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A Study of Acoustic Characteristics at Sea Bottom Sediment Including Organic Matter

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ABSTRACT

At shallow area, organic rich sediment is piled up and run away according to the tidal stream or upper sea water movement. Authors measure the acoustic characteristics of organic rich sediment to monitor the movement of those sediment at the sea bottom. The bottom statement environmental changes affect benthic activities. Sample sediment was obtained from the Ariake Sea in Japan, mostly consist with cray and many organic matters, was measured its acoustic speed and attenuation with the frequency of 2 MHz in laboratory. At the same time, the grain size distribution was also measured. This result will help to understand the reflected waves from the sea bottom and sound propagation simulation in models.

Keywords: Sediment Properties, Underwater sound

1. INTRODUCTION

Assessment of the impact on coastal environments caused by global warming has mainly been done so far based on disappearance of sandy beach areas by sea surface elevation, and changes of biota by elevated water temperature. However, it is required to carry out composite environmental assessment to understand unequivocal ongoing global warming. At the boundary of water and seabed, there are mixed layer with water and particle of sediments. The particle includes not only sand, mad, silt but also organic matter such as plankton and algae. The thickness and density of the boundary area effect benthic ecosystem. Therefore, it is important to monitor temporal and spatial change of the boundary configuration. Acoustic is one of the best methods for underwater monitoring.

Multipath transmission is one of the major reasons to deteriorate of underwater sound communication[1, 2)]. Usually, reflected waves arrives a receiver after the direct signal from a source. But in case of short travel distance or very shallow area, there is not so much time lag between the direct signal and the reflected signals. Therefore, as reflected signals overlap with the direct signal, signal-to-noise ratio decrease because of reflected signals. Sometimes, as coherent with reflected signals and a direct signal makes destructive interference, sound signal from the source cannot be received at the receiver[3)]. It is very important to understand how much the reflected signals affect to the main direct signal. Calm sea surface could be assumed as a mirror acoustically. According to the sea state or wind speed, many approximate formula or sea surface model were studied to explain the effect of sea surface reflection and scattering[4, 5)]. The same methods are also applied to understand the sea bottom reflection[6)]. But as the sound propagation of the sediment at the bottom sometimes very similar behavior to sea water especially the sediment consists with mad and contained much water. Moreover, some sound wave incident into the sediment and refracts upper side then they re-enter to the sea water. To understand such behavior of the sound at the sea bottom, it is necessary to know acoustic characteristics such as sound speed, sound attenuation of the sediment and their dependency of the depth from the sea bottom.

In this paper, we suggest acoustic monitoring method for the bottom boundary layer and get a sample data as the first step. Although the measurement used only one frequency and particle size was almost uniform, this experiment will useful to assess boundary condition in future work.

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2. EXPERIMENTAL METHODS

2.1 Sampling Area

The sediment sample was obtained from the Ariake Sea in Japan. As the sea is surrounded by land and there are several rivers, many dirt is carried from rivers. The depth of the Ariake Sea is less than 50 m, and tidal elevation exceed more than 4 m. The rich mad sediment is good place for marine creatures especially for benthos. For many years, the sediment conditions such as pH, density, and thickness of the boundary layer has been monitored with core samples by Research center for fisheries and environment in the Ariake and Yatsushiro bays, Seikai National Fisheries Research Institute to investigate environmental changes and understanding their impacts on biological production. The sediment sample was obtained by a diver at the monthly sampling by the research center. In addition, we use the sample obtained other area of the Ariake Sea provided by Dr. Nakagawa.

Before sound speed measurement, the samples were screened by wet sieve analysis. At first, sample on the sound speed measurement system was put on a scale to measure weight of the system including the sample. As the weight of the system without any sample was measured in advance, the sample weight M can be calculated by the subtraction of the weight of the empty measurement system. Then, the sample was screened by wet sieve analysis. Three sieves (0.6 mm, 0.15 mm, and 0.075 mm) were used for this screening. They were set on a motor-driven shaking apparatus (Tsutsui: VSS-50). All sieves were dried by an electric dryer for 24 hours and measured each of the weight to get particle size distribution. The sum of all particle size weight becomes total particle weight and the difference between the wet sample weights indicates water weight M_V in the sediment sample. Suppose all space among the particle in the sediment were filled with water, the porosity of the sediment β can be written as

$$\beta = \frac{V_V}{V} \times 100 \tag{1}$$

where, V_v and V are volume of the space and that of the total including the space, respectivel[8]. The total volume V is the obtained from the inner volume of a pipe and the volume of the space is calculated from the weight of water in the sediment and water density. Although the particle size has distributed, average density of the particles ρ_r is obtained as

$$\rho_r = \frac{M - M_V}{V - V_V} \tag{2}$$

Table 1 shows all weight according to the particle weight distribution. We could screen samples of two different places in the Ariake Sea. As the sieves mesh size is not enough fine, we could not separate silt and clay. But the percentage of sand was less than 5%, sediment samples were categorized as clay or silt According to the soil texture triangle provided by United States Department of Agricultur[9].

