Temporal Variation of Resuspended Matter for 
One Tidal Cycle in the Hiuchi-Nada Area*

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Abstract: The observed relation between the vertical distribution of suspended matter and the size distribution of bottom sediment in the Hiuchi-Nada area indicates that a turbid bottom water layer exists above the bottom when the bottom sediment is of silt size. The turbid bottom water is thought to be produced by resuspension of bottom sediment.

Measurements of the temporal variation of resuspended matter and water movement near the bottom was carried out for one full tidal cycle at an anchored station. The concentration of resuspended matter reached a maximum at the time of strongest ebb and flood flow.

1. Introduction

Tidal resuspension of estuarine sediments may result in a significant input of biologically usable energy from the bottom to the water column. ROMAN and TENORE (1978) and ROMAN (1978), in their study of Buzzards Bay, found that tidal resuspension of bottom sediment resulted in a greater than 50% increase in particulate carbon, primary productivity and chlorophyll-a in the water column. FUKUDA (1974) has suggested that the high concentration of suspended matter near the bottom in coastal areas is due to resuspension of bottom sediment. RHOADS and YOUNG (1970) showed that the intensive reworking of a mud bottom by deposit feeders produced a fluid fecal-rich surface which was easily resuspended by low-velocity currents. The periodic resuspension of sediments in shallow estuarine systems is caused by several physical factors such as wind driven and density-driven circulations, tidal currents and wave action. These factors vary widely in time and space.

A new instrument system to measure near-bottom current velocity and concentration of suspended matter concurrently has been constructed by LAVELLE et al. (1978) and CACCHIONE and DRAKE (1979).

From August 29 to September 10, 1978, the vertical distribution of suspended matter was measured in the Hiuchi-Nada area of the Seto Inland Sea. Suspended matter was so distributed that the concentration was maximum at the bottom and decreased exponentially with distance from the bottom. We report herein measurements of the temporal variation of resuspended matter and water movement in the Hiuchi-Nada area. Our attention is focused on the water layers in close proximity to the bottom, where we find evidence of entrainment of bottom sediment into suspension by tidal currents in amounts proportional to the current velocity.

2. Methods

The sampling pattern for study of suspended matter employed in this study consisted of 50 sampling stations (Fig. 1) and a 12-hour anchored station (Stn. 30: marked in Fig. 1). The Hiuchi-Nada area is located in the central part of the Seto Inland Sea, and the depth throughout most of the area is 16 to 30 meters. The tide is of semi-diurnal type and current velocity is generally slow except near straits. A weak counterclockwise circulation is observed in the eastern part of the area (YANAGI and HIGUCHI, 1979).

We employed two methods of data collection. The first method was regional sampling of suspended matter and hydrographic parameters (water temperature and the size distribution of bottom sediment) in order to examine spatial variation of suspended matter. The vertical distribution of the beam attenuation coefficient was measured at each sampling station by an in situ beam attenuation meter. The general
and 60 cm above the bottom surface for one full tidal cycle using three beam attenuation meters which were placed at each level. Concurrently current velocity at 50 cm above the bottom surface was recorded with a savonius type current meter (Tsurumi Seiki: TS-MTCM type). The continuous data were read every 5-minutes. The vertical distribution of suspended matter was measured every hour during the period of continuous sampling.

3. Results and discussions

3.1. Vertical distribution of suspended matter

Investigation of the relation between the vertical distribution of suspended matter and the size distribution of bottom sediment in the Hiuchi-Nada area was carried out in this study. The vertical distributions of the beam attenuation coefficient are shown in Fig. 2. FUKUDA (1974) has suggested that the vertical distribution of the beam attenuation coefficient in the coastal area can be classified into three components. The first component consists of suspended matter identical to bottom sediment and, therefore, maximum attenuation occurs at the bottom and attenuation decreases exponentially with distance from the bottom. The second is composed of land-driven matter whose concentration decreases with increasing depth. The third is composed of dissolved matter or very fine particles which are distributed homogeneously at all depths. Each vertical distribution shown in the left side of Fig. 2 is divided into two portions. The portion where the beam attenuation coefficient exhibits uniform values in the surface layer corresponds to the third component of Fukuda’s classification. A high attenuation value near the bottom is produced by resuspension of bottom sediment. There are some vertical distributions of beam attenuation coefficient near

Fig. 1. Sampling stations. The double circle is an anchored station. Dotted lines are depth contours.

Fig. 2. Vertical distributions of beam attenuation coefficient. Numerals are station numbers.
the Kurushima Channel given in Fig. 2 (Stn. 48 and Stn. 49), in which no prominent peaks are observed in the bottom water. KRANK (1975, 1979) investigated the relation between the size distribution of bottom sediment and that of suspended matter in the water above, and concluded that the concentration and size distribution of suspended matter in the overlying water column depended on the nature of the bottom sediment.

