclides to be considered dissolved in seawater (A. Battaglia et al., 1988...), so in surf zone or at sites inshore, where there are drastic influence of wave driven current, tidal current or force bottom current, these radio-nuclides are expected to appear in components of heavy minerals and their distributions are arranged in predominant direction of general current. ^{40}K is of highest content in 200μm grain size and in lower one of coarse and fine grain size, especially radio-nuclides in U, Th series is of very low content in coarse grain size (R.J. de Meijer and L.W. Put et al., 1988). In the present paper we report studied results of the sediment transport and bottom sediment regime in Nhatrang bay under the fingerprinting properties of natural and fallout radio-nuclides.

METHODS

Sample collection

Sampling occurred on 27-29 August 1997 and 27-29 February 1998 at 16 sites with 32 samples (Figure 1).

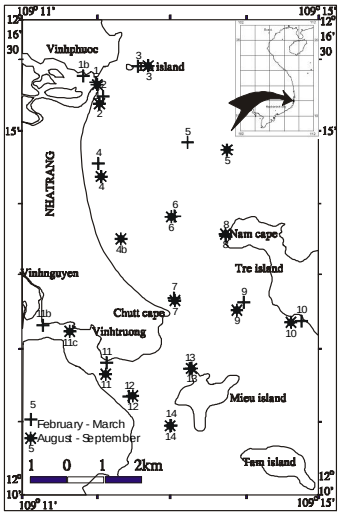

Figure 1: Sampled sites in Nhatrang bay

Sampling strategy was planned to collect samples at the beginning and the end of rainy

season. Bulk samples of sediments were gathered by US sampler of 10x20 cm in square and 10 cm high, dried at 100^{o}C in 48 hours, ground in amount of 500g, sieved to have identical size smaller than 100μm, canned under geometry of well shape, measured by Canberra gamma spectrometry with high purity germanium detector in Canberra lead shield for 24 hours. Gamma spectrometry of genie 2000 software provided measurements of ^{137}Cs, ^{7}Be, ^{210}Pb, ^{226}Ra, ^{214}Bi, ^{228}Ac, and ^{228}Th, ^{234m}Pa. Measurements of ^{137}Cs, ^{7}Be, ^{210}Pb occurred via their direct decay lines, ^{226}Ra, ^{234m}Pa via its lines at 186 keV and 1001 keV, ^{228}Th via its daughters ^{224}Ra, ^{212}Pb, and ^{208}Tl (R.J. de Meijer and L.W. Put, 1988, T.M. Williams, A.B. Mackenzie, R.D. Scott et al., 1988, G.J. Hankcok and J.R. Hunter, 1999).

^{238}U, ^{232}Th were determined by method of El-Assaly although ^{234m}Pa was suggested. However, using ^{234m}Pa to calculate ^{238}U is more reasonable because it is product of ^{234}Th – a direct product of ^{238}U, moreover daughters of ^{238}U such as ^{226}Ra may be lost very much by its nature of dissolve in marine system.

Beside of determining radionuclides, salinity was also determined on purpose of obtaining the trace of plumes and the salt invasion.

Data treatments

Disconnected datum of each radio-nuclide in space were interpolated by Kriging method to have the crude characteristics of bottom sediment regime. In order to use multiple fingerprinting properties to provide an objective assessment of bed erosion, sediment transport, sites of heavy mineral accumulation, and also to find out space structure of each radio-nuclides group, the principal components analysis in R-mode with Oblique non-orthogonal rotation was used and factors of sites were gathered by reverse transformations and identified to each group of radio-nuclides by mathematical regression. Oblique technique had been used by Imbrie and Val Andel to study on structure of heavy minerals (1966).

RESULTS

Salinity

Salinity is an element sensible to climate and hydrodynamic regime, but it is of strict relation to climate, hydrodynamic regime, formulation of flocculation, and dissolve of chemical elements…. During rainy season, there were strong gradient of salinity between surface and bottom layer, inside and outside of two river mouths, one situated in north part, another in the south (Figure 2).

