JARQ 32, 153–158 (1998)

C, N, P Composition of Suspended Matter in Matang mangrove Estuary, Malaysia

Katsuhisa TANAKA*[1], Kazuo SUGAHARA*[2], Yoshinari OHWAKI*[2] and Poh-Sze CHOO*[3]

*[1] Marine Productivity Division, National Research Institute of Fisheries Science (Kanazawa, Yokohama, 236-8648 Japan)
*[2] Okinawa Subtropical Station, Japan International Research Center for Agricultural Sciences
(Kawarabaru, Ishigaki, Okinawa, 907-0022 Japan)
*[3] Aquatic Ecology Section, Fisheries Research Institute, Department of Fisheries, Malaysia
(11960 Batu Maung, Pulau Pinang, Malaysia)

Abstract

Distribution of suspended matter and its chemical composition were investigated in the Sangga Besar River Estuary in Matang Mangrove Forest, Malaysia. The C, N contents were higher in the upper part of the river and decreased towards the river mouth. Phosphorus content was as high as 129 μmol/g in the fresh water area, in which inorganic phosphorus accounted for about 70% of the total. Potentially bio-available phosphorus extracted by the citratedithionite-bicarbonate procedure (CDB-P) was the major component of inorganic phosphorus. Phosphorus content in the suspended matter decreased linearly with salinity, reflecting the process of CDB-P release from suspended matter into the estuarine water during the transportation to the sea. The average C: N: P atomic ratio of the organic substances contained in the suspended matter in the estuary was estimated to be 140 : 16 : 1, which is considerably different from the ratios for mangrove litter and rather similar to the Redfield ratio, indication the higher contribution of living microorganisms than that of the mangrove litter.

Discipline: Fisheries/Environment
Additional key words: phosphorus forms, soil erosion, mangrove litter

Introduction

Suspended matter, which originates from the erosion of soil from forests and farmlands, is discharged in large quantities from rivers, especially in the tropics, where thunderstorms often occur. The suspended matter contains many kinds of nutrients such as nitrogen and phosphorus. The phosphorus content in the soil is especially large, and phosphorus usually runs off in a particulate form[4,6,16,18].

Viner[20] who studied river sediments collected in the Purari river in Papua New Guinea, estimated that most of the available phosphorus occurs in bound forms in the suspended load, rather than in free dissolved forms in the river water. However, in the case of tropical mangrove ecosystems, the role of suspended matter in nutrient enrichment in the estuaries is poorly documented and there are very few studies on the chemical composition of the suspended matter. The C:N:P ratios of the organic substances contained in the suspended matter may also provide a better understanding of the importance of suspended matter as a food source for suspension feeders.

To address some of these issues, a study was carried out in the Matang Mangrove Forest Reserve in Perak, Malaysia, reputed to be the world's best managed mangrove forest. This Reserve, situated on the northwestern coast of Peninsular Malaysia, consists of some 40,000 ha of mainly *Rhizophora apiculata* mangroves[10]. This largest tract of man-

This report was written within the framework of the integrated project entitled "Productivity and Sustainable Utilization of Brackish Water Mangrove Ecosystems" in collaboration with University of Malaya, Fisheries Research Institute, Forestry Research Institute of Malaysia and JIRCAS (Japan International Research Center for Agricultural Sciences), during the period of 1995 to 2000.

grove forest in Peninsular Malaysia has been under sustainable management since the early part of the century.

In the current investigation, attempts were made to study the distribution of suspended matter and its C, N, P composition in the estuary of the Sangga Besar River in the Matang Mangrove Forest. Phosphorus forms contained in the suspended matter were also examined.

Materials and methods

This study was conducted during the spring tide on Jan. 22, 1996 in 7 stations along the Sangga Besar River Estuary located in the northern part of the Matang Mangrove Forest Reserve. The locations of the stations are shown on the map in Fig. 1. Salinity, temperature and turbidity were measured with a T-S meter (ALEC ACT20-D) and a light scattering type turbidimeter (ANALITE 152) at 1 m intervals in the section from Stn. 1 to Stn. 7.

