The first trial of in situ measurement of mercury transport by using an oceanographic method in the Minamata Bay

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Abstract: Recently, measurement result of mercury distribution obtained by sediment sampling shows that mercury-contaminated sediment has been dispersing in the Yatsushiro Sea from the Minamata Bay. In order to realize mercury transport from the Minamata Bay measurements of tidal current and sediment concentration were carried out from 8 Nov. to 17 Dec 2002. In this research, as the first trial of in situ measurement of mercury transport, both Acoustic Doppler Current Profiler (ADCP) and optical Turbidity meter were applied to measurement of suspended sediment (SS). ADCP can measure both vertical profiles of three velocity components and SS concentration simultaneously by acoustic backscatter from suspended particulate matter (SPM). It becomes possible to estimate mercury transport with high temporal and spatial resolution by this oceanographic methodology.

Key words: Mercury Transport, Minamata Bay, Sediment Transport, Acoustic Doppler Current Profiler.

INTRODUCTION

As is well known, 0.8 million m^3 of bottom sediment, which was contaminated by mercury has been dredged up for remediation of water and bottom sediment environment in the Minamata Bay. However, the recent measurement result of mercury distribution by Tomiyasu *et al.*(2000) has shown mercury transport from the Minamata Bay to the outer sea area, the Yatsushiro Sea. Although the measured concentration of mercury in bottom sediment is trace, prediction of mercury dynamics is necessary.

In order to predict the mercury dynamics accurately, we need to get a fundamental knowledge of physical mechanism of mercury transport in coastal area. Thus, it is necessary to carry out an oceanographic observation for dynamics of bottom sediment and seawater, especially a long-term simultaneous measurement on vertical profiles of tidal current velocity and suspended sediment (SS) [see the latest review by THORNE AND HANES (2002)]. "Acoustic Doppler Current Profiler" (ADCP) fits this objective. ADCP is an instrument to measure the vertical profile of three velocity components by using Doppler frequency shift of acoustic backscatter from suspended particulate matter (SPM), that is SS, plankton, detritus and so on. ADCP can also measure the vertical profile of SS concentration by using echo intensity of acoustic backscatter. As the first trial of in situ measurement of mercury transport, we carried out ADCP measurement in the Minamata Bay.

RESULTS AND DISCUSSION

One ADCP (Aquadopp Profiler 1000kHz, Nortek Co.), six optical turbidity meters (Compact-CLW, Alec Electronics Co.) and one wave meter (WaveHunter-99S, IO-Technique Co.) were set on the sea bottom in the Minamata Bay from 8 Nov 2002 to 17 Dec 2002 (Fig. 1). A mud layer with 15 cm thickness existed on the sea bottom. A height a from the lowest turbidity meter to the top of the mud layer at the beginning and the end of measurement were 4 cm and 14 cm, respectively. As a result of measurement, time series of vertical profiles (every 0.5m layer from 80cm above the bottom) of three velocity components and echo intensity, turbidity at six layers, which are 4, 24, 54, 84, 234, 384 cm layers, and wave conditions (wave height, wave direction, water particle velocity, etc.) were observed. Any significant storm conditions were not found in this observation period.

In order to estimate time series of vertical profile of SS concentration, we attempted calibration between SS and compensated ADCP echo intensity (*SV*), which was evaluated by the following relation indicated in dB unit [Urick(1975), Medwin and Clay(1998)]:

Sonar Equation:

$$SV = RL + TL - (SL + A) \quad (1)$$

in which, *RL*: echo intensity recorded by ADCP, *TL*: transmission loss by spreading and sea water absorption, *SL*: source level of transducer, and *A*: reverberation volume due to beam-width pattern peculiar to transducer. *TL* was evaluated by total absorption coefficient, which is expressed as a function

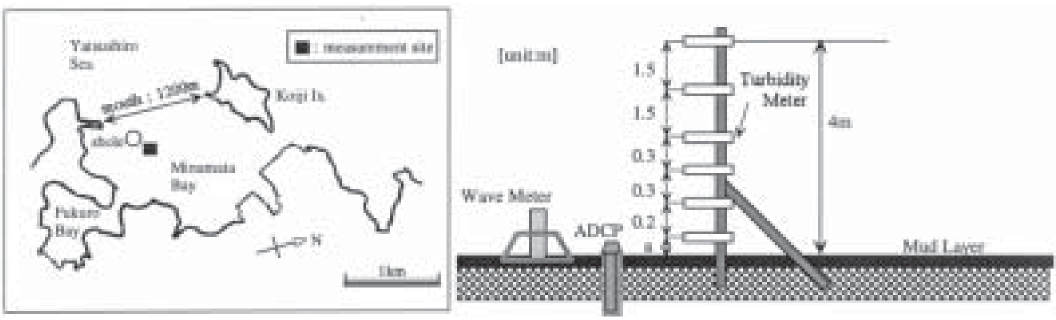


Figure 1. Measurement site and measurement setup.

