D-1.1.2 Studies on the Evaluation of the Settling and Decomposition Processes of Particulate Matter using Sediment Traps in the Changjiang Estuary

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Abstract

Experiments using sediment traps were conducted to measure the flux and decomposition rate of the sinking particles in the Changjiang Estuary in autumn 1997 and spring 1998. There was a close relationship between the water column conditions and the level of particulate flux. When the water column was stratified, there was a large difference between the upper (5m depth, in water depth of about 20m) and lower (15m depth) layers in size, type and quantity of particles. When the water column was well mixed, there was little such difference, due to the resuspension of sediments from the seabed. The chemical composition of the sinking particles suggests that biological production was mainly by diatoms in autumn and by other phytoplankton, such as dinoflagellates, in spring. The higher C/N ratio of sinking particles in autumn than in spring suggests high biological productivity in autumn and high frequent resuspension events in spring in spite of the high biological productivity. The decomposition rate of sinking particles was low due to the influence of a large amount of lithogenic particles.

1. Introduction

The Bohai and East China seas have huge continental shelf areas and high biological productivity due to the large nutrient and suspended sediment inputs from the Huanghe and Changjiang rivers. Excess application of artificial chemicals due to the recent rapid development of agriculture and industry and the population explosion in coastal regions in China has accelerated the increase of riverine pollutants. Further the increased exploitation of water and energy resources and changing land use pattern have also led to changes in the amount and concentration of riverine pollutants. Particulate matter supplied from the rivers creates high turbidity in the Changjiang Estuary. Heavy metals of Fe, Al, Cu, Pb and Zn in dissolution once entered the estuary environment were absorbed into the particluate matter due to the mixing of fresh and sea water and aggregation has been shown to occur in the area ranging from 15 to 24 of salinity [1]. More than 80% of the hydrophobic organic matter was transferred in a particulate form to the sea, such as PCBs [2]. Various dissolved pollutants are absorbed to the particulate matter in the high turbidity area and transported offshore. It is necessary for evaluating the influence of these pollutants on the marine ecosystem to clarify the transport mechanism of particulate matter in the estuarine and offshore areas.

2. Research Objectives

The particles creating high turbidity in the Changjiang Estuary are removed by physical, chemical and biological processes. Little research on the transport of sinking particles in the Changjinag Estuary has been carried out. This study aimed to provide the fundamental data for clarifying the processes of sinking and decomposition of particulate matter in the Changjiang Estuary.

3. Research Method

3.1. Sampling Method

Experiments using sediment traps were conducted to measure the flux and decomposition rate of sinking particles in the Changjiang Estuary in autumn, 11 to 13 October 1997, and spring, 20 May to 1 June 1998 (Table 1). Experimental site was at lat 30°52.5'N, long 122°36.5'E, in

water depths of about 20m (Fig. 1). In the autumn experiment, two sediment traps (twin-cylinder type) were submerged from the R/V 'Haijian 49' for about 2 d at depths of 5 and 15m, respectively. Formalin (5ml per 500ml-sample bottle) was added in advance to a sample bottle attached to one of the cylinders at each depth. The formalin-containing samples were used for measuring the flux and chemical composition of sinking particles, while the other samples were used for measuring the decomposition rate of the sinking particles. In spring, four experiments (Exps. I- IV) were conducted to measure the flux and decomposition rate of sinking particles. Exp. I and III were done to measure the flux of sinking particles for 1.15 to 1.97 d and Exp. II and IV were for measuring the decomposition rate of sinking particles for 10 h.

3.2. Analysis and Measurement

To analyze the flux and chemical composition of sinking particles, after extra large particles (>1000μm) were removed by nylon net, each sample was divided into two size fractions (<100 and 100 to 1000μm) by nylon net and filtering through GF/F and/or Nuclepore (pore size 0.6μm) filters. The samples were weighed before analysis for organic carbon, organic nitrogen, biogenic silica and lithogenic silica content. Organic carbon and nitrogen were measured using an elemental analyzer (EA1110; CE Instruments). Biogenic and lithogenic silica were measured using a spectrophotometer (UV1600; Simazu).

To measure the decomposition rate of sinking particles, samples were placed in DO bottles on board, packed in a dark bag and incubated at the sea surface. Water temperatures in autumn and spring were 23.1 to 23.8 and 19.2 to 20.7°C, respectively. Subsampling was carried out at intervals of 3hs to 1d and the decomposition rate was determined by two methods in the DO bottles: measurement of oxygen consumption by Winkler method (O_2 method) and from the decrease in organic carbon using an elemental analyzer (direct method).

The amount of oxygen consumption is converted to the decreased amount of the organic carbon by the following chemical equation:

$$(CH_2O)_{106}(NH_3)_{16}H_3PO_4+138O_2 \rightleftarrows 106CO_2+16HNO_3+H_3PO_4+122H_2O$$

138 moles of oxygen atoms are necessary to decompose 106 moles of carbon atoms.