Surface water samples were passed through a 200 μm mesh size nylon net to eliminate large-sized particles. Samples of suspended matter for chemical analysis were collected on Whatman GF/C filters by filtration. The samples of suspended matter on the filters were dried and kept in a desiccator until analysis. After acid treatment for the elimination of inorganic carbon[5], the contents of organic carbon (Org-C) and total nitrogen (Total-N) were measured with an elemental analyzer (FISONS EA1108).

The procedures of Williams et al.[22] were adopted for serial extraction of the inorganic phosphorus for separation into the following 3 fractions (details of the procedures were described in the report of Tanaka[19]).

1) Phosphorus extracted by the citrate–dithionite-bicarbonate procedure (CDB-P): forms extracted

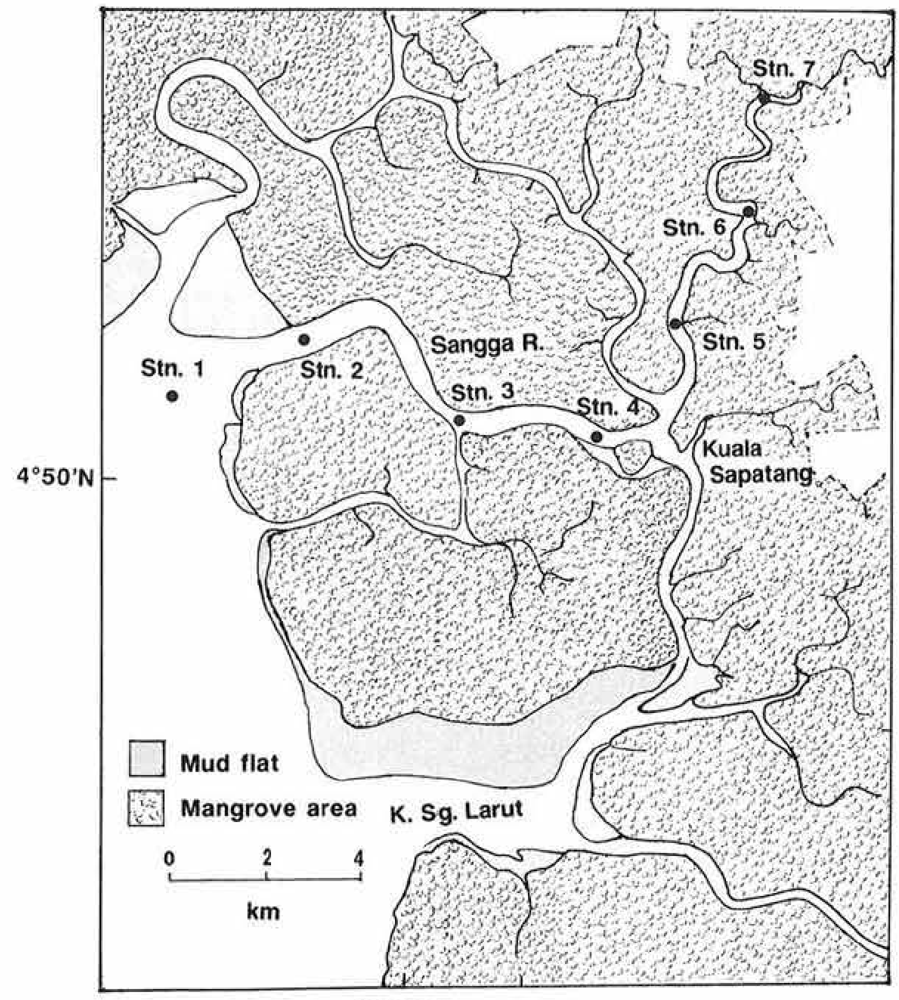

Fig. 1. Sampling stations in the estuary of the Sangga Besar River in Matang Mangrove Forest

included most of the iron phosphate minerals and adsorbed phosphate which is dissolved under anaerobic conditions[8,19].

2) Phosphorus extracted by 1N-sodium hydroxide solution (NaOH-P): forms extracted included aluminium phosphorus and any iron-bound phosphorus forms not extracted in the CDB treatment.
3) Phosphorus extracted by 1N-hydrogen chloride (HCl-P): forms extracted included varieties of apatite (calcium phosphate).

