

Partial Sediment Dredging Method Developed for Conserving Ecosystem and Recycling Sedimentary Material

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ABSTRACT: In this research, we report about the improvement of a sediment dredging method and cases of application. The flocculation tank and the sedimentary sand tank were made one for a small space technology. All parts of this technology can be transported by one truck. An inverter was used so that the frequency can be changed. Accordingly, we can change the rotational frequency of the dredged pump. The flocculation tank was placed below a screen. The hydro-extractor discharge rate of sludge increased approximately twofold. This dredging method does not need a large space. We propose that this dredging method can be used at lakes in parks, small ponds, and other places. Furthermore, we propose that dredged sludge can be used for agricultural applications.

Keywords: Partial dredging method, Recycled sediment, Floating pump, Conserve ecosystem

1. INTRODUCTION

1.1 Reservoirs in Japan

According to a survey conducted by Ministry of Agriculture, Forestry and Fisheries, there are approximately 210,000 agricultural reservoirs located throughout Japan at present [1]. In the number of reservoirs, Hyogo Prefecture holds the highest with approximately 40,000 reservoirs, followed by Hiroshima Prefecture with 20,000 and Kagawa Prefecture with 16,000 reservoirs. Even in Gunma Prefecture where Gunma National College of Technology is located, there are approximately 600 reservoirs. However, along with the pervading agricultural canals, the importance of these reservoirs has declined. Additionally, due to depletion and ageing in the farm population, dredging has not been periodically conducted. Because of that, many reservoirs are at risk of being filled up due to the sand flowing into them during rain.

However, unlike the concrete agricultural canals, reservoirs are untouched and neglected. Furthermore, reservoirs form the reserve of many conventional species of animal and plants. In addition, they also serve as the habitat for waterfowls and are an extremely important place from the ecosystem conservation point of view.

In the future, it is expected that periodic dredging of the sludge be conducted while preserving the ecosystem. Current dredging technology can be roughly divided into grab dredging using buckets and pump dredging. Dredging ships utilising a barge-type platform are used in dredging the inner bays, estuaries and lakes. The objective of dredging is to secure the traffic route, the electricity (power plant cooling water) and to preserve the human living environment. In addition, dredging also fulfils a major role in improving and preventing eutrophication and the like in closed water areas. On the other hand, dredging methods for mid-scale lakes, swamps and rivers that remove sand

and sludge using large and heavy equipment for draining and thus alter flow the path are becoming common. Thus, with the present dredging technology, large-scale equipment and work are becoming necessary, and it is feared that it will invite the destruction of the bio-ecosystem of the water area[2] [3]. In addition, in cases in Japan, where garbage such as plastics, bottles and cans are mixed in the removed sand and sludge, it must be treated as industrial waste. Because of that, the actual cost involved in dredging will be tremendous.

1.2 Partial sediment dredging method developed

Therefore, this research group conducted research aiming to develop a dredging technology that conserves the ecosystem, and to establish a dredging system that does not produce waste by recycling the dredged sludge (added value). Baruzzo has studied recycling dredged sludge and using it effectively in ceramic tiles[4]. Takayama has studied the use of dredged sludge in tidal flat construction, but the lack of a disposal site is a main problem [5]. There are numerous research cases in existence. However, there are possibilities that heavy metals and the like are contained in the dredged sludge, and as such there lies the risk of these being released after recycling and re-using [6] [7]. Because the major portion of the dredged sludge volumetric capacity is water, to carry out draining after making effective use of dredging will be a Herculean task. The draining time reduced using a drain and the effective use of dredged sludge is being studied [8]. In addition, reduction of the sludge draining time is possible when using polymer coagulant in flocculating and draining the dredged sludge, but due to the non-degradable coagulant, there is a problem of the resource utilization being limited.

Bearing in mind the above-mentioned issues, this research reports on the ecosystem conservation partial dredging method using a special dredging pump, and cases of application.

