TURBID WATER TREATMENT IN A RESERVOIR USING NATURAL COAGULANT

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Abstract:

Long-term persistence of turbidity is a major water quality problem in Japan's reservoirs. We showed that the turbid components of a reservoir could be coagulated by the use of natural coagulant with appropriate treatment methods.

Our experimental aim was to find a coagulation method that was effective against turbid water in a reservoir. A set of settling cylinders was prepared for a coagulation experiment. Turbid water was poured into a cylinder and natural coagulant was added. Next, the natural coagulant was distributed and the turbid water was circulated. Several different circulation conditions were prepared, and different durations of distribution were examined for their effects on the degree of turbidity after coagulation treatment. The effects of coagulation were compared among the different treatment conditions.

There were three main findings. The first was that allophane was useful as a coagulant for the treatment of turbid water from reservoirs. Second, distribution of the coagulant by using supersonic waves was indispensable for effective coagulation. Third, the optimum input of coagulant depended on the degree of turbidity of the water if the sampling sight was the same. We expect that coagulation by this method using allophane will be of practical use.

Keywords:

Long-term persistence of water turbidity, natural coagulant, allophane, settling cylinder, distribution of coagulant, circulation

1. Introduction

We showed here through several experiments that the turbid components of reservoir water could be coagulated by natural material.

Long-term persistence of turbidity is a major water quality problem in Japan's reservoirs. Selective intake facilities and fences for controlling turbid water flow have been employed as countermeasures against this problem. However, the effects of conventional countermeasures are limited, and sometimes, if all of the reservoir water turns turbid, as can occur after large flood inflows or large-scale water circulation, all that can be done is to wait for the particulate matter to settle.

Coagulation is expected to be an effective countermeasure in such conditions where all of the water is turbid. Treatment of deposited sediments, however, can present a serious problem when artificial coagulants are used. Here, we examine the use of natural coagulants or soil colloids, which can be deposited in reservoirs.

2. Sampling of Turbid Water

Large-scale reservoir inflows were observed in September 2007 in Japan, especially in the Kanto Region, where persistent turbidity developed in several reservoirs. We obtained samples of turbid water from the Kawaji Dam Reservoir and the Shimokubo Dam Reservoir to examine the performance of natural coagulant. The locations of the two dams are shown in Fig. 2.1.

Water was sampled three times from the Kawaji Dam Reservoir and once from the Shimokubo Dam Reservoir. The dates of water sampling and the degrees of observed turbidity (kaolin-based) are shown in Table 2.1. In December, water was sampled from both dams. The turbidity of the Kawaji Dam water was higher than that of the Shimokubo Dam Reservoir. Photo 2.1 shows the turbid nature of the water in Kawaji Dam on the December sampling day; this photo was taken 3 months after the large-scale inflow.

The change in the degree of turbidity at the Kawaji Dam Reservoir is shown in Fig. 2.2. The figure shows that circulation of all the water layers in the reservoir started to occur between 10^{th} and 20^{th} of October 2007. Before that time, the degree of turbidity was low in the surface layer, and turbidity was not a problem as long as the surface intake remained effective. In October, the temperature declined and the surface of the reservoir cooled. This cooling of the surface layer caused full circulation, because the water densities of the surface layer and the other layers became almost the same. At the time of sampling in December, turbidity had persisted for more than one month and a half since this mixing of the water layers. Waiting for sediment deposition to occur had been the only strategy taken.

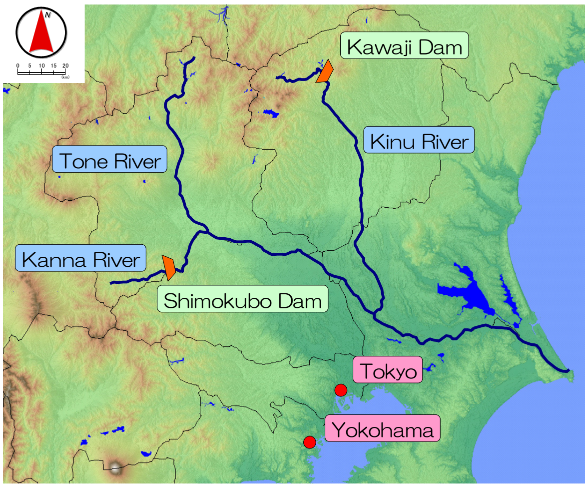

Fig. 2.1 Locations of dams

Table 2.1 Sampling dates / degrees of turbidity

No.	Date	Sight	Turbidity [degree]
1	8 Sep 2007	Kawaji D.	more than 200
2	6 Dec 2007	Kawaji D.	110
3	23 Jan 2008	Kawaji D.	90
4	10 Dec 2007	Shimokubo D.	57