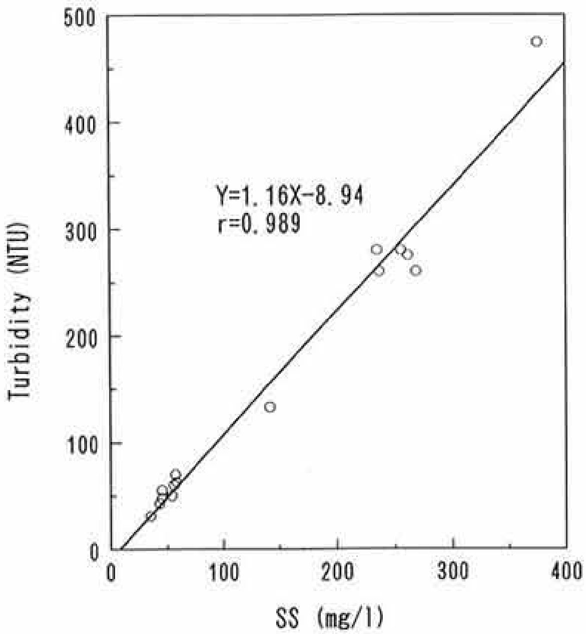

Fig. 2. Relationship between measured turbidity (NTU) and dry weight of the suspended solids (SS)

Total phosphorus (Total-P) concentrations were obtained after leaching the samples for 15 min with boiling 1N HCl on a hot plate following 1-h combustion at 550°C[2]. Organic phosphorus content (Org-P) was estimated by the difference between the amount of Total-P and that of total inorganic phosphorus (CDB-P + NaOH-P + HCl-P). The concentration of iron in the solution for Total-P (1N HCl-Fe) was determined using an atomic adsorption spectrophotometer (Z-8000; Hitachi), with air acetylene flame[7].

Results

1) Distribution of the suspended matter

Salinity (Fig. 3) ranged from nearly 0 (Stn. 7) to over 24 (Stn. 1). The water was vertically well-mixed and only a very weak salinity gradient was observed between Stn. 4 and Stn. 6 in the range from 4 to 6 m. There was a high linear correlation (r = 0.989) between the turbidity measured in NTU and the concentration of suspended solids (SS) (Fig. 2). Turbidity in the Sangga Basar River Estuary (Fig. 4) ranged from 32 to 479 NTU (SS: 35–421 mg/l). High turbidity values were observed between the mud flat area (Stn. 1) and river mouth (Stn. 2) and below the salinity gradient from Stn. 4 to Stn. 6. Surface water turbidity in the fresh water area (Stn. 7) exceeded 50 NTU, while it was lower than 50 NTU in Stn. 4 to Stn. 6, indicating that the deposition of suspended matter carried by the river was taking place in that area. This phenomenon may be attributed to the flocculation of riverine suspended matter at the interface of sea water and

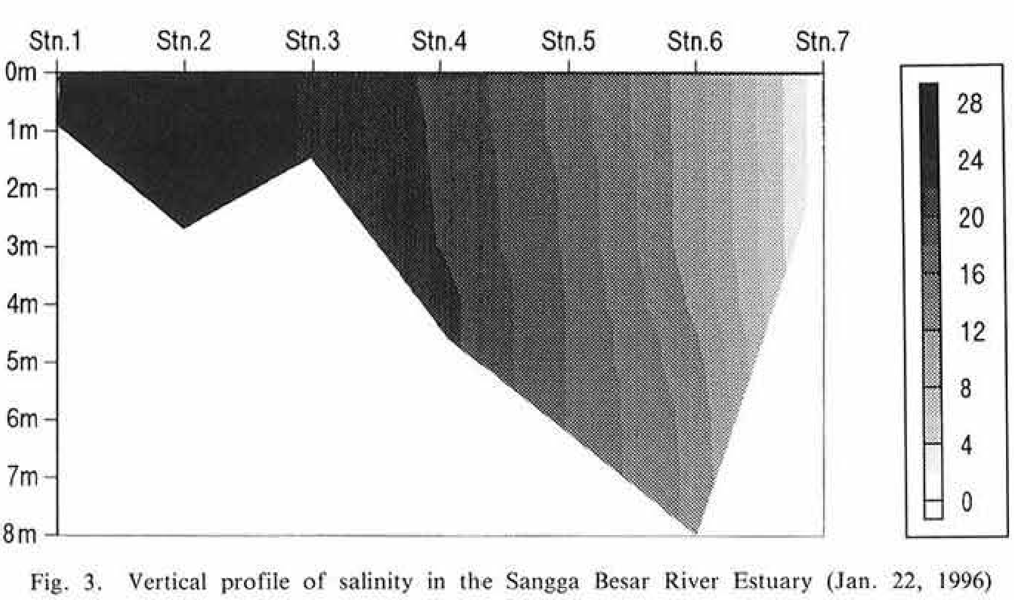

Fig. 3. Vertical profile of salinity in the Sangga Besar River Estuary (Jan. 22, 1996)