Assuming that the decomposition process is logarithmic with time, the decomposition rate (k, d^{-1}) of sinking particles during incubation period (t, day) is approximated as

$$k = -1/t \cdot \ln[(N_0-\Delta D)/N_0],$$

where N_0 is the initial amount of organic carbon in the sinking particles and ΔD is the decreased amount of the organic carbon during t days [3].

4. Results and Discussion

4.1. Flux and chemical composition of sinking particles

4.1.1 Experiment in autumn 1997

In autumn 1997, vertical profiles of water temperature and salinity showed that the water column was stratified (Fig. 2a). The dry weight flux was 29.6 and 96.5 $g \cdot m^{-2} \cdot d^{-1}$ in the upper (5m) and lower (15m) layer, respectively, and tended to increase in the lower layer (Fig. 3). The organic carbon content was 1.89 and 0.88% in the upper and lower layer, respectively. The biogenic silica content reached 1.98% in the upper layer, while the lithogenic silica content reached 46.6 and 51.5% in the upper and lower layer, respectively (Fig. 4). Small particles (<100μm) constituted over 80% of the sinking particles (Fig. 5). Although the large particles (100-1000μm) constituted 12.4% of the sinking particles in the upper layer, the organic carbon flux of these large particles accounted for 34.9% of the total organic carbon flux (Fig. 6). From this, it was considered that large particles contribute significantly to the organic matter content in the sinking particles. Cloern [4] repoted that phytoplankton blooms often coincide with stratification events that reduce the mixed detph. In this study also, it is suggested that relatively high biological productivity occurred due to the improvement of light condition and mainly consisted of diatoms in the upper layer. $BSiO_2$/POC ratio (w/w) was 1.05 in the upper layer. Considering a ratio of 0.65±0.20 for live diatoms [5], this suggests that diatoms in the sinking

particles were well decomposed so that they became detritus. On the other hand, the high flux and low organic carbon content of the sinking particles in the lower layer is considered to be due to the resuspension of sediments from the sea bottom. The C/N ratio (w/w) of the sinking particles in autumn was about 5.0 in both layers (Fig. 7), which indicates that the organic matter of the sinking particles has a strong influence on the high biological productivity at the experiment site in autumn.

4.1.2 Experiment in spring 1998

In spring 1998, the water column was stratified during Exps. I and II; vertical mixing developed during Exp. III under the influence of the spring tide and passage of an atmospheric depression, and this mixing began to weaken during Exp. IV (Fig. 2b). The dry weight flux varied greatly during the experimental period; at 5m it was 43.8, 45.6, 370.2 and 148.1 $g \cdot m^{-2} \cdot d^{-1}$ in Exps. I, II, III and IV, respectively (Fig. 8). The dry weight flux in the upper layer was higher under the mixing conditions in Exps. III and IV than under the stratified conditions in Exps. I and II. The organic carbon content varied from 0.74 to 1.90% (Fig. 9) and tended to be inversely related to increase in dry weight flux. In Exp. III, the dry weight flux reached 370.2 $g \cdot m^{-2} \cdot d^{-1}$ and the organic carbon content was 0.74, which suggests that the influence of resuspension of the surface sediments from the sea bottom reached to the upper layer. In Exps. II and IV, sediment traps were also installed at 15m where the dry weight flux was 547.9 and 229.2 $g \cdot m^{-2} \cdot d^{-1}$, respectively (Fig. 3). In Exp. II, the dry weight flux in the lower layer was extremely high and the organic carbon content was 0.63%. Considering 0.47% of organic carbon content of the surface sediment on the sea bottom, the particles resuspended from the sea bottom influenced the composition of the sinking particles in the lower layer below the pycnocline. In Exp. II, the organic carbon content reached 1.9% in the upper layer, but the biogenic silica content was about 1% (Fig. 4), which indicates that the biological productivity in spring was due to other phytoplankton, such as dinoflagellates, while that in autumn was due to diatoms. The lithogenic silica content in spring reached more than 50% (Fig. 4) and the fraction of small particles was more than 80% except for 68.5% in the upper layer during Exp. II (Fig. 5), a tendency similar to that in autumn. In Exp. II, large particles constituted 31.5% of the sinking particles in the upper layer, furthermore, the organic carbon flux of large particles reached 47.1% of the total organic carbon flux (Fig. 6). This indicates that large particles contributed significantly to organic matter content in the sinking particles. However, the C/N ratio (w/w) of sinking particles in spring was 7.2 to 8.4 (Fig. 7), which was higher than that in autumn. This result suggests that the sinking particles had a strong influence due to the large amount of resuspended surface sediment that had already decomposed.

4.2. Decomposition rate of sinking particles

In autumn, the decomposition rate of sinking particles sampled for 1.15 to 1.97 d was measured. The results by the O_2 method were 0.026 and 0.022 d^{-1} at 5m and 15m, respectively (Fig. 10). Decomposition rate was higher in the upper layer than the lower layer due to the high ratio of organic matter in the upper layer.

