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Stable Carbon and Nitrogen Isotope Ratios of Sediment in Ban Don Bay: Evidence for Understanding Sources of Organic Matters in the Coastal Environment

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ABSTRACT

Sedimental cores from Ban Don Bay and adjacent areas were collected by gravity core samplerfor examination of $\delta^{13}C$, $\delta^{15}N$, organic carbon and nitrogen contents. The $\delta^{13}C$ of surface (0-1 cm) sediments from the whole sampling area ranged between –28‰ and -20‰. The $\delta^{15}N$ values of sediments near the river mouth were somewhat higher than those in the outer part of the bay. Sediments with high organic carbon content occurred in the river and the most outer part of the bay. Organic nitrogen contents in the sediment showed almost same pattern as those of organic carbon contents. The atomic ratios of carbon to nitrogen were high in the river and river mouth. These ratios decreased with the increase in distance from the river mouth. Overall, our results clearly demonstrated most of the terrestrial organic matters discharged from the river into the Ban Don Bay had been deposited onto the bottom sediment inside the bay, they had not been expanded cover to the Angthong Islands.

Key words: Ban Don Bay, stable carbon isotope, stable nitrogen isotope, sediment, coastal environment

INTRODUCTION

Ban Don Bay is one of the productive coastal areas in the southern part of Thailand. This bay is located in Surat Thani Province, Southern Thailand. The bay recieves surface freshwater runoff from rivers and canals such as Tapi River, Thathong Canal, Donsak Canal. The fishery productions in the bay have now disappointingly been decreased. This decrease was probably caused by over fishing and environmental change. It is said that the increasing population and the intensification of agro-industrial activities gradually have caused serious aquatic environmental problems in this area.

The Ban Don Bay has frequently been contaminated with direct and indirect discharges of untreated industrial and domestic wastes passing through canals and rivers from the town. Intensive shrimp farming has rapidly expanded to coastal areas around the bay during the last two decades. Many mangrove forests were accordingly cut down for shrimp pond digging. Since the average feed conversion ratio of shrimp was estimated to be about 2.0-2.5, large amounts of organic matter were daily input into the ponds (Musig *et al*., 1995). Effluents from shrimp farmings also caused pollution problems in aquatic environments nearby. This bay has thus faced with problems of organic matter accumulating from the land by recent man-

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made activities and natural runoff of river. However, the extent of the effects of these materials on the whole bay is poorly known.

Sediment research is one useful approach for the study of these questions. One way to evaluate the extent to which sedimentary records reflect actual biological and geographic sources is to directly compare the compositions of organic materials settling through the water column with those preserved in the underlying sediments. This present study is the first attempt to use stable carbon and nitrogen isotope techniques to understand the coastal environment of the Ban Don Bay. The stable carbon and nitrogen isotopes have been used by a number of authors to identify the origins of organic matters (Thornton and McManus, 1994; Guo *et al*., 1996; Meksumpun *et al.*, 1998a) and to determine the trophic structure of marine communities (Wada *et al.*, 1991; Parson and Chen, 1995; Wu *et al*., 1997). Mishima *et al.* (1996) have tried to estimate the movement of both terrestrial and marine organic matters in the Osaka Bay (Japan) by using the stable carbon and nitrogen isotopes technique.

Here we report a study of the carbon and nitrogen contents, and the stable carbon and nitrogen isotope ratios of particulate organic materials in surface sediments of the Ban Don Bay. Other related aquatic factors have also be integrated. The goal of this study is to understand the terrestrial organic material movement and coastal environment of the Ban Don Bay.

MATERIALS AND METHODS

At least two sedimental cores were sampled from each sampling station in the Ban Don Bay and adjacent area during August 18-20, 1999. The map of the sampling locations (12 stations) was shown in Figure 1. Water depth and salinity were also measured with STD meter (Mini STD SD202). The water depth and surface salinity contour lines were shown in Figures 2 and 3, respectively. The sediment cores were sectioned for every 1 cm interval and immediately frozen at -40 ^{o}C until further analysis.