Photo 2.1 Condition of Kawaji Dam Reservoir

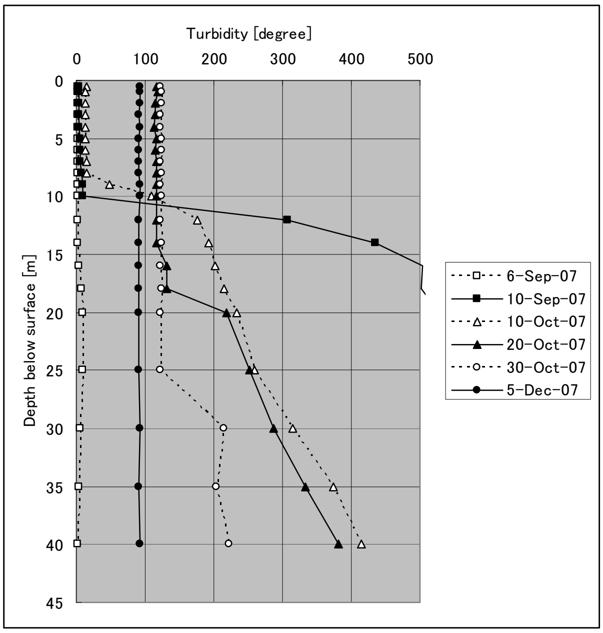

Fig. 2.2 Change in the degree of turbidity (Kawaji Dam Reservoir)

3. Preliminary Study

3.1 Selection of Coagulant

Allophane, a natural coagulant, was used in the experiments (Photo 3.1). Allophane is present at high levels in weathered volcanic ash and volcanic soils. Volcanic soils are widely distributed in the Hokkaido, Tohoku, and Kyushu regions of Japan and are easily obtained. Moreover, coagulation with allophane is considered to minimize the environmental impact on reservoirs and downstream rivers.

Allophane is used in several industries. It is a porous material used as a drying or adsorption agent. Because of its water-absorbing capacity we expected that it would be capable of coagulating particulate matter in water.

Photo 3.1 The allophane used in the experiment

3.2 Determination of Coagulant Quantity

Before we performed the main experiment, we conducted a preliminary experiment to determine the quantities of coagulant appropriate for varying degrees of turbidity. We used the following procedure:

1) Six medium-sized beakers were prepared and 1L of turbid water was poured into each one.

2) A 50-mL sample of turbid water was taken from each beaker and placed into a small beaker. A predetermined quantity of coagulant was added.

3) The coagulant was distributed by supersonic wave distributor. The specification of distributor will be explained in **4.1**.

4) The mixture of turbid water and coagulant was returned to each medium-sized beaker and then agitated by stirring apparatus to accelerate coagulation of the turbid particles (Photo 3.2).

5) The mixture of turbid water and coagulant was left undisturbed and the change in the degree of turbidity was observed. The degree of turbidity was observed 4 cm below the surface.