In spring, the decomposition rate in sinking particles sampled over 10 h in the upper layer was measured by two methods. The direct method results were 0.223 and 0.035 d^{-1} at 8m in Exp. I and at 5m in Exp. III, respectively. The O_2-method results were 0.053 and 0.024 d^{-1} at 8m in Exp. I and at 5m in Exp. III, respectively (Fig. 11), being directly proportional to the level of organic carbon in the sinking particles. The decomposition rate of the particles measured by the direct method tended to be higher than that by the O_2 method, particularly at higher organic carbon levels in the sinking particles (Fig. 12). However, only when the organic carbon content of sinking particles was more than 5%, the decomposition rate reached more than $0.1 d^{-1}$ [3]. It was considered that the decomposition rate was overestimated by the direct method due to elution of organic carbon from sinking particles during filtration.

Although the organic carbon content of sinking particles in autumn was higher than that in spring, the decomposition rate in autumn was lower than that in spring. It was considered that most of the sinking particles had already decomposed during the 2-d sampling in autumn. Collection of fresh sinking particles during short-term sampling is necessary to determine accurately the decomposition rate.

The decomposition rate of the sinking particles at the experiment site had a low value due to

the influence of a large amount of lithogenic particles. For example, in spring, 10% of the organic carbon in the sinking particles decreases for 2 days at a rate of 0.053 d^{-1} and for 4 days at a rate of 0.0024 d^{-1}. At the experiment site, the resuspension of surface sediments from the sea bottom frequently happens due to the strong tidal currents and/or the passage of atmospheric depressions. It is possible that the low decomposition rate of sinking particles and frequent resuspension events supply organic matter to the water column constantly. When these particles containing organic matter are transported offshore, it can be considered that the estuary plays an important role as a source of not only nutrients but also organic matter. To clarify the particulate transport mechanism, a survey from the estuary to the offshore area should be carried out in future.

5. Reference

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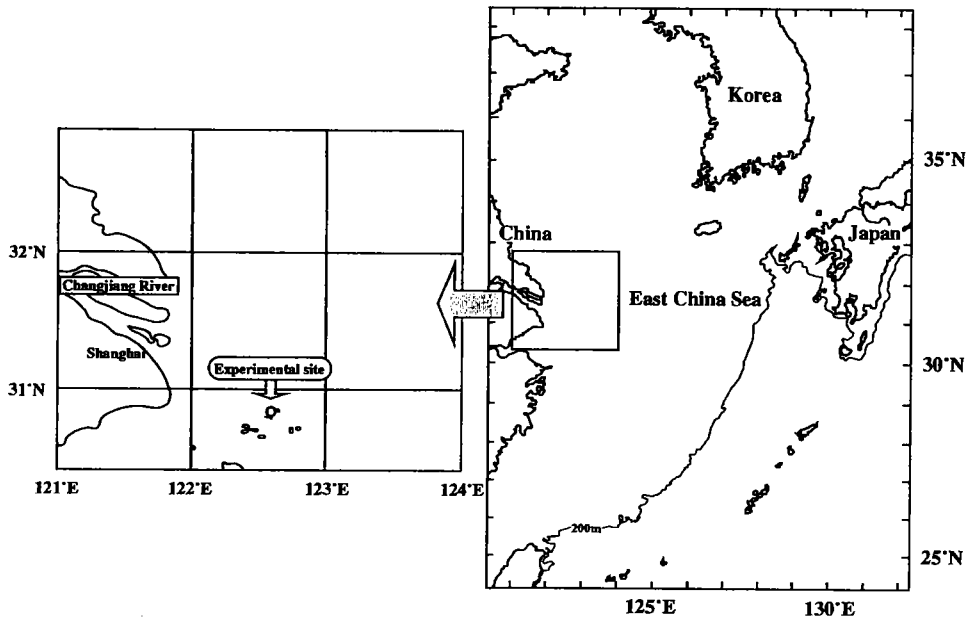

Fig. 1 Location of the study area

Table 1 Time table of the trap experiments

Experiment No.	Experimental date	Duration period (d)	Installed depth (m)	Measurement items
Exp.	11 - 13 October, 1997	2.19	5, 15	Flux, Decomposition rate
Exp. I	20 May, 1998	0.42 (10h)	8	Decomposition rate
Exp. II	22-23 May, 1998	1.15	5, 15	Flux
Exp. III	26 May, 1998	0.42 (10h)	5	Decomposition rate
Exp. IV	30 May - 1 June, 1998	1.97	5, 15	Flux