The sediment samples were freeze-dried in laboratory. The dried sediment samples were then ground and packed in silver cups. In order to remove carbonate, the sediments in silver cups were treated with 1N-HCl solution. They were again dried and packed in tin cups prior to analysis. The total organic carbon and nitrogen contents, together with carbon and nitrogen isotopic compositions in sediment samples were obtained using a continuous flow analytical system joining an elemental analyzer (Carlo Erba, NA-1500) with a stable isotope ratio analyzer (Finnigan MAT252). Measuring standards consisted of CO_2 gas produced from NBS18 standard and N_2 gas produced from L-alanine. The final results are reported as δ^{13}C and δ^{15}N (‰) relative to the Peedee belemnite (PDB) limestone standard (carbon) and atmospheric N_2 (nitrogen), as defined by the following equation:

$$\delta^{13}C \text{ or } \delta^{15}N \text{ (‰)} = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 100$$

where R = $^{15}N/^{14}N$ or $^{13}C/^{12}C$. Data quality control throughout the analysis was ensured by running a reference standard after every 10 runs. The analytical precision for standard preparation and mass spectrometric analysis was less than ± 0.1‰ and ± 0.2‰ for δ^{13}C and δ^{15}N, respectively.

RESULTS

Stable carbon isotope ratio (δ^{13}C)

The δ^{13}C value of surface sediments in the river at station 1, where salinity was estimated to be 0 psu, was –27.8‰. The highest δ^{13}C value of surface sediment obtained at station 10 with the value of –20.5‰. The contour map of δ^{13}C values of surface sediments (0-1 cm) in the Ban Don Bay is shown in Figure 4. The δ^{13}C values of the surface sediments increased gradually with increasing distance from the river mouth. However, the vertical profiles of δ^{13}C values at most sampling stations were generally constant. Table 1 shows the vertical profiles of $\delta^{13}C$ values in sediments at stations 1, 6 and 11.

Stable nitrogen isotope ratio ($\delta^{15}N$)

Figure 5 showed the contour map of $\delta^{15}N$ values of surface sediments in the Ban Don Bay. The $\delta^{15}N$ values of the surface sediments near the river mouth were generally higher than those around the Angthong Islands (Figure 5). The lowest $\delta^{15}N$ value was found at station 12 (3.8‰).

Organic carbon and nitrogen contents

Total organic carbon contents of the surface sediments in the Ban Don Bay and adjacent area were ranged between 6.20 and 14.75 mg/g (dry weight). The highest organic carbon content was found at station 12 at value of 14.74 mg/g. Low organic carbon contents (lower than 10.00 mg/g) were found at the river mouth. The contour map of organic carbon content of the surface sediment in the bay and adjacent area was shown in Figure 6.

The highest nitrogen content of the sediment was found in station 12, closed to Samui and Phangan Island, at the value higher than 2.00 mg/g. Figure 7 showed contour map of organic nitrogen content of sediment in the study area. The organic nitrogen content showed almost same pattern as that of the organic carbon content. Low nitrogen contents of the sediments were found in the stations near the river mouth.

Atomic C:N values of the sediments were shown in Figure 8. The values were usually high (ranged from 11.7 to 13.9) in the sediment obtained from river and closed to the river mouth (stations 1-3). The lowest C:N value was found at station 12. The C:N ratios in the other areas (stations 4-8) varied between 9.5 and 10.3 with an average of 9.72 (SD ± 0.63). The C:N ratios of the surface sediments at station 9-11 varied between 8.3 and 8.4 with an average of 8.3 (SD ± 0.06).

DISCUSSION

Data analysis for $\delta^{13}C$

In general, the value of $\delta^{13}C$ of terrestrial organic matter and marine organic matter are distinctly different. Stable carbon and nitrogen isotope compositions of organic matter in sediment had been studied to examine the movement of

Table 1 Vertical profiles of stable carbon isotope ratios ($\delta^{13}C$) of sediment samples collected in August 1999.