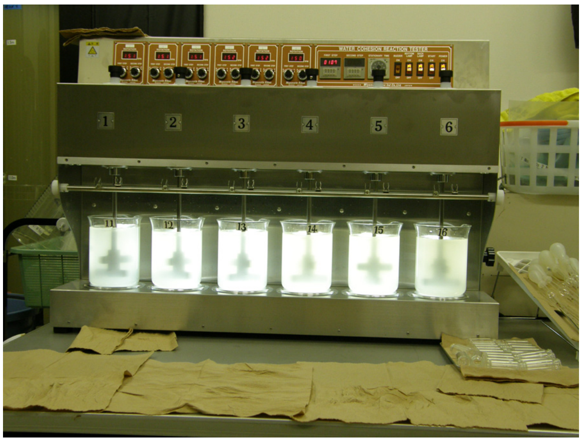

Photo 3.2 Stirring apparatus

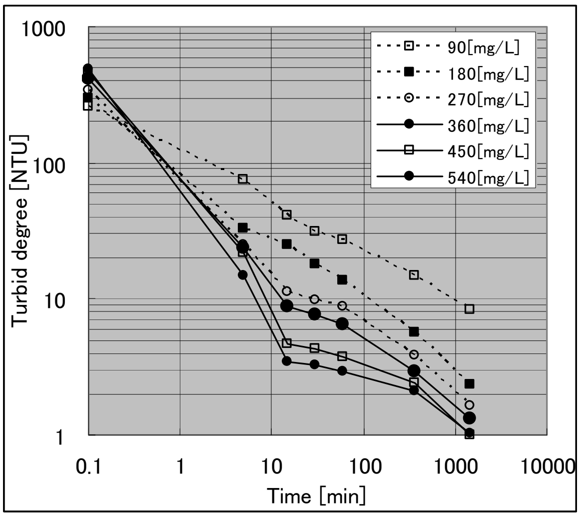

Fig. 3.1 Changes in the degree of turbidity

The details of each experimental case are shown in Table 3.1 and the results are shown in Fig. 3.1. The target degree of turbidity was set at less than 5 NTU at the 30 min after the coagulation treatment.

First, we found that the degree of turbidity declined with time. Second, the degree of turbidity declined with increasing coagulant concentration. Thirty minutes after coagulation treatment the turbidity in Case 1.4 was 7.7 NTU and that in Case 1.5 was 4.3 NTU. The appropriate concentration of coagulant for water with an initial turbidity of 200 NTU was considered to be 360 mg-dry/L, so we adopted this rate for the main experiment.

3.3 Distribution and Circulation

The distribution of coagulant and the degree of stirring to achieve effective coagulation were examined in a previous study[1]. This previous experiment was performed in beakers, so here we expanded it by using settling cylinders.

To determine an appropriate combination of coagulant distribution and circulation of turbid water in the settling cylinder, we prepared four experimental conditions (Table 3.2). Each settling cylinder was 390 mm in diameter and 2,200 mm deep. Three intake cocks were installed in each cylinder for water sampling (Fig. 3.2).

Table 3.1 Details of the experimental cases used to determine coagulant quantity

Case No.	1.1	1.2	1.3	1.4	1.5	1.6
Initial turbidity [NTU]	208	207	205	206	215	217
Coagulant input [mg/L]	90	180	270	360	450	540
Distribution [sec]	10	10	10	10	10	10
Agitatition [sec]	180	180	180	180	180	180

Table 3.2 Conditions used for distribution and circulation

Case No.	2.1	2.2	2.3	2.4
Initial turbidity [NTU]	200	200	200	200
Coagurant input [mg/l]	360	360	360	360
Operation of distribution [min]	6	6	6	6
Circulation apparatus	Aeration	Aeration	Submerged motor pump	Submerged motor Pump
Position of apparatus (above bottom)	0.5m	1.5m	0.5m	1.5m
Operation of circulation [min]	9	9	9	9

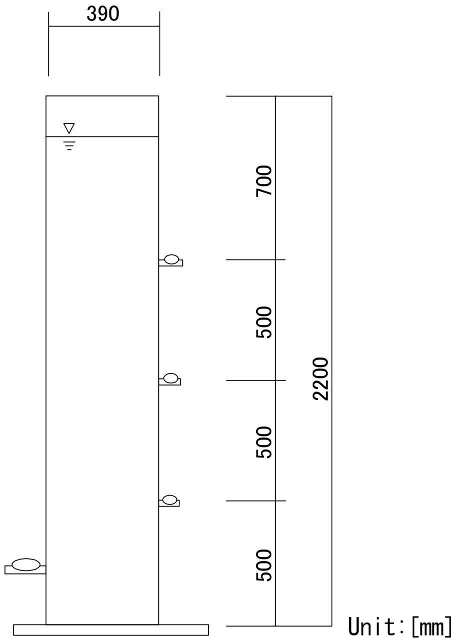

Fig. 3.2 Shape of the settling cylinder

The experimental procedure was as follows:

1) Artificial turbid water was created from sediments from the Kawaji Dam Reservoir. The target initial degree of turbidity was set at 200 NTU.

2) A settling cylinder was prepared and the artificial turbid water was poured to a depth of 2.0 m. The volume of artificial turbid water was 238.9 L.

3) A sample of 25 L of turbid water was removed from the settling cylinder into a bucket, and a predetermined quantity of coagulant was added. The concentration of coagulant was 360 mg-dry/L.

4) The mixture of sampled water and coagulant was returned to the settling cylinder, and then the coagulant and artificial turbid water were distributed by supersonic wave distributor for 6 min while the circulation was being operated.