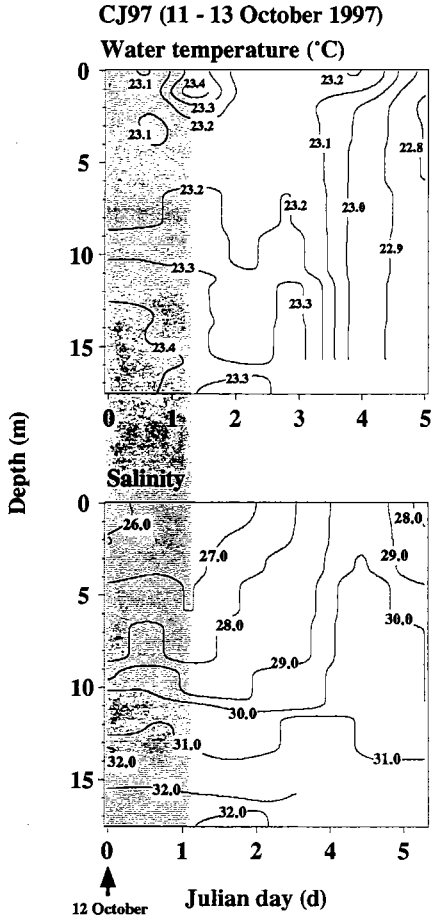

Fig. 2a Vertical profiles of water temperature (°C) and salinity during the experimental period in autumn 1997. The gray area shows the experimental period.

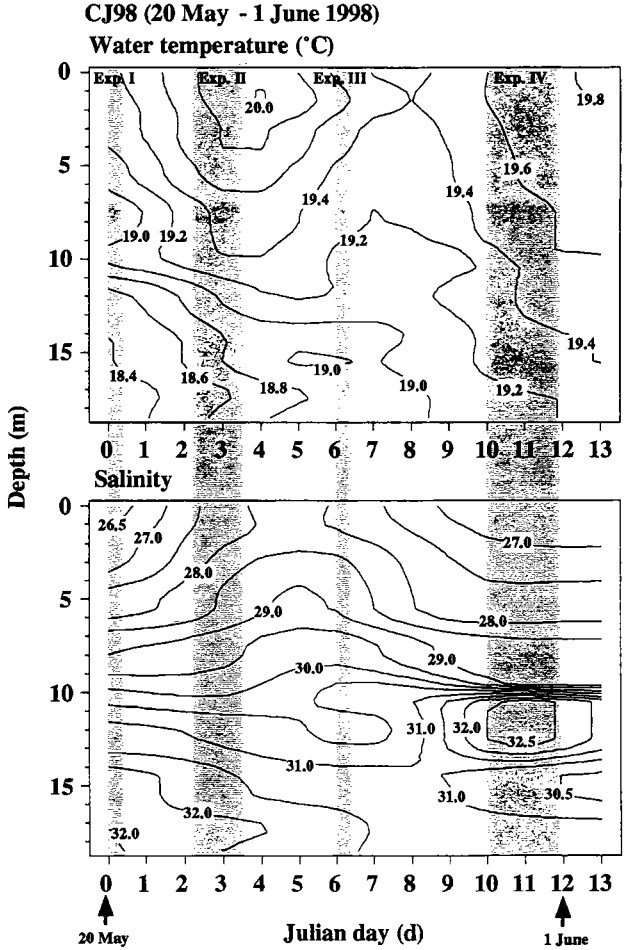

Fig. 2b Vertical profiles of water temperature (°C) and salinity during the experimental period in spring 1998. Gray areas show the experimental period.

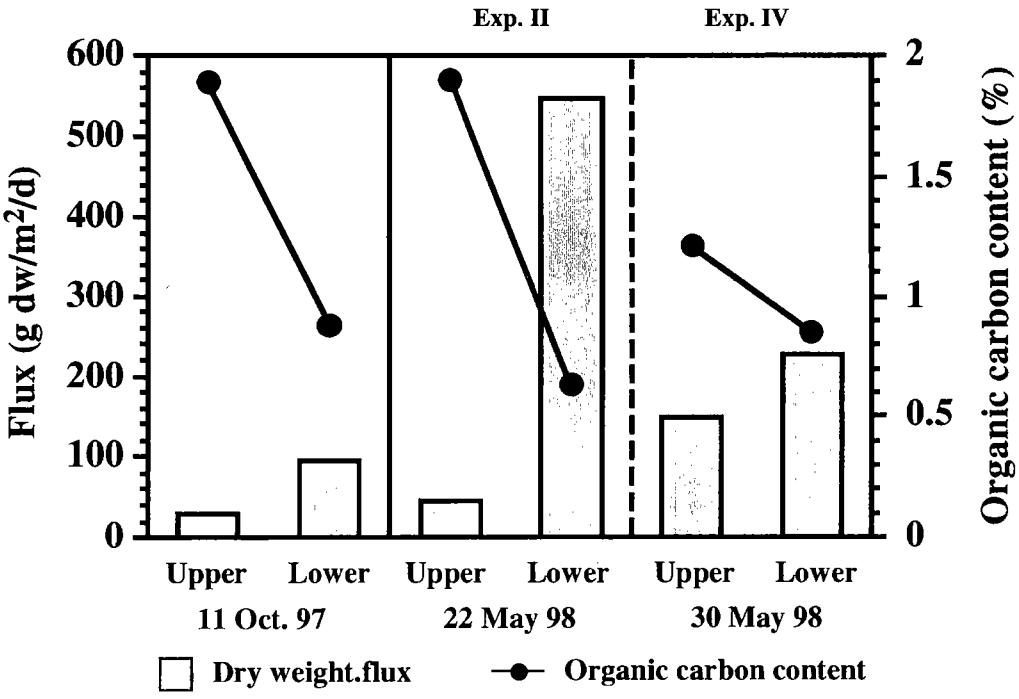

Fig. 3 Dry weight flux and organic carbon content of sinking particles in the upper and lower layer at the experimental site during the autumn and spring experiments.