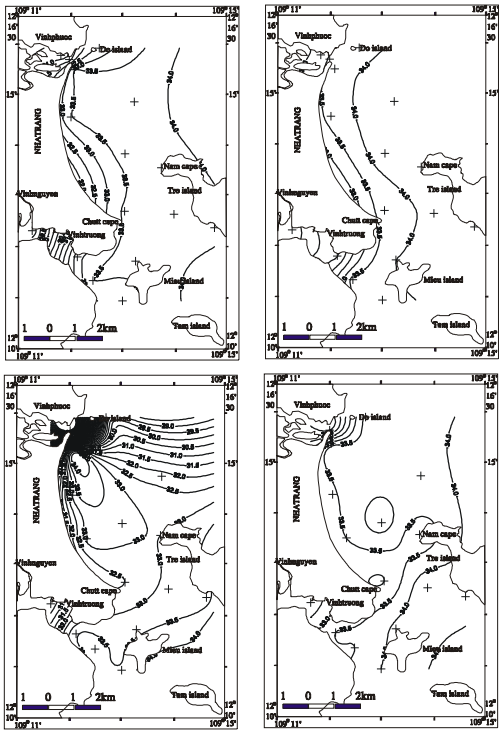

Figure 2: Distribution of salinity (‰) in Nhatrang bay (above: February, 1998: left: surface, right: bottom layer; under: August, 1998: left: surface, right: bottom layer)

As the consequence of force runoff from upper stream, a turbidity plumes spread directly from Cai river mouth to offshore and were narrowed toward the south part to Mieu island but they have never gone to the Nam cape opposite to city sea-beach, normally they ran along the shoreline and separated seawaters of bay into two parts with inside

very turbid and outside clearer. Minimum salinity of river mouth 1.6‰, 16.0 – 33.6 ‰ on surface and 31.0 – 34.4‰ in bottom layer with the features of salt invading from South-East direction.

Distribution of radionuclides

^{210}Pb-excess, ^{137}Cs in sediments concentrated inside and outside of river mouth with contours upward to the North correspondent to 80 – 100 and 1.27 – 1.47 Bq/Kg, rapidly decreased, and extended to the offshore with 20.07 – 30.07 and 0.07 – 0.27 Bq/kg respectively. However, the dispersion of ^{137}Cs that was more extensive showed the appearance of ^{137}Cs mostly in very fine grain size of material flow from river (Figure 3).

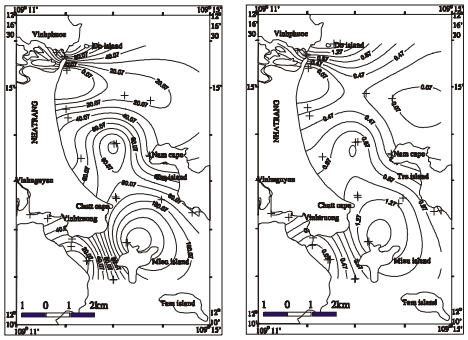

Figure 3: Distribution of ^{210}Pb-excess (left), ^{137}Cs (right) content (Bq/kg.dry)

The same situation from distribution of ^{232}Th, which was strong association with terrigenous particles traced direct influence of Cai river to this part of bay. The segments around the Nam cape opposite to sea-beach were low in content of ^{232}Th to 20 Bq/kg and 10 Bq/kg of ^{238}U. Furthermore, ^{210}Pb-excess and ^{137}Cs had other two accumulative sites, one smaller nearly in the south of bay central respective to 90, 1.07 Bq/Kg and another larger of 100 – 140, 1.27 – 1.47 Bq/kg near to Mieu island whereas ^{232}Th had spot accumulation at this site, and only concentrated near middle of shoreline. Contours of ^{232}Th and ^{238}U were narrowed and ran along the coast to southeast direction (Figure 4).