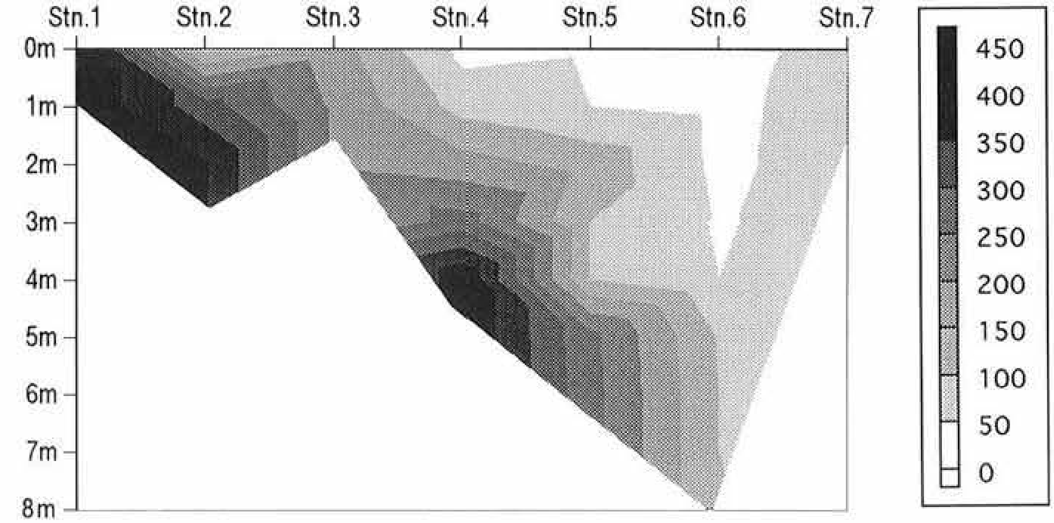

Fig. 4. Vertical profile of turbidity (NTU) in the Sangga Besar River Estuary (Jan. 22, 1996)

river water[15]. Since the observation was made just before the low water during the spring tide, the high turbidity area between the shallow mud flat (Stn. 1) and river mouth (Stn. 2) can be attributed to the resuspension of mud flat sediments. Near Stn. 4, there is a small mud flat area which may also affect the distribution of suspended matter by the resuspension of sediments.

2) Chemical composition of the suspended matter

Changes in the concentrations of organic carbon and nitrogen in the suspended matter samples in the surface water are shown in Fig. 5. The C, N contents were higher in the upper part of the river (Stn. 6, 7), and decreased towards the river mouth with a significant gradient between Stn. 6 and Stn. 5. The C:N atomic ratios of the suspended matter ranged from 8.1 to 10.5 and averaged 9.0.

Fig. 6 shows the phosphorus content and composition in the suspended matter in each station. The main components of phosphorus in the suspended matter were CDB-P and Org-P. Phosphorus content was as high as 129 μmol/g in the fresh water area (Stn. 7) in which inorganic phosphorus accounted for about 70%, suggesting that the inorganic phosphorus load exceeds that of Org-P. CDB-P, potentially biologically available phosphorus, was the major component of inorganic phosphorus. The amount of inorganic phosphorus decreased from about 70 to 47% from Stn. 7 to 6 at the interface of fresh and brackish water.