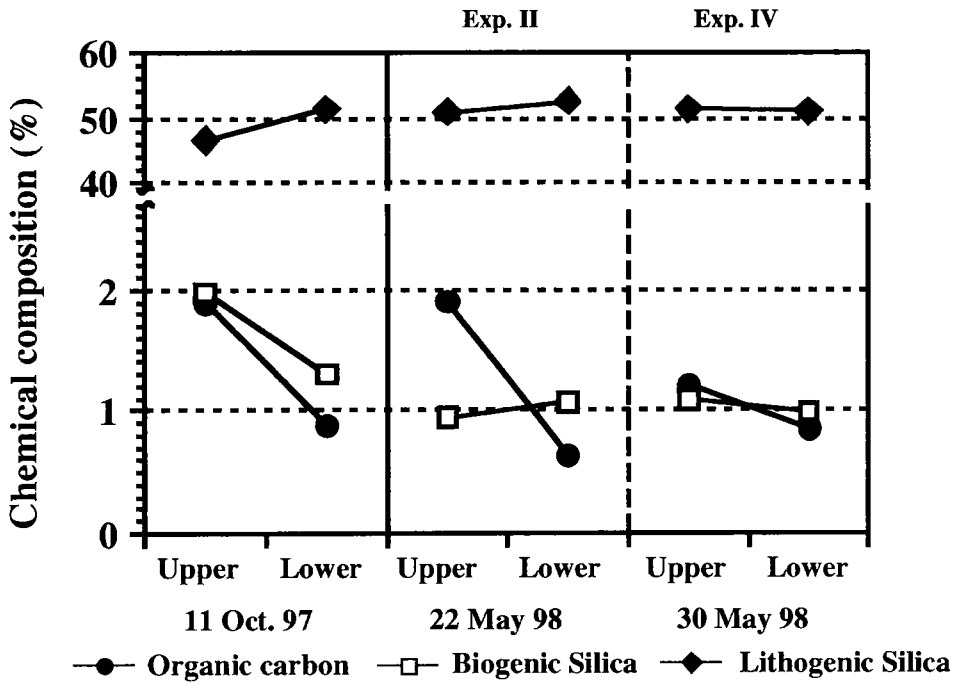

Fig. 4 Organic carbon, biogenic silica and lithogenic silica contents of sinking particles in the upper and lower layers at the experimental site during the autumn and spring experiments.

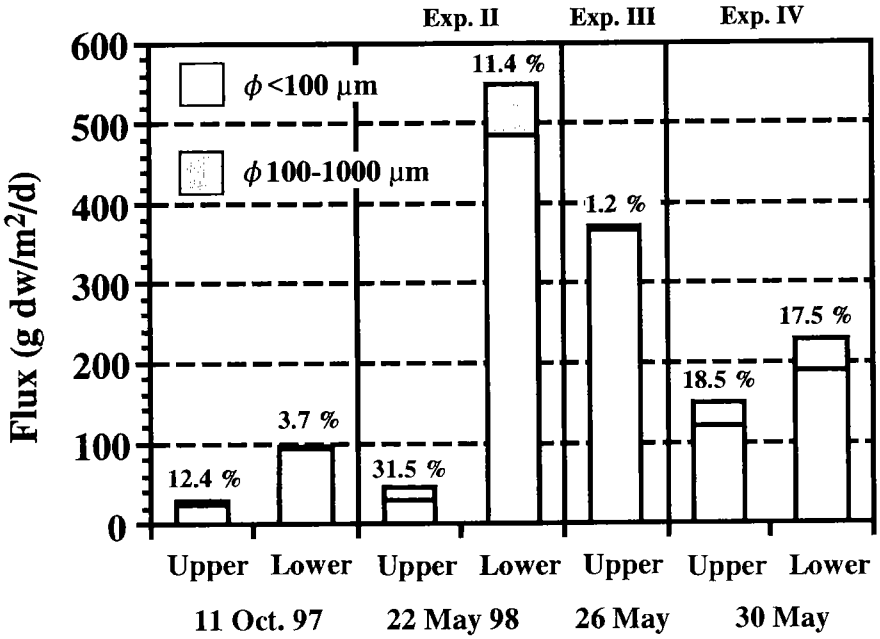

Fig. 5 Fluxes of two-size fractions of sinking particles in the upper and lower layers at the experimental site during the autumn and spring experiments