of water temperature, salinity, frequency of ADCP, pH of sea water and depth, summarized by FRANCOIS AND GARRISON (1982). Based on assumptions that diameter distribution of suspended particles is almost constant and transmission loss due to high turbidity condition (>> 100 ppm) can be neglected, it is concluded that SS are exponentially related to *SV* as follows:

$$SS = 1.3\exp(0.1SV \qquad (2)$$

Fig. 2 shows the comparison between measured SS by turbidity meter and estimated SS by ADCP echo intensity at 230cm layer above the bottom. SS was calibrated versus turbidity, which is measured by an optical turbidity meter by water sampling.

Time series of SS flux at each layer were calculated from the data of tidal current velocity and SS. The directional distributions of SS transport per unit width at 80cm and 380cm layer for overall measurement period are shown in Figs. 3(a) and (b). It shows that the dominant direction of SS transport is between N and NW, that is, the direction from the Minamata Bay to the Yatsushiro Sea (see Fig. 1). Fig. 3(c) shows net SS transport integrated from bottom to water surface* (*ADCP actually can't measure in 15 % surface layer because of the effect of sidelobes reflection at water surface). In addition, a rough estimate of annual mercury transport from the Minamata Bay to the Yatsushiro Sea was calculated by orthogonal component of net SS transport and the existing data of

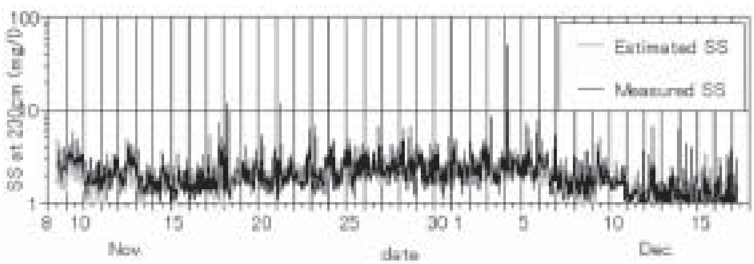
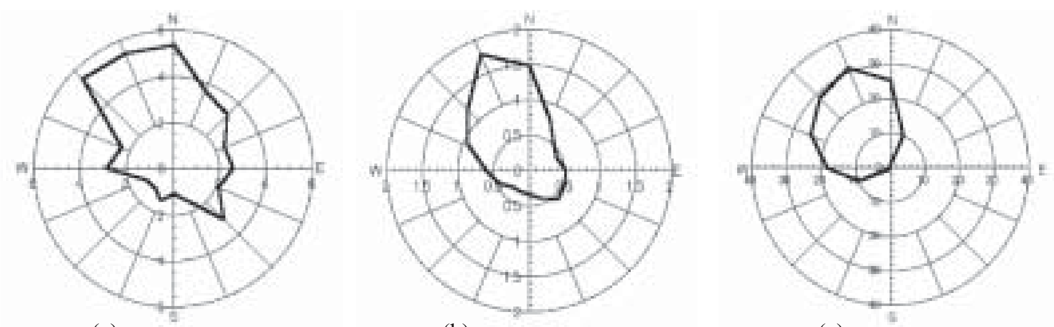


Figure 2. Time series of measured and estimated SS.



(a) (b) (c)

[unit: 10 kg/m]

Figure 3. Directional distribution of SS transport at (a) 80cm, (b) 380cm layer and (c) net depth-integrated SS transport for the measurement period.

mercury concentration in bottom sediment (HARAGUCHI ET AL., 2000), that is, Total-Hg: 1.0-9.0 μg/g and Methylmercury: 0.4-13.5 ng/g (dry wt.). Total-Hg and Methylmercury transport through the mouth of Minamata Bay (see Fig. 1) is calculated about 8-75 kg and 0.004-0.12 kg, respectively.

CONCLUSIONS

We attempted in situ measurement of mercury transport from the Minamata Bay by acoustic and optical instruments for an oceanographic observation. As a result of this research, it became clear that i) ADCP is a suitable instrument for measuring both tidal current velocity and SS concentration simultaneously, ii) ADCP measurement can estimate temporary vertical profile of mercury flux. Thus, we have established the basic system for measurement of mercury transport in coastal area.

Acknowledgements

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