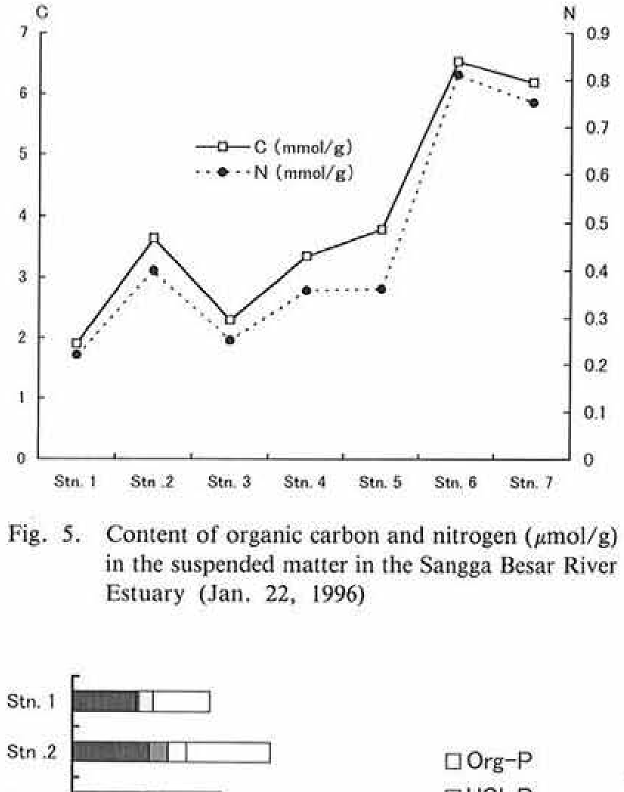

Fig. 5. Content of organic carbon and nitrogen (μmol/g) in the suspended matter in the Sangga Besar River Estuary (Jan. 22, 1996)

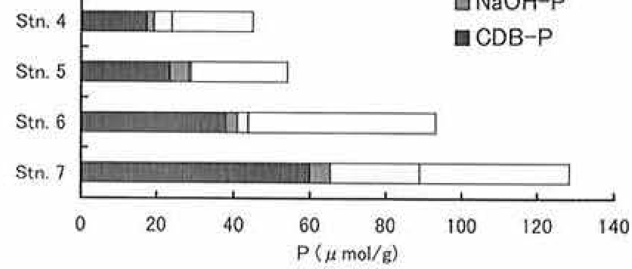

Fig. 6. Phosphorus fractions of suspended matter in the Sangga Besar River Estuary (Jan. 22, 1996)

Discussion

A simple linear correlation coefficient matrix among the variables was computed using phosphorus fractions as dependent variables and other parameters as independent variables. Table 1 shows an abbreviated form of the matrix. In this table, only r values significant at the 99% confidence level are listed.

Phosphorus and iron contents in the suspended matter decreased linearly with salinity, indicating that phosphorus and iron were released from the suspended matter into the estuarine water during the transportation to the sea. Iron hydroxides display a strong affinity for phosphate and are considered to be primarily responsible for phosphate adsorption in the oxidized environments[11,17]. The release of phosphorus from sediments under anaerobic conditions in coastal waters has been investigated experimentally, and it has been generally recognized that the contribution of inorganic phosphorus (adsorbed phosphorus and iron phosphate minerals) is more important than that of organic phosphorus[9,23]. CDB-P showed a positive correlation with 1N-HCl extractable iron (Fig. 7) and the decrease in Total-P mainly accounted for the decrease of the CDB-P fractions (Fig. 6). These results reflect the desorption of adsorbed phosphate from the iron hydroxides and elution of reductant soluble phosphorus from iron phosphate minerals in the anoxic sediment during the tidal resuspension and transportation of suspended matter to the sea.

Org-P showed a highly positive correlation with Org-C in the suspended matter. Fig. 8 depicts the linear regression analysis of this relationship. Based on the slope of the regression line, the atomic ratio of Org-C to Org-P was calculated to be 140:1, and the average C:N:P atomic ratio of organic substances contained in the suspended matter of the Sangga Besar River Estuary was estimated to be 140:16:1, which is considerably different from the

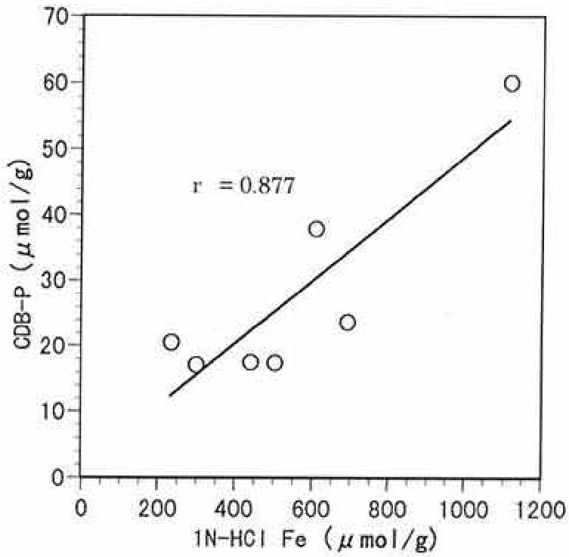

Fig. 7. Relationship between CDB-P and 1N-HCl extractable iron (1N HCl-Fe) contents in the suspended matter in the Sangga Besar River Estuary (Jan. 22, 1996)