Station 1		Station 6		Station 11	
Sediment depth (cm)	$\delta^{13}C$ (‰)	Sediment depth (cm)	$\delta^{13}C$ (‰)	Sediment depth (cm)	$\delta^{13}C$ (‰)
0-1	-27.7	0-1	-21.9	0-1	-20.7
1-2	-27.6	1-2	-21.8	1-2	-20.5
2-3	-27.6	2-3	-22.2	2-3	-20.5
3-4	-27.6	3-4	-21.7	3-4	-20.6
4-5	-27.8	4-5	-21.9	4-5	-20.7
5-6	-27.6	5-6	-21.8	5-6	-21.0
6-7	-27.7	6-7	-21.3		
		7-8	-21.3		
		8-9	-21.7		
		9-10	-21.3		

terrestrial organic matter by several workers (e.g. Thornton and McManus, 1994; Yamada *et al.*, 1996; Mishima *et al.*, 1996; Meksumpun *et al.*, 1998b). Although the values of $\delta^{13}C$ and $\delta^{15}N$ of particulate organic matter often showed distinct seasonal variations (e.g. Voss *et al.*, 1996), the particulate matter in water column and sedimental samples collected from off shore areas in the same time for $\delta^{13}C$ and $\delta^{15}N$ determinations were reported to have no statistical difference at the α=0.10 level and were assumed to be isotopically equivalent (Goering *et al.*, 1990). In this study, the levels of $\delta^{13}C$ ranged from –27.8‰ at the riverine station to more than –20.4‰ in the area from station 10. Such $\delta^{13}C$ data thus indicated no effect of major terrigeneous materials in sediments of the area from station 10 to the outer part of the bay. Here the $\delta^{13}C$ value of terrestrial organic matter and marine organic matter were approximately –27.5‰ and –20.5‰, respectively. The $\delta^{13}C$ data of this study correspon-ded with the report of Gearing *et al.* (1984) in which the $\delta^{13}C$ of phytoplankton collected from Malaysian water was -21.0‰. Moreover, the data were also well corresponded with several authors who found that the $\delta^{13}C$ for coastal and offshore marine sediments ranged from -23‰ to -18‰ (e.g.Tan *et al.*, 1991; Meksumpun *et al.*, 1998b), whereas the $\delta^{13}C$ for terrestrial organic matters ranged from -28‰ to -26‰ (e.g. Tan *et al.*, 1991; Thornton and McManus, 1994; Mishima *et al.*, 1996). Watanabe *et al.* (1997) had also shown that the mean $\delta^{13}C$ value of sediment and suspended solids in the Choa Praya estuary at the upper most sampling station was close to -26.5‰.

Since the $\delta^{13}C$ of the marine planktonic source was definitely different from those of most terrestrial organic material sources, we could clarify the impact of terrestrial organic matter on the marine ecosystem. In order to estimate the movement pattern of terrestrial organic matter which had been loaded from the river into the Ban Don Bay, the percentages of terrestrial organic carbon (T) in each sampling station were calculated by the following equation:

$$T\ (\%) = \frac{\delta^{13}C_{\text{marine}} - \delta^{13}C_{\text{sample}}}{\delta^{13}C_{\text{marine}} - \delta^{13}C_{\text{terrestrial}}} \times 100$$

$\delta^{13}C_{\text{marine}}$: $\delta^{13}C$ of marine organic matter
$\delta^{13}C_{\text{sample}}$: $\delta^{13}C$ of measured sample
$\delta^{13}C_{\text{terrestrial}}$: $\delta^{13}C$ of terrestrial organic matter

Based on our $\delta^{13}C$ data, we decided the end members of $\delta^{13}C_{\text{marine}}$ and $\delta^{13}C_{\text{terrestrial}}$ to be –20.5‰ and –27.5‰, respectively. Our calculated data showed that the percentages of terrestrial organic matters in the surface sediment decreased gradually from about 70 % in the area near the river mouth to less than 20 % in the outer area close to the Angthong Islands (Figure 9). Such occurrences were considered to be due to comparative weak current of water movement so as the loaded particles can be easily sinked down onto the bottom deposits.