The distribution median grain size (Md₉) of the bottom sediment (Wentworth scale) (Fig. 3) shows that most of the area is floored with sediment >6µ in median diameter and sandy sediment is observed only near the Kurushima Channel. Cross sections of temperature, concentration of suspended matter and the beam attenuation coefficient along a transect from Stn. 2 to Stn. 48 (Fig. 4) show that the thermocline exists at a depth of from 6 to 14 meters in the eastern area and the bottom water below the thermocline is turbid compared to the surface water. The beam attenuation coefficient and the concentration of suspended matter near the Kurushima Channel are vertically uniform. The bottom sediment in this sandy area, which is devoid of silt and clay sized particles, is probably not easily resuspended by tidal currents. As shown in Fig. 4, resuspension of bottom sediment is observed in all areas where the bottom has silt size sediment.

3.2. Temporal variation of resuspended matter

The beam attenuation coefficient in each layer 15, 30 and 60 cm above the bottom and water movement at 50 cm above the bottom were continuously measured for one full tidal cycle at Stn. 30 (see Fig. 1: ○ mark). Temporal variations of attenuation and current velocity are shown in Fig. 5. Attenuation values are expressed in values relative to distilled water and the unit is arbitrary. Current velocity near the bottom diminishes to zero from 07:10 to 07:35 and from 13:30 to 14:20. The strongest flood flow is observed from 09:00 to 10:00. On the whole, current velocity changes periodically with a period of about 6-hours, as the tide in this area is close to semi-diurnal in type. Attenuation values have a dominant component with the same period as current velocity. The amplitude of variation of attenuation in each layer decreases with increasing distance from the bottom. The aberrant peak at 07:00 is supposed to be due to instrumental error.

The vertical distributions of the beam attenuation coefficient (full line) and suspended matter concentration (dotted line) at each observation time are shown in Fig. 6. The beam attenuation coefficient exhibits uniform values in the
upper 10 meters and temporal variation is not observed in the surface layer. An appreciable variation is observed near the bottom. The net attenuation coefficient due to resuspended matter is defined by subtracting the uniform value in the surface layer from each measured value. The vertical distribution of net beam attenuation coefficient due to resuspended matter is shown in Fig. 7. The concentration of resuspended matter very near the bottom increases gradually from 07:00 to 09:00 and reaches a maximum at the time of strongest flood flow. Water movement near the bottom entrains bottom sediment into suspension in an amount proportional to current velocity. The elevated concentration decreases rapidly within one hour as current velocity decreases. It is thought that the settling velocity of resuspended matter is fast. The vertical distributions from 11:00 to 13:00 show the same pattern, although current velocity varies slightly with time. The concentration of resuspended matter a few meters above the bottom increases from 07:00 to 08:00, when current velocity is still comparatively slow. This may be caused by a complication in the mechanism of resuspension.

NAKATA and HIRANO (1978) observed a similar tidal fluctuation in resuspended matter in the Mekari Strait of the Seto Inland Sea. In contrast, D’ANGELEJAN and INGRAM (1976) demonstrated that maximum concentration of suspended matter in the St. Lawrence River estuary was observed only at the end of ebb flow, because of the dominance of advection over resuspension. KAJIHARA et al. (1974) measured temporal variation of the vertical distribution of suspended matter and water movement near the bottom in the Tsugaru Strait. On the basis of their data, ICHIYE

![Graph](image1)

Fig. 5. Temporal variation of attenuation near the bottom, and water movement. Numerals indicate distance from the bottom surface in centimeters.

![Graph](image2)

Fig. 6. Temporal variation of the vertical distribution of beam attenuation coefficient.
Temporal Variation of Resuspended Matter

Fig. 7. Temporal variation of the vertical distribution of the net beam attenuation coefficient due to resuspended matter. Each numeral indicates sampling time.

(1975, 1976) and KAJIHARA et al. (1975) discussed the relation between the appearance of a maximum or minimum layer in the vertical distribution of suspended matter and the vertical eddy diffusivity. They also discussed the period of temporal variation of resuspended matter. Our observations suggest that a sharp maximum or minimum layer is not observed in the vertical distribution of resuspended matter and the concentration varies with the same period as water movement.

4. Conclusions

The vertical distribution of suspended matter in the Hiuchi-Nada area exhibits a maximum concentration at the bottom where the bottom sediment is of silt size. The high concentration of suspended matter near the bottom is produced by resuspension of bottom sediment. In order to discuss temporal variation of resuspended matter, the beam attenuation coefficient near the bottom and water movement were continuously measured for one full tidal cycle at an anchored station. The data indicate that the concentration of resuspended matter varies with the same period as water movement.

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References


NAKATA, H. and T. HIRANO (1978): On the dis-
経瀬における1潮汐間の再懸濁物質の時間変動

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要旨: 経瀬において、懸濁物質の鉛直分布と堆積物の粒度の関係を調べたところ、堆積物がシルトサイズである海域で、にごった底層水が観測された。このにごった底層水は堆積物の再懸濁によって生じると考えられた。そこで、再懸濁物質と底面近くの流れの時間変動に関する調査を1潮汐間行った。再懸濁物質の最高濃度は流れが最も速くなる時間帯に出現した。

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