5) Circulation continued for 3 min after the end of the supersonic distribution.

6) The mixture of artificial turbid water and coagulant was left undisturbed and the change in the degree of turbidity was observed at a point 4 cm below the surface and the three intake cocks.

The results of the experiment are shown in Fig. 3.3. The data in this figure are the means of the results for the four points at which turbidity was observed in each cylinder. Of the four experimental cases, Case 2.3 showed the most effective performance in decreasing turbidity. There were two findings. The first was that agitation by submerged motor pump was more effective than aeration. The second was that for effective circulation the apparatus needed to be positioned in the deeper part of the settling cylinder. The conditions used in Case 2.3 were adopted as the distribution and circulation conditions for the main experiments described below.

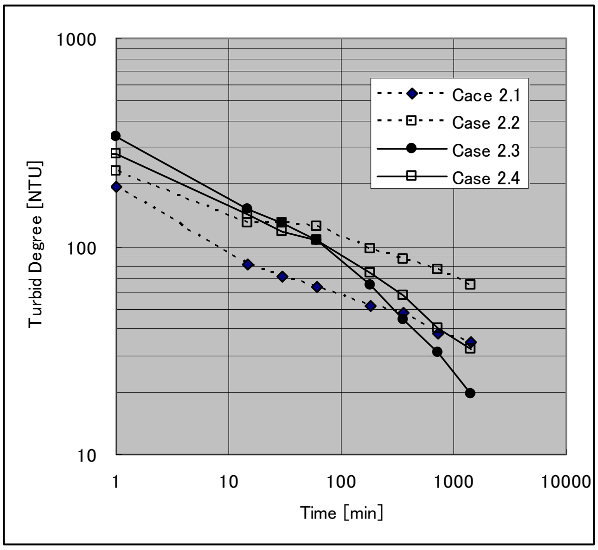

Fig. 3.3 Changes in the degree of turbidity

4. Main Experiment

In this part of the study we aimed to find a coagulation method that was effective against turbidity in a reservoir. The objectives were as follows:

1) To confirm that allophane was useful for

treating persistent turbidity.
2) To determine a suitable duration of supersonic distribution for effective coagulation.
3) To examine the appropriate quantities of coagulant for treatment of varying levels of turbidity.
The experimental method and results are described below.

4.1 Methods

A set of equipment consisting of three settling cylinders was prepared for the coagulation experiment. Twelve cases were used (Table 4-1). The experimental procedure was essentially the same as that used in the preliminary study, with the following differences:

1) Artificial turbid water was used in the preliminary study; in the main study we used turbid water sampled from reservoirs.
2) The concentration of coagulant was fixed at 360 mg-dry/L in the preliminary study, but in the main experiment it was 90 to 360 mg-dry/L for the water from Kawaji Dam Reservoir and 32 mg-dry/L for that from Shimokubo Dam Reservoir. The concentration of coagulant was determined to suit the degree of turbidity of the water and the characteristics of the sampling site.

A supersonic distributor was used to distribute the coagulant. The tip of the oscillating arm was soaked in turbid water to transfer vibration to the coagulant. The output of the apparatus was 600 W, the frequency was 20 kHz, and the maximum amplitude was 35 μm. The duration of distribution was set to either 6 or 12 min. The conditions used in Case 2.3 (Table 3.2) were adopted as the circulation conditions for this experiment. The target degree of turbidity was set to less than 5 NTU at the 24 h after coagulation treatment.

Table 4-1 Details of the experimental cases used in the main experiment

Case No.	3.1	3.2	3.3	3.4	3.5	3.6
Sample sight	Kawaji	Kawaji	Kawaji	Kawaji	Kawaji	Kawaji
Initial turbidity [NTU]	240	240	240	85.5	85.5	85.5
Coagurant input [mg/l]	360	360	0	180	180	0
Distribution [min]	6	12	none	6	12	none
Circulation [min]	9	15	none	9	15	none

Case No.	3.7	3.8	3.9	3.10	3.11	3.12
Sample sight	Kawaji	Kawaji	Kawaji	Shimo-kubo	Shimo-kubo	Shimo-kubo
Initial turbidity [NTU]	55.0	55.0	55.0	37.0	37.0	37.0
Coagurant input [mg/l]	90	90	0	32	32	0
Distribution [min]	6	12	none	6	12	none
Circulation [min]	9	15	none	9	15	none

4.2 Results

The results of the experiment are shown in Fig. 4.1 to 4.4. The degree of turbidity was observed at four points in each cylinder. The data in the figures are the averages from these four points. Two different durations of distribution were set to compare the performance. A cylinder without coagulation treatment was used as a control.