Table 1 – Particle size distribution of sample sediments

Particle size [μm]	Weight ratio [%]	
	Sample A	Sample B
600 ≧	2.85	1.25
150-600	3.68	0.74
75-150	38.85	1.16
75<	54.62	96.84

2.2 Measurement System

In this study, acoustical characteristics, especially the sound speed changes according to the density of sediment matters in water are the most interesting topic. As the obtained sample includes different grain size sediment, authors decided to compare the difference between the upper side and the lower side of the sample. Therefore, a new measurement system to sound speed of a sample in a 4 cm diameter cylinder with 3 cm height is required. Figure 1 shows a diagram of the sound speed measurement system. A transmitter and a receiver (KGK: 2 MHz) were faced each other across the sample with 3 cm distance fixed with acrylic pipe which has the same diameter and thickness to that of used at the core sampling. As sound speed varies according to temperature, it is important to control temperature of the sample. Therefore, a part of the measurement system including the sample which is indicated by dashed line in Fig. 1 was put into an incubator to control the temperature but it was broken in this experiment. To monitor temperature changes of the sample, a K-type thermocouple was inserted into the sample from the upper side of the pipe. The burst signal was sending from the transmitter and received at the receiver located opposite side of the pipe. The career frequency was 2 MHz which is resonance frequency of the transmitter and the receiver. Both sending and receiving signals were monitored by an oscilloscope (Agilent: 33220A) to measure travel time. After recording the receiving signal through the oscilloscope, peak time was measured as the difference of phase from oscilloscope monitor.

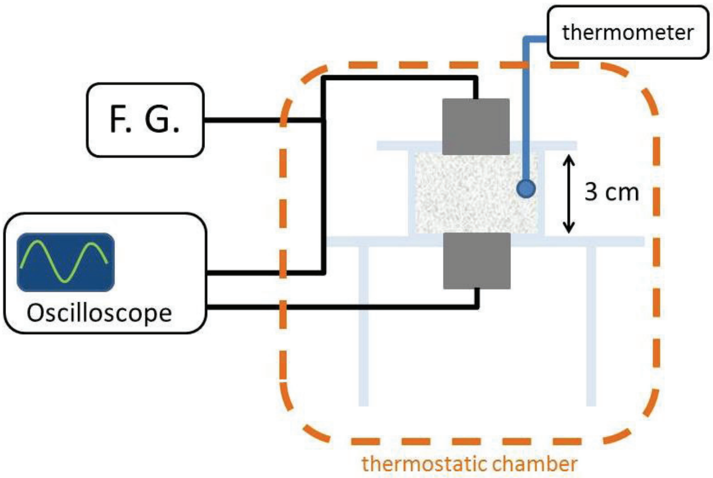


Figure 1 – A diagram of sediment sound speed measuring system.

3. RESULTS

3.1 Distance Calibration

To get the accurate distance between the transceiver and the receiver, water was stored in the acrylic pipe and measured travel time and the temperature at that time. The sound speed was calculated from measured temperature with UNESCO equation. From measured travel time and calculated sound speed, the distance between the transceiver and the receiver was 35 mm.

3.2 Sound Speed Measurement

At the boundary layer, small size particles mast float with some density distribution. To recreate the boundary layer, add the sediment of the smallest particle size into water of 70 ml and stir it for 1 min. Then the liquid put into the acrylic pipe and measured travel time. The travel time measured 5 times and took their average to calculate sound speed. Figure 2 shows measured sound speed according to the amount of sediment in water. Unfortunately, the thermostatic chamber could not keep temperature with some trouble, the liquid temperature was not same throughout the all experiment. As the temperature also affect the sound speed, Figure 3 shows ratio to pure water at the measured temperature. The sound speed of the pure water was calculated from UNESCO equation[7]. From Fig. 3, sound speed clearly decreases when the sediment weight percentage increases.

In the same way, sound attenuation of received signal to the sending signal was monitored as shown in Figure 4. When the added sediments amount over 15‰, the received signal could not confirm from the oscilloscope. As the density of the particles increase, sound scattered and could not reach to the receiver side.

4. CONCLUSION

In this paper, the grain size distribution of the Ariake Bay was investigated and measure the acoustic properties with frequency of 2 MHz. In this method, it is possible to measure sound speed and attenuation according to the contained sediment amount. As it was measured only single frequency, we will carry out the same experiment with different frequency. Also, as the contained sediment material was limited the particle size, more close-to-reality contamination is better for future experiments.