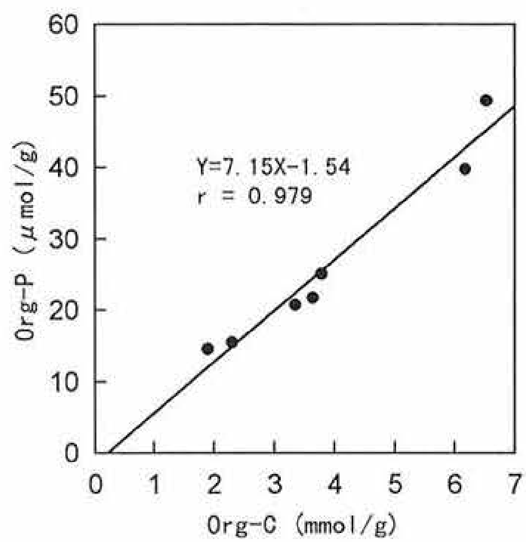

Fig. 8. Relationship between organic phosphorus (Org-P) and organic carbon (Org-C) contents in the suspended matter in the Sangga Besar River Estuary (Jan. 22, 1996)

Table 1. Correlation coefficients (r) of phosphorus fractions in the suspended matter with some parameters

	Total-P	CDB-P	NaOH-P	HCl-P	Org-P
Salinity	−0.974	−0.975	–	–	–
Org-C	0.914	–	–	–	0.979
Total-N	0.923	–	–	–	0.982
1N HCl-Fe	–	0.877	–	–	–

Only r values at the 99% confidence level are shown.

ratio for mangrove litter (415:8:1) of Missionary Bay[1] and rather similar to the Redfield ratio (106:16:1)[14]. According to Wafar et al.[21], in the course of decomposition, the concentration of C and P in mangrove leaves decreased, while that of N increased. As a result, the C:P and N:P ratios increased, reaching values as high as >1000 and >300, respectively, after 15 weeks of the decomposition experiments. These findings indicate the higher contribution of living micro-organisms in the organic suspended matter than that of the particles derived from the fragmentation of mangrove litter. Suspended matter in mangrove estuaries contains aggregates colonized by microbes and meiofauna formed from the leachates of mangrove litter[3]. Ong et al.[13] demonstrated that the net aquatic community productivity in Matang Mangrove Forest is almost zero compared to the tree production. Therefore, in terms of C, N, P composition of the suspended matter, the direct energy flux to the particulate food chain from mangroves by the decomposed litter may not be as important as that through the microbial food chain, as discussed by Wafar et al.[21] in the study of mangrove forests on the southwestern coast of India.

Particulate nitrogen and phosphorus concentrations in the fresh water area (Stn. 7) were 34 μM and 5.8 μM, respectively, while the concentrations of dissolved nitrogen and phosphorus in the fresh water area of the Sangga Besar River Estuary were reported to be about 24 μM and 1 μM, respectively[12]. These data indicate the importance of particulate phosphorus load from the river. The particulate loading in the present study is likely to be lower than the average because sampling was carried out during the dry season. The importance of particulate nitrogen and phosphorus load from the river would be much higher in the wet season.