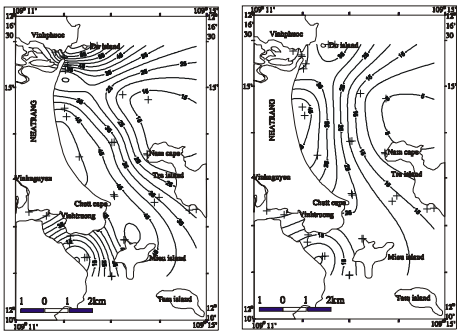

Figure 4: Distribution of ^{232}Th (left), ^{238}U (right) content (Bq/kg.dry)

Undoubtedly, these arranges of ^{232}Th, ^{238}U contours implicated that deposition of ^{232}Th, ^{238}U in the material flow came from river, and basement ^{232}Th, ^{238}U in sediments were transported by longshore current, sifted and winnowed by lateral transport. Whereas ^{210}Pb-excess, ^{137}Cs were carried, deposited and accumulated somewhere and sometime that happened the lack of general current, mostly ^{40}K was only concentrated just at sites of shoreline and had the same process as ^{232}Th, ^{238}U (Figure 5).

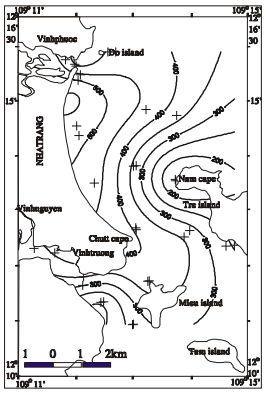

Figure 5: Distribution of ^{40}K content (Bq/kg.dry)

Spatial Structure of ^{210}Pb-excess and ^{137}Cs, U and Th, and ^{40}K

Distributions of every radionuclides in sediments reflected the variation of their concentration in spatial – temporal pattern as well as showed some information on abilities of sediment transport and accumulation,

however these aspects were under the primitive considerations. Walling and Woodward (1995) showed that a single trace points strongly to importance of a particular process, but the possibility of the sediment being a mix of two other different processes cannot be ruled out. It needs to find out features of each group of radionuclides in order to reconstruct sediments transport and regime. Three factors obtained by Principal component analysis with oblique rotation explained 92.5% information, described the main processes that affected to the distribution of matters in sediments of Nhatrang bay.

First factor of 71% variance was identified as spatial structure of radionuclides in U, Th series (Figure 6).

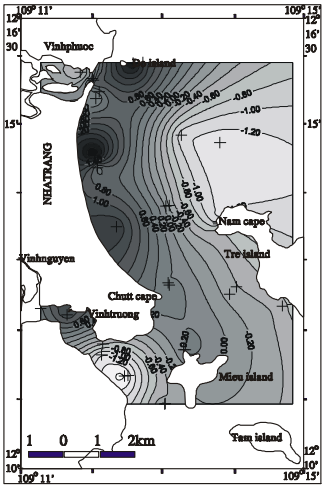

Figure 6: Spatial structure of radionuclides in U and Th series

Two remain factors of 21.5% variance, second factor described for ^{210}Pb-excess, ^{137}Cs and third factor was spatial structure of ^{40}K. According to De Meijer, Put et al., (1988), U and Th are mainly present in the heavy minerals, which are usually a smaller fraction of sand, and their concentration varies depending on the selectivity in the transport processes. K is associated with light minerals and its concentration varies slowly with enrichment factor whereas ^{210}Pb-excess was strictly related to silt and ^{137}Cs mainly for clay and silt (Bradley et al., 1988). Three analyzed factors recorded their fingerprinting properties of sediment transport in Nhatrang bay. The zero contour in structure of U, Th of 23 and 42 Bq/kg as boundary separated bay into two parts with strong gradient on both sides. Inside part, the concentration of radio-nuclides in U, Th series increased toward the coast with four centers of heavy mineral accumulation, highest nearby river mouth, the next at upper of coast center, the third about 5km from river mouth, and the lowest one beside Mieu island. Outside part, their concentration decreased fast with contours ran along the coast and bent toward offshore in front of river mouth. Thus, this boundary revealed that sediments coming from river was stopped and transported along the boundary toward southeast as main process. Sediments escaping across boundary, caused by lateral transport with properties of sifting and winnowing heavy minerals, were also controlled by longshore current. This boundary superposed to front of turbid plume in rainy season. In segment of river mouth, most of heavy minerals deposited and accumulated close to river mouth, some of them that extended across boundary to offshore implied that they were in form of very fine materials. Two accumulative areas along shore reflected unstability of shoreline and was consequence of bed load and beach erosion. Undoubtedly these sites were records of forming shoal bank for long time in future. Lowest accumulative area close to Mieu island was proof witness of sediments enough fine to be transport longshore.