Data analysis for $\delta^{15}N$

The $\delta^{15}N$ values of the sediments of sampling stations in the Ban Don Bay (stations 1-6) were markedly higher than those of stations nearby Angthong Islands (stations 10-12). Base on these results, together with the results of $\delta^{13}C$ analyses, the data suggested that organic matters in those two areas, which may contribute substantial inputs of carbon and nitrogen onto the sediments, had different isotopic compositions. As previously reported by Goering *et al.* (1990) that the $\delta^{15}N$ values of mixed phytoplankton dominated by diatom (*Thalassiosira aestivalis*, *Skeletonema costatum* and *Chaetoceros debilis*) collected in Auke Bay during the prebloom in spring was 3.3 ± 0.6‰, the results here which indicated the $\delta^{15}N$ values of 3.8 ± 0.1‰ in sediment collected at station 10-12 may imply the dominance of diatoms in the water column along those stations. Although there were some differences in origin of organic deposition, the ranges of $\delta^{15}N$ in our results could clearly confirm that the sediments in the outer area were mostly derived from the primary production in overlying water column.

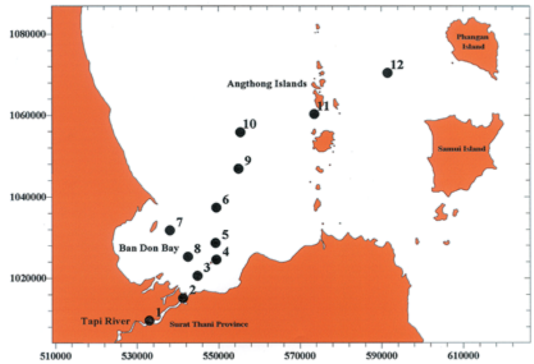

Figure 1 Sampling stations in the Ban Don Bay and adjacent area in Surat Thani province, Thailand.

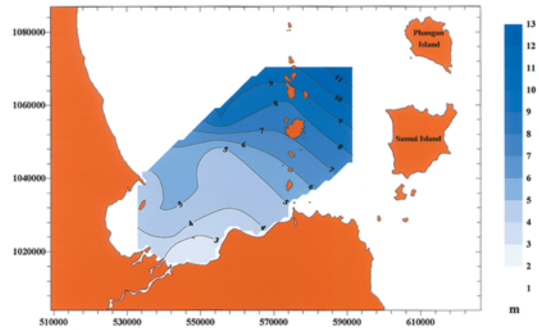

Figure 2 Contour graph of water depths in the Ban Don Bay and adjacent area.

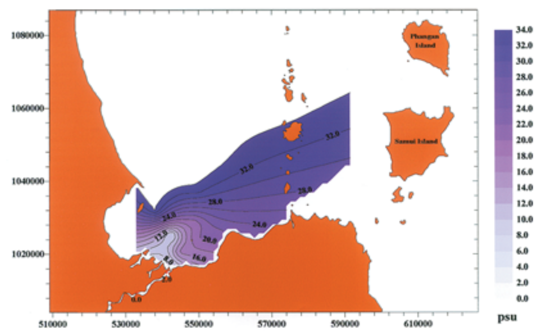

Figure 3 Contour graph of surface salinities (psu) in the Ban Don Bay and adjacent area.