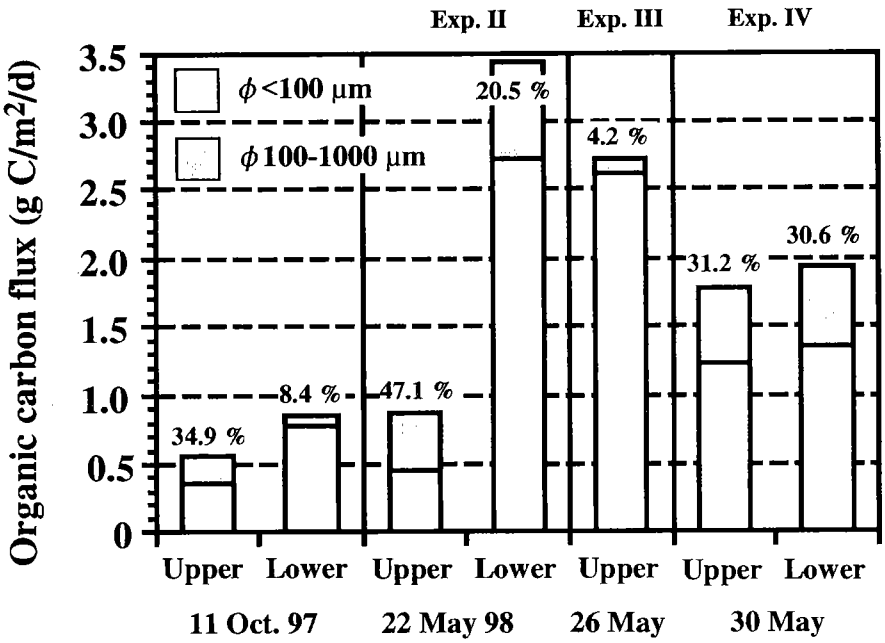

Fig. 6 Organic carbon fluxes of two-size fractions of sinking particles in the upper and lower layers at the experimental site during the autumn and spring experiments

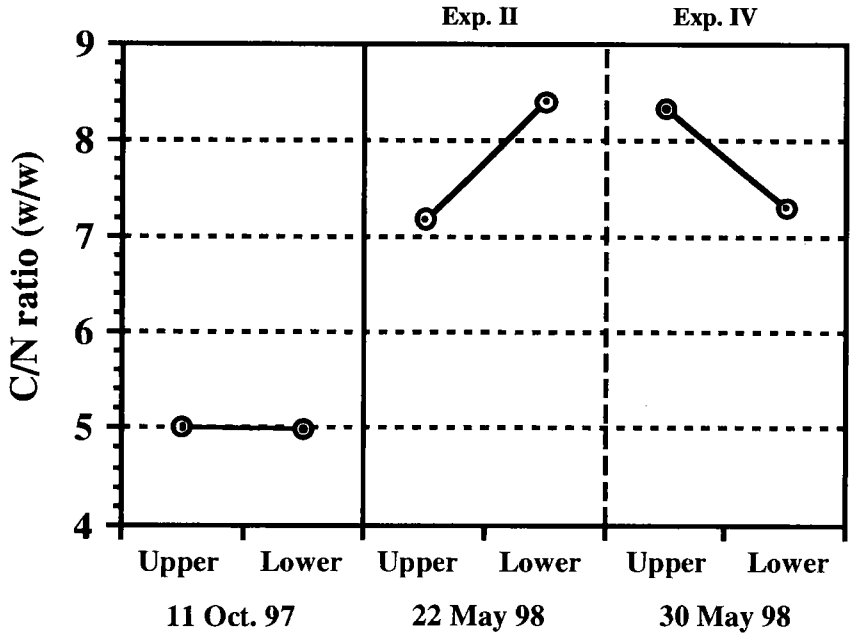

Fig. 7 C/N ratio of sinking particles in the upper and lower layers at the experimental site.during the autumn and spring experiments