Spatial structure of ^{210}Pb-excess, ^{137}Cs described also two areas of sediment accumulation, one nearby river mouth that was not far from site of U, Th accumulation (Figure 7).

Thus sediments from river that deposited in range of heavy minerals, gross silt and clay was controlled by size of front, hydrological conditions of flocculation forming. The further extending of contours to offshore and bending toward the south presented nature of sediments in which ^{210}Pb-excess, ^{137}Cs were present. Most of fine grains that were carried

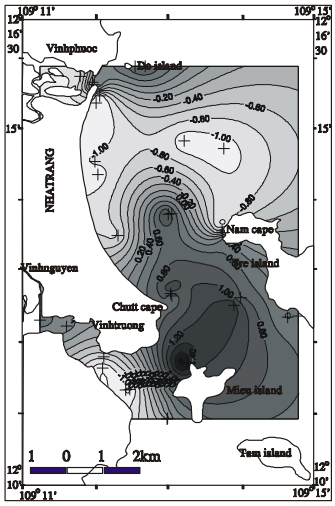

Figure 7: Spatial structure of ^{210}Pb-excess and ^{137}Cs

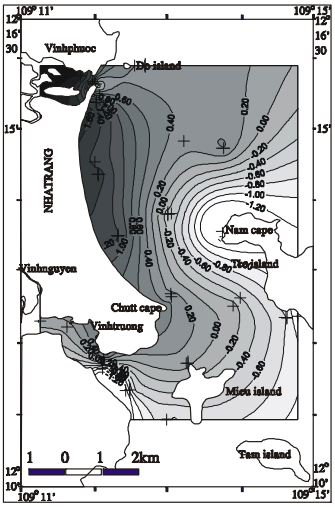

Figure 8: Spatial structure of ^{40}K

along shore as suspended load accumulated in large areas nearby Mieu island. This feature cited the lack of hydrodynamic processes, and also bottom current was not enough force to keep sediments from accumulation. There was two areas in which ^{210}Pb-excess, ^{137}Cs correspondent to 10 and 0.20 Bq/Kg extremely low limited by contours of –1.0, one nearby beach characterized potential erosion of beach that was observed in abnormal climate of 1999, and in addition to other one recorded surface erosion of sediments. Spatial structure of ^{210}Pb-excess and ^{137}Cs different from one of U and Th suggested that sediments containing silt and clay. Sediments in areas between contours of –1 to -0.8 respective to smaller 30 Bq/Kg for ^{210}Pb-excess and 0.37 Bq/Kg of ^{137}Cs, were easily considered to be reworked by seasonal change of these fallout radionuclides content.

Spatial structure of ^{40}K was similar to U, Th, however there was no accumulative site near river mouth accept to extending contours with steady gradient toward offshore (Fig. 8).

So compositions of sediments containing ^{40}K were fine grains which were not controlled by flocculation mechanisms. The highest concentration of ^{40}K with contour of 1.4 corresponding to 500 Bq/Kg along shore indicated sediments originated from beach erosion.

CONCLUSIONS

Sediment flow from river came to Nhatrang bay was stopped and longshore transported as main process traced by radionuclides in U, Th series, lateral transport was only sifting and winnowing process. The path of fine sediments escaping toward offshore and accumulative sites indicated by fallout radionuclides such as ^{210}Pb-excess and ^{137}Cs, especially eroded areas predicted by their low contents and calculated by factor analysis of oblique rotation. Sediments originated by beach erosion were determined by highest content of ^{40}K adjoining to shoreline.

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