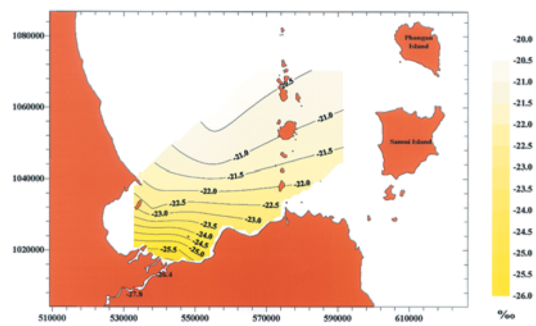

Figure 4 Contour graph of carbon isotope ratios ($\delta^{13}C$) of the surface (0-1 cm) sediments in the Ban Don Bay and adjacent area.

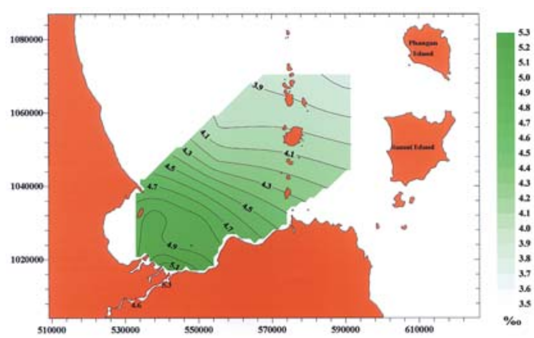

Figure 5 Contour graph of nitrogen isotope ratios ($\delta^{15}N$) of the surface (0-1 cm) sediments in the Ban Don Bay and adjacent area.

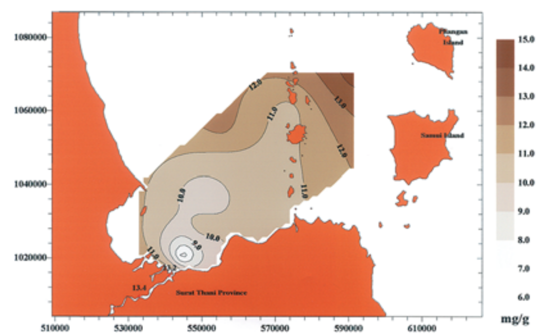

Figure 6 Contour graph of total organic carbon contents of the surface (0-1 cm) sediments in the Ban Don Bay and adjacent area.

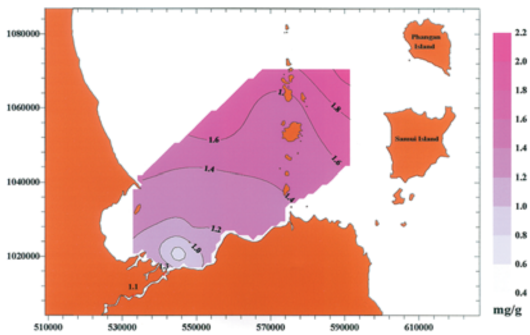

Figure 7 Contour graph of total organic nitrogen contents of the surface (0-1 cm) sediments in the Ban Don Bay and adjacent area.

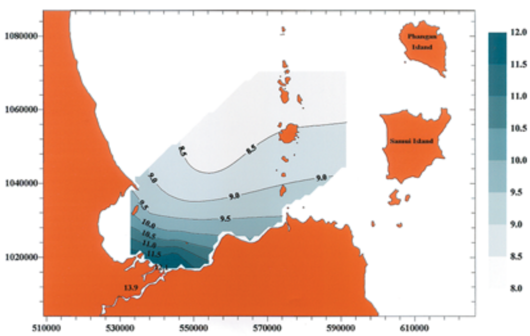

Figure 8 Contour graph of C:N ratios of the surface (0-1 cm) sediments in the Ban Don Bay and adjacent area.