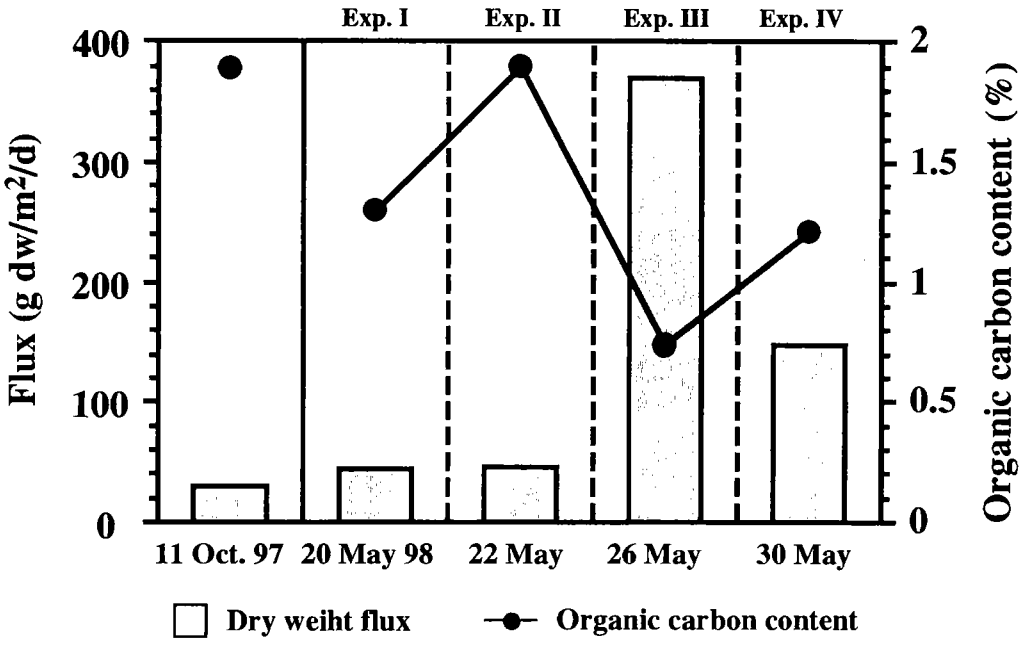

Fig.8 Dry weight flux and organic carbon content of sinking particles in the upper layer at the experimental site during the autumn and spring experiments.

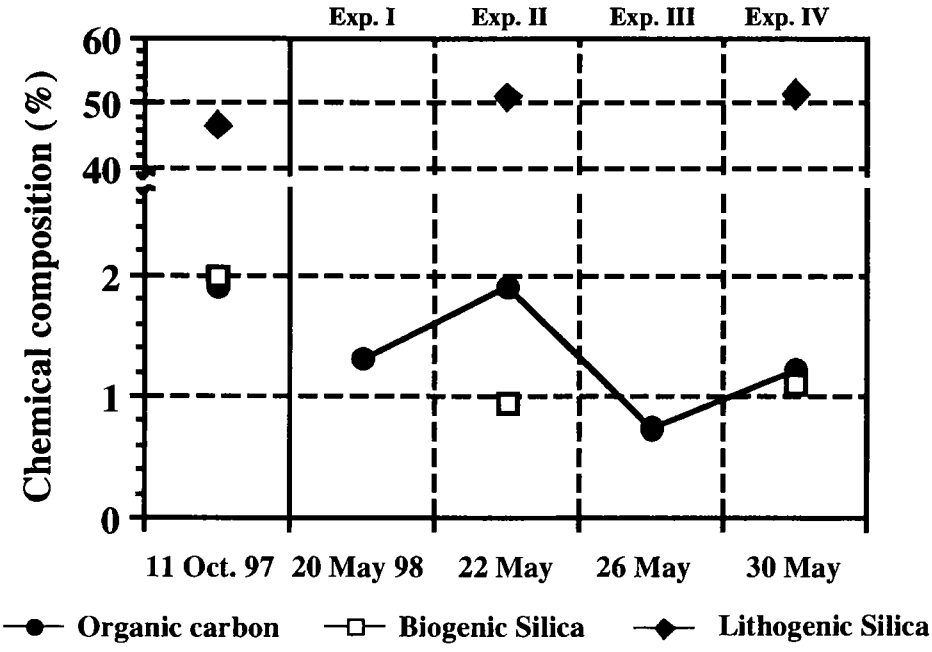

Fig. 9 **Organic carbon, biogenic silica and lithogenic silica contents of sinking particles in the upper layer at the experimental site during the autumn and spring experiments.**

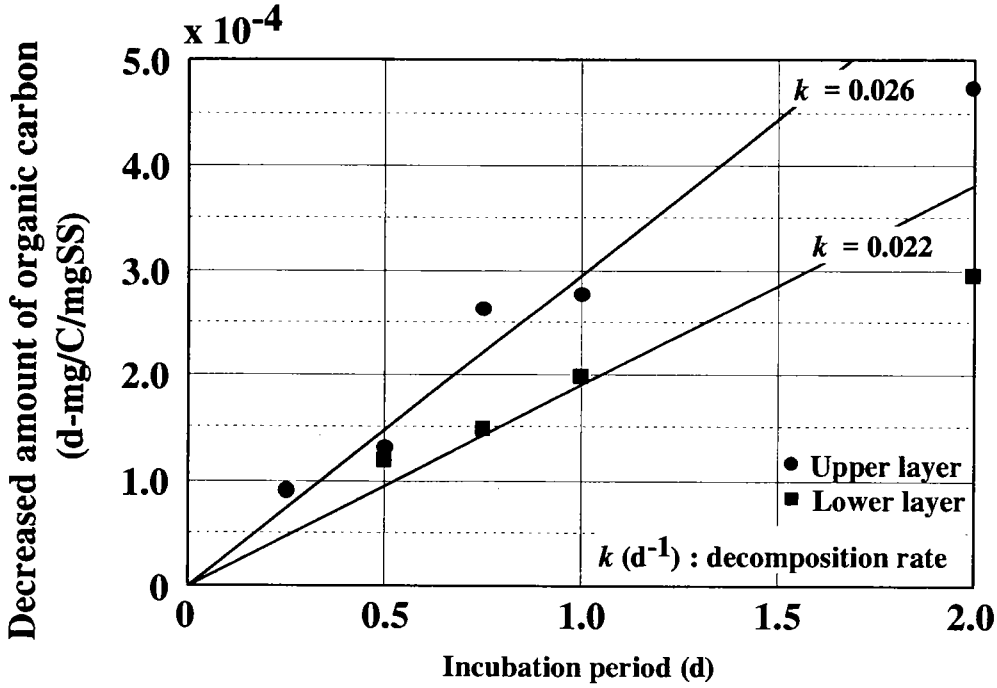

Fig.10 **Decreased amount of organic carbon in the sinking particles measured by the O_2 method in autumn 1997.**