References

1) Alongi, D. M. (1990): Effect of mangrove detrital outwelling on nutrients regeneration and oxygen fluxes in coastal sediments of the Central Great Barrier Reef Lagoon. *Estu. Coast. Shelf Sci.*, **31**, 581-598.
2) Andersen, J. M. (1976): An ignition method for determination of total phosphorus in lake sediments. *Water Res.*, **10**, 329-331.
3) Camelleri, J. C. & Ribi, G. (1986): Leaching of dissolved organic carbon (DOC) from dead leaves, formation of flakes of DOC, and feeding on flakes by crustaceans in mangroves. *Mar. Biol.*, **91**, 337-344.
4) Chase, E. M. & Sayles, F. L. (1980): Phosphorus in suspended sediments of the Amazon River. *Estu. Coast. Shelf Sci.*, **11**, 383-391.
5) Hedges, J. I. & Stern, J. H. (1984): Carbon and nitrogen determination of carbonate containing solids. *Limnol. Oceanogr.*, **29**(3), 657-663.
6) Inoue, T. & Ebise, S. (1991): Runoff characteristics of COD, BOD, C, N and P loadings from rivers to enclosed coastal seas. *Mar. Poll. Bull.*, **23**, 11-14.
7) Itoh, H. (1975): *In* Methods of crop plant analysis. ed. M. Kubota, Youkendou, Tokyo, Japan, 96-99 [In Japanese].
8) Izawa, H. & Seiki, T. (1983): Evaluation of CDB (citrate, dithionite, bicarbonate) extraction on behavior of phosphorus in coastal marine sediments. *Bull. Hiroshima Pref. Cent. Environ. Sci.*, **5**, 44-47 [In Japanese with English summary].
9) Joh, H. (1982): Fractionation of phosphorus and releasable fraction in sediment mud of Osaka Bay. *Bull. Jpn. Soc. Sci. Fish.*, **49**, 447-454 [In Japanese with English summary].
10) Khoo, K. H. (1989): The fisheries in the Matang and Merbok mangrove ecosystem. *In* Proc. 12th Annual Seminar of the Malaysian Society of Marine Sciences, 147-169.
11) Lucotte, M. & d'Anglejan, B. (1988): Process controlling phosphate adsorption by iron hydroxides in estuaries. *Chem. Geol.*, **67**, 75-83.
12) Nixon, S. W. et al. (1984): The role of mangrove in the carbon and nutrient dynamics of Malaysia estuaries. *In* Proc. As. Symp. Mangr. Env.-Res. & Manag., 534-544.
13) Ong, J-E. et al. (1984): Contribution of aquatic productivity in managed mangrove ecosystem in Malaysia. *In* Proc. As. Symp. Magr. Env.-Res. & Manag., 209-215.
14) Redfield, A. C., Ketchum, B. H. & Richard, F. A. (1963): The influence of organisms on the composition of sea-water. *In* The sea, Vol. 2. ed. Hill, M. N., J. Wiley & Sons, New York, 26-87.
15) Sakamoto, W. (1972) Study on the process of river suspension from flocculation to accumulation. *Bull. Ocean Res. Inst. Univ. Tokyo,* **5**, 1-46.
16) Schubel, J. R. & Hirschberg, D. J. (1978): Estuarine graveyards, climatic change, and the importance of the estuarine environment. *In* Estuarine interactions. ed. Wiley, M. L., Academic Press, New York, 285-304.
17) Sundby, B. et al. (1992): The phosphorus cycle in coastal marine sediments. *Limnol. Oceanogr.*, **37**(6), 1129-1145.
18) Tanaka, K. (1995): Runoff loadings and chemical forms of soil phosphorus from rivers in Japan during the high flow stages. *JARQ,* **29**(4), 223-229.
19) Tanaka, K.(1995): Effects of soil loading on the phosphorus cycle in estuarine and coastal marine environments. *Bull. Nansei Natl. Fish. Res. Inst.*, **28**, 73-119 [In Japanese with English summary].
20) Viner, A. B. (1982): A quantitative assessment of the nutrient phosphate transported by particles in a tropical river. *Revue Hydrobiologie Tropicale,* **15**, 3-8.
21) Wafar, S., Untawale, A. G. & Wafar, M. (1997): Litter fall and energy flux in a mangrove ecosystem. *Estu. Coast. Shelf Sci.*, **44**, 111-124.
22) Williams, J. D. H., Jaquet, J. M. & Thomas, R. H. (1976): Forms of phosphorus in sediments of Lake Erie. *J. Fish. Res. Bd. Can.*, **33**, 413-429.
23) Yamada, H. & Kayama, M. (1987): Distribution and dissolution of several forms of phosphorus in coastal marine sediments. *Oceanol. Acta,* **10**, 311-321.

(Received for publication, September 29, 1997)