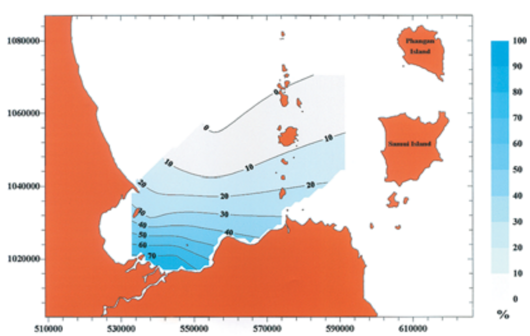

Figure 9 Contour graph of percentages of terrestrial organic matters in surface (0-1 cm) sediments in the Ban Don Bay and adjacent area.

Data analysis for organic carbon and nitrogen contents

An accumulation patterns of organic carbon and nitrogen should depend upon the distribution of water masses and currents which were in turn influenced by wind velocity and direction and topography. Because of the surface current velocity and direction in the Ban Don Bay were remarkably influenced by the monsoon, the accumulation patterns of organic carbon and nitrogen were considered to be directly controlled by monsoon-induced currents in the whole study area. Distributions of organic contents of carbon and nitrogen of surface sediment showed almost the same pattern. Although low carbon and nitrogen contents of surface sediment were found in small areas closed to the river mouth, the mean values of the organic carbon and nitrogen contents of the whole sampling area were still high. The organic contents of carbon and nitrogen of surface sediments in some parts of the study area were as high as the high production areas e.g. in the Osaka Bay (12-22 mg/g for carbon and 1.8-2.4 mg/g for nitrogen), Japan (Montani *et al*., 1991; Mishima *et al*., 1996). Such high concentrations of organic materials deposited in the Ban Don Bay may be one of the reasons that causes this area characterizes as a comparatively high fishery production zone of the Gulf of Thailand.

Data analysis for C:N ratios

Atomic C:N ratios of particulate organic matter have been employed as source indicators of sedimentary particulate organic matter by numerous workers (e.g Prahl *et al.*, 1980; Thornton and McManus, 1994). Additionally, Hedges *et al.* (1988) indicated that the elemental compositions from trap samples in various water depths were similar to those of the underlying surface sediments, and the C:N ratio of the particulate organic matters in the upper layer of water column was only slightly lower than those in the lower layers. Our C:N distribution clearly showed that the C:N ratios of surface sediment close to the river mouth were higher than those in the Ban Don Bay and these ratios gradually decreased from the river to the outer part of the bay. Generally, the high values of C:N ratios (>10) of sediments from mid-latitude areas had been interpreted to be a large effect of terrigenous materials input (Thornton and McManus, 1994; Mishima *et al.*, 1996). The results from $\delta^{13}C$ clearly demonstrated that the sediments close to the river mouth were affected by terrigeneous materials, whereas those in stations nearby Angthong Islands were mostly derived from authochthonous primary production. The mean value of C:N ratio of area that marine organic sources should be the major contributor to the sediment organic matter pools (stations 9-12) was estimated to be 8.3 ± 0.2. Tan *et al*. (1991) have similarly revealed that the C:N ratios of sediment in the East China Sea, which contain a dominant contribution of marine organic carbon, lie in the range 6.2 to 8.8.

In conclusion, the distribution pattern of stable isotope composition of sediments in Ban Don Bay implied that most of terrestrial organic matter discharged from the river into the Ban Don Bay had entirely been deposited onto the bottom sediment within the Ban Don Bay. Such discharges could not reach the Angthong Islands.

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LITERATURE CITED

Gearing, J.N., P. J. Gearing, D.T. Rudnick, A.G. Requejo, and M.J. Hutchins. 1984. Isotopic variability of organic carbon in a phytoplankton-based, temperate estuary. Geochemica et Cosmochimica Acta. 48 : 1089-1098.

Goering, J., V. Alexander, and N. Haubenstock. 1990. Seasonal variability of stable carbon an nitrogen isotope ratios of organisms in a North Pacific Bay. Estuarine, Coastal and Shelf Science. 30 : 239-260.