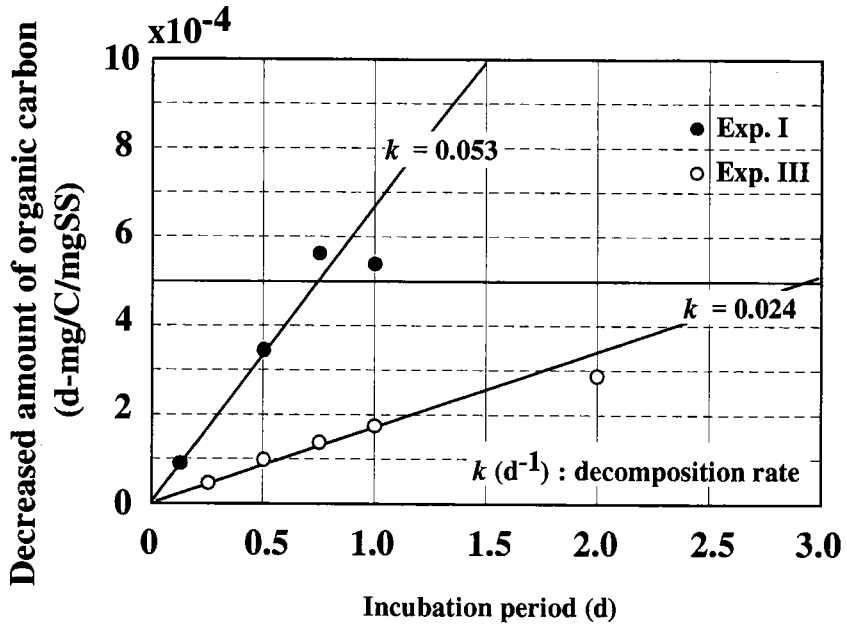

Fig. 11 Decreased amount of organic carbon in the sinking particles measured by the O_2 method during Exps. I and III in spring 1998.

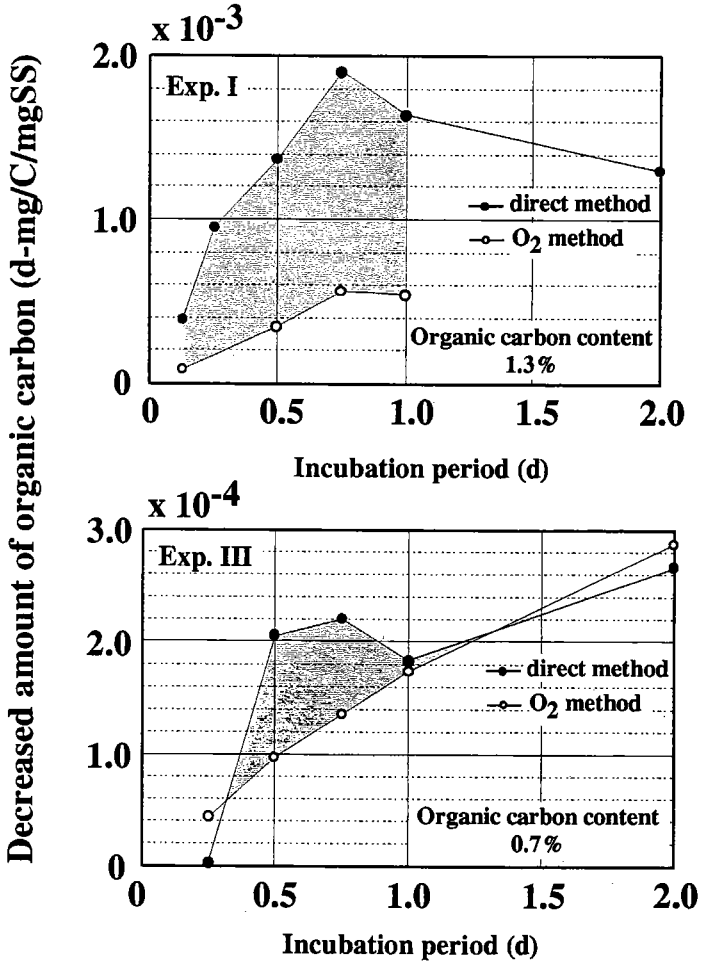

Fig. 12 Decreased amount of organic carbon in the sinking particles measured by the O_2 method and the direct method during Exps. I and III in spring 1998.