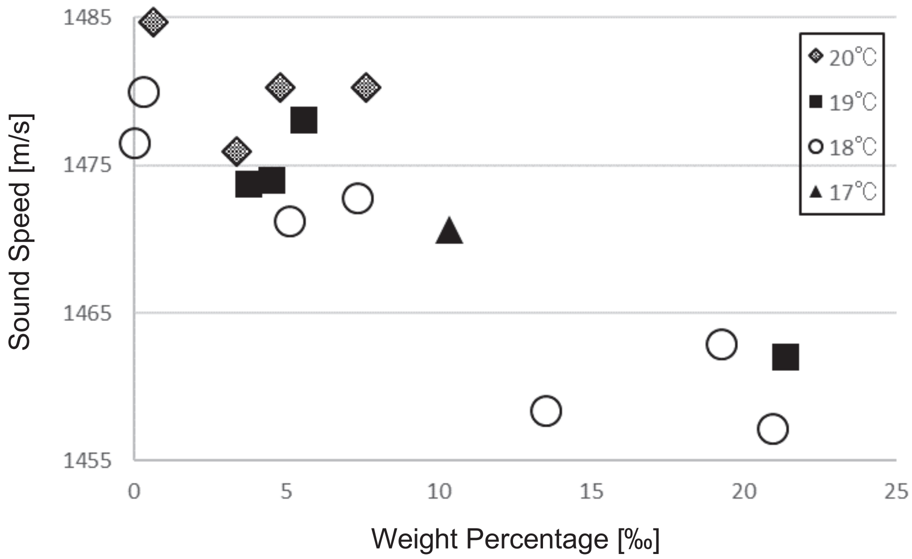


Figure 2 – Estimated sound speed according to the weight percentage.

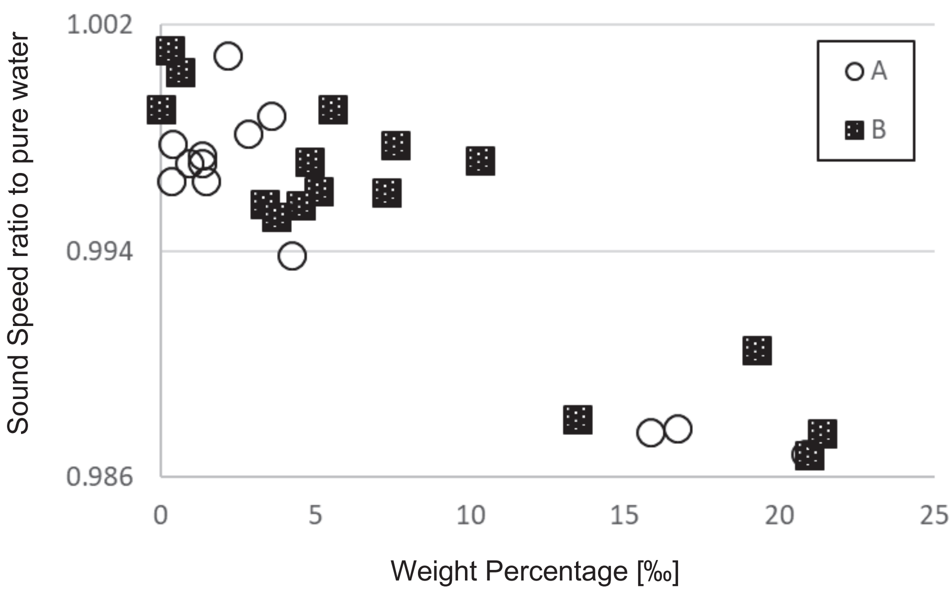
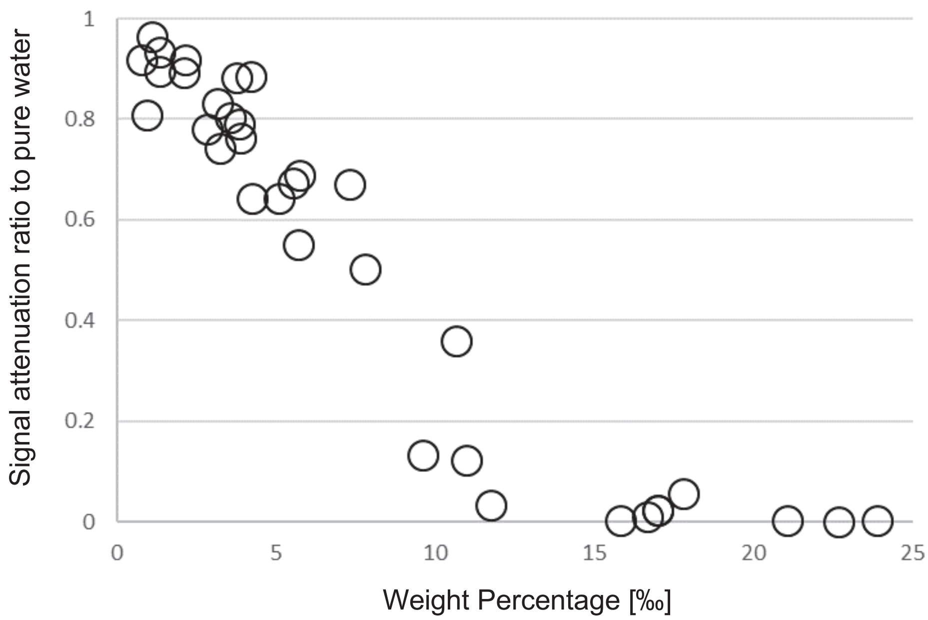


Figure 3 – Ratio of liquid sound speed to pure water according to the weight percentage.



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