Guo, L., P.H. Santschi, L.A. Cifuentes, S.E. Trumbore, and J. Southon. 1996. Cycling of high-molecular-weight dissolved organic matter in the carbon isotopic (^{13}C and ^{14}C) signatures. Limnol. Oceanogr. 41 : 1242-1252.

Hedges, J.I., W.A. Clark, and G.L. Cowie. 1988. Organic matter sources to the water column and surficial sediments of a marine bay. Limnol. Oceanogr. 33 : 1116-1136.

Meksumpun, S., C. Meksumpun, A. Hoshika, T. Tanimoto and Y. Mishima. 1998a. The use of stable isotopes for understanding coastal environment of the Hiroshima Bay. Scientific Report of Chugoku National Research Institute. 51 : 17-24.

Meksumpun, S., C. Meksumpun, A. Hoshika, Y. Mishima, and T. Tanimoto. 1998b. Stable isotope technique for evaluation of organic matter movement and coastal environment status., pp.189-204. *In* D. Almoza and H.M. Ramos (eds.). Applied Sciences and Environment. WITpress. Southampton.

Mishima, Y., A. Hoshika, and T. Tanimoto. 1996. Movement of terrestrial organic matter in the Osaka Bay, Japan, pp. VI-20-25. *In* Proceedings of the third International Symposium of ETERNET-APR : conservation of the Hydrospheric Environment, 3-4 December 1996, , Bangkok.

Montani, S., Y. Mishima, and T. Okaichi. 1991. Scavenging processes of marine particles in Osaka Bay. Marine Pollution Bulletin EMECS'90. 23 : 107-111.

Musig, Y., W. Ruttanagosrigit, and S. Sampawapol. 1995. Effluents from intensive culture ponds of Tiger Prawn (*Penaeus mododon* Fabricus). Kasetsart University Fishery Research Bulletin. 21 : 17-24.

Parsons, T.R. and Y.-L L. Chen. 1995. The comparative ecology of a subarctic and tropical estuarine ecosystem as measures with carbon and nitrogen isotopes. Estuarine, Coastal and Shelf Science. 41 : 215-224.

Prahl, F.G., J.T. Bennett and R. Carpenter. 1980. The early diagenesis aliphatic hydrocarbons and organic matter in sedimentary particulates from Dabob Bay, Washington. Geochemica et Cosmochimica Acta. 44 : 1967-1976.

Tan, F.C., D.L. Cai, and J.M. Edmond. 1991. Carbon isotope Geochemistry of the Changjiang Estuary. Estuarine, Coastal and Shelf Science. 32 : 395-403.

Thornton, S.F. and J. McManus. 1994. Application of organic carbon and nitrogen stable isotope and C/N ratios as source indicators of organic matter provenance in estuarine systems: Evidence from the Tay Estuary, Scotland. Estuarine, Coastal and Shelf Science 38 : 219-233.

Voss, M., M.A. Altabet, and B.V. Bodungen. 1996. $\delta^{15}N$ in sedimenting particles as indicator of euphotic-zone processes. Deep-Sea Research. 43 : 33-47.

Wada, E., H. Misutani, and M. Minagawa. 1991. The use of stable isotopes in food web analysis. Critical Reviews in Food Science and Nutrition 30 : 361-371.

Watanabe, H., K. Ohta, K. Sawada, and Y. Nozaki. 1997. Distribution of terrestrial organic matter in the Choa Praya estuary (Thailand). An abstract presented in the Seminar on Geochemistry (Chikyu-Kagaku) 17-19 September 1997, Tokyo, Japan. (in Japanese)

Wu, J., S.E. Calvert, and C.S. Wong. 1997. Nitrogen isotope variations in the subarctic northeast Pacific: relationships to nitrate utilization and trophic structure. Deep-Sea Research. 44 : 287-314.

Yamada, Y., T. Ueda, and E. Wada. 1996. Distribution of carbon and nitrogen isotope ratios in Yodo River watershed. Jpn. J. Limnol. 57 : 467-477.

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