There were three findings of the experiment. The first was that the degree of turbidity after coagulation treatment with allophane declined with time (Photo 4.1). In contrast, there was very little change in turbidity with no coagulation treatment. Thus the allophane was useful as a coagulant.

The second finding was that 12 min of supersonic distribution was more effective than 6 min. Among the four cases for each distribution condition, three cases given the 12-min treatment achieved the 5 NTU target within 24 h (Cases 3.2, 3.5, and 3.8), but none of the cases given the 6-min treatment achieved this level. This result indicated that an adequate duration of coagulant distribution by using supersonic waves was indispensable for effective coagulation.

The third finding was that the appropriate input of coagulant depended on the degree of turbidity of the water if the sampling site was the same. Fig. 4.5 shows the degree of turbidity of the sample water, and the coagulant input, in Cases 3.2, 3.5, and 3.8; all of them achieved the target.

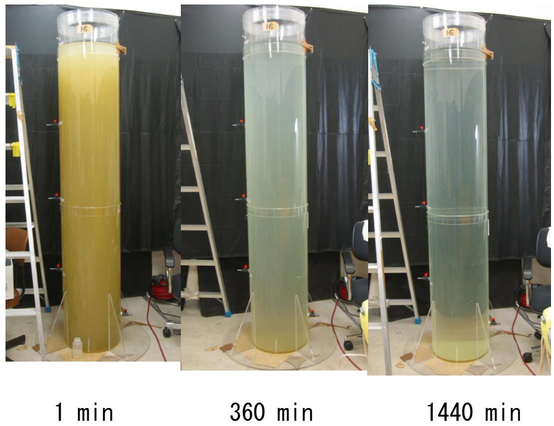

Photo 4.1 Change in degree of turbidity (Case 3.5)

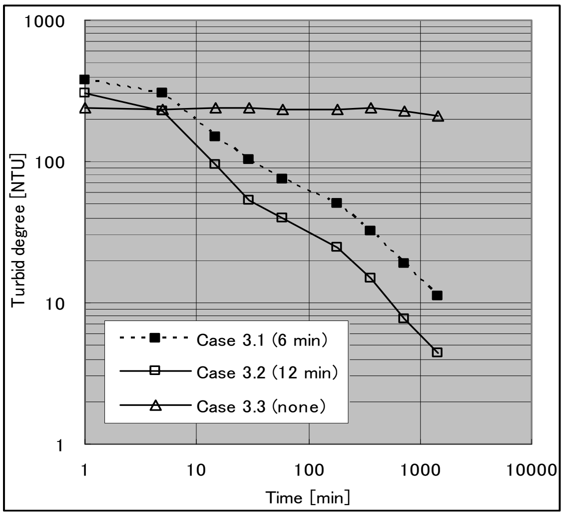

Fig. 4.1 Change in degree of turbidity (Kawaji 1/3)(Cases 3.1, 3.2, and 3.3)

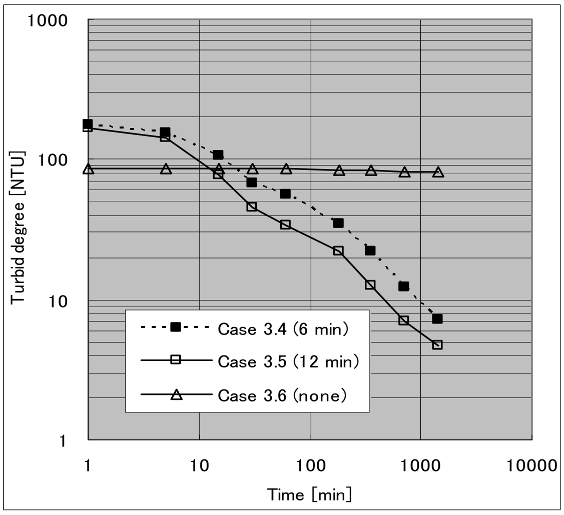

Fig. 4.2 Change in degree of turbidity (Kawaji 2/3)(Cases 3.4, 3.5, and 3.6)

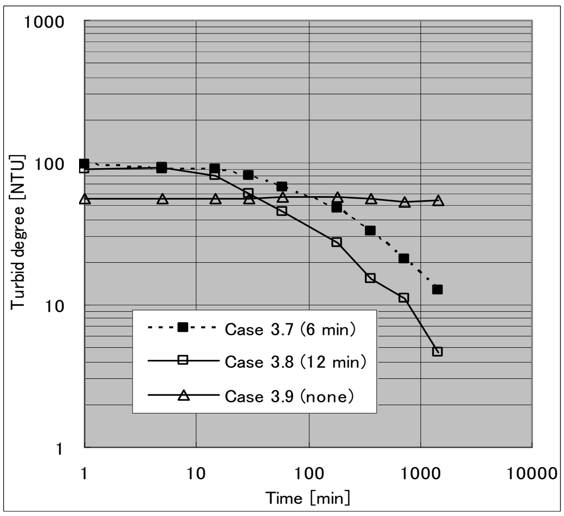

Fig. 4.3 Change in degree of turbidity (Kawaji 3/3)(Cases 3.7, 3.8, and 3.9)

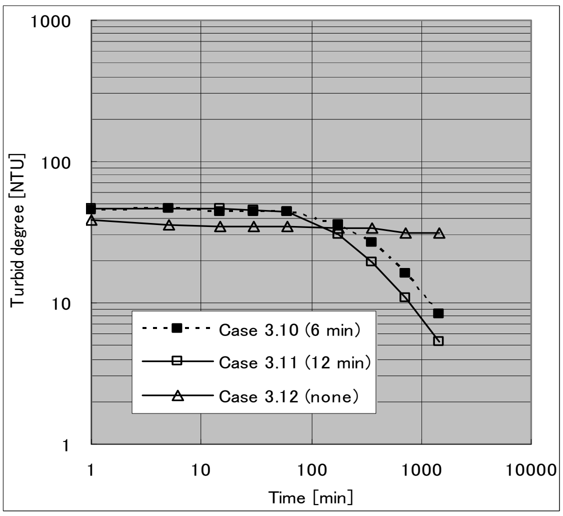

Fig. 4.4 Change in degree of turbidity (Shimokubo)(Cases 3.10, 3.11, and 3.12)

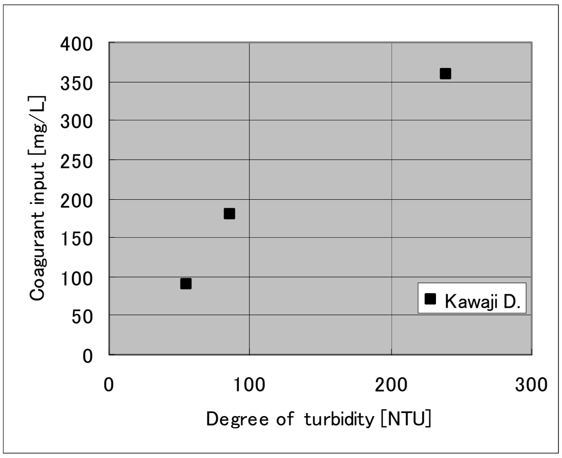

Fig. 4.5 Degree of turbidity/coagulant input

Before the experiment, we hypothesized that the coagulant input would depend on the degree of turbidity, and we then determined the coagulant input for the waters of Kawaji Dam. The results from these three cases showed that the target could be achieved and proved that the hypothesis was appropriate.

5. Application to Reservoirs

All the experiments described above were executed in a laboratory. The applicability of coagulation used allophane needs to be confirmed in a reservoir with persistent turbidity.

We envisage two kinds of treatment plant that could be used for the reservoir experiment[2]. One is a lakeside plant and the other is a boat-based plant. Both plants are composed of four items: an absorption pump for taking in turbid water; a water tank for mixing turbid water and allophone; a supersonic distributor for distributing allophone; and a submerged pump for circulating the mixture of turbid water and allophane. Photo 5.1 is an image of a boat-based plant.

We anticipate that in future a practical experiment will be performed as part of the continued development of this method of coagulation of persistent turbidity.

Photo 5.1 A boat-based plant

6. Conclusion

We showed that the turbid components of a reservoir could be coagulated by the use of a natural coagulant and appropriate treatment methods. We expect that this allophone-based treatment will be of practical use.

We thank the Kawaji Dam and the Shimokubo Dam administrative staff, who provided reservoir data and facilitated our observation.

References

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