2. MATERIAL AND METHOD

2.1 New dredging pump

Until now, two types of pumps were tested – the non-clogging cutter pump and the sand pump for dredging. However, when using the sand pump for dredging, fibrous garbage such as vegetation roots and soft plastics became tangled in the impeller causing the pump to become unable to function, while solid waste such as empty cans sucked in and blocked the suction port when using the cutter pump. Therefore, the characteristics of the non-clogging cutter pump were combined with the sand pump, and an improved pump based on the non-clogging cutter pump was developed. The dredging pump developed is a pump where a shaft with self-created agitating propeller was fixed to the impeller's lock bolt ($\phi 12$), with a cutter pump (Tsurumi, 15-CE2, 1.5 kW) as its base. Figure 1 shows the pump developed [9]. With this feature, the pump's sandy soil agitating performance is improved, and empty cans and the like passed through the suction gate, thus avoiding blockage problems. The drawbacks of the cutter pump could be overcome by the above-mentioned improvement. This improved dredging pump was installed on the dredging boat (FRP-made float lift) and made to move back and forth, left and right on water. In addition, by making the dredging pump able to go up and down using a chain hoist, it was given a height-regulating function. Furthermore, in order to examine the dredging capability of the improved dredging pump, dredging was actually conducted and the pump discharge rate of sludge was verified.

2.2 The partial dredging method developed

Partial dredging system was built with the application of the above-mentioned non-clogging dredging pump with agitating propeller and inorganic coagulant with calcium as its main component (Figure 2) [9]. This system consisted of a dredged sand and mud transportation part from the dredging pump to the movable screens, and a resource recovery part from the sedimentary tank to the hydro extractor (CS-1, Sekisui Aqua Systems Co., Ltd.).

When dredging using the system, vegetation limbs and leaves, garbage (bottles, cans, soft plastics), mixed in the reservoir sludge sent by the pump can be removed with the automatic screens. The sludge with garbage removed gets separated into sand and mud in the sedimentation tank. Next, the dredged sludge with sand removed is flocculated using coagulant in the flocculation tank, and after being settled in the settling tank, the clear upper portion is returned to the reservoir. On the other hand, the settled mud is sent to the hydro extractor, where after removal of the water, it undergoes a collecting process.

2.3 Improvement of partial sediment dredging method

We developed our system by a combination of inorganic coagulant and dewatering, reported previously as close to commercialization [10]. Sediments and water separation tank could be reduced by the use of inorganic coagulant. By using the dehydrator in this system, it also significantly reduces the sediment dewatering operation. The system was improved for further dredging, aiming to further practical

applications. The special pump developed was fitted with an inverter. This ensures that by changing the frequency, the number of special pump motors can be changed. We were able to change the flow rate through the pump intake. The flocculation tank and the separation tank were made one for a smaller space.

2.4 Sediment concentration and flow rate during continuous operation of each process

Using improved equipment, we continuously dredged sediment of ponds located in Gunma National College of Technology. Suspended Solid (SS) concentration was measured in each dredging process. SS analysis was performed by glass fiber filter paper method. A high

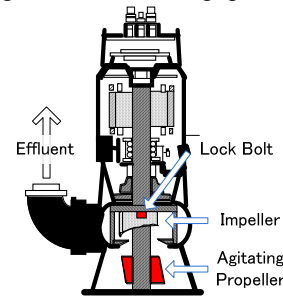


Figure 1 Improved dredging pump [9]

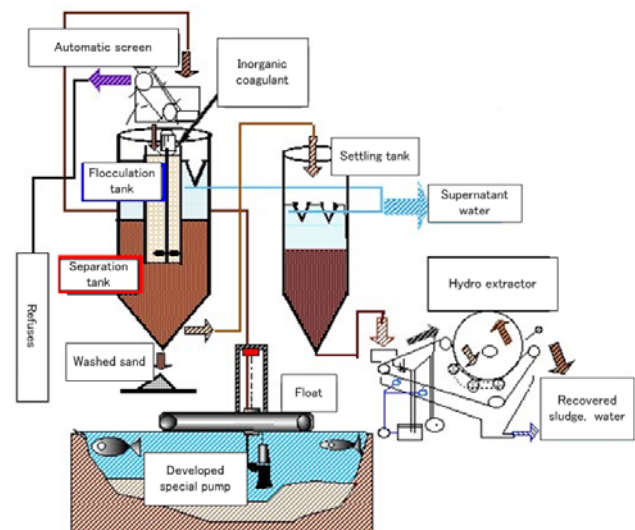


Figure 2 An outline of the improvement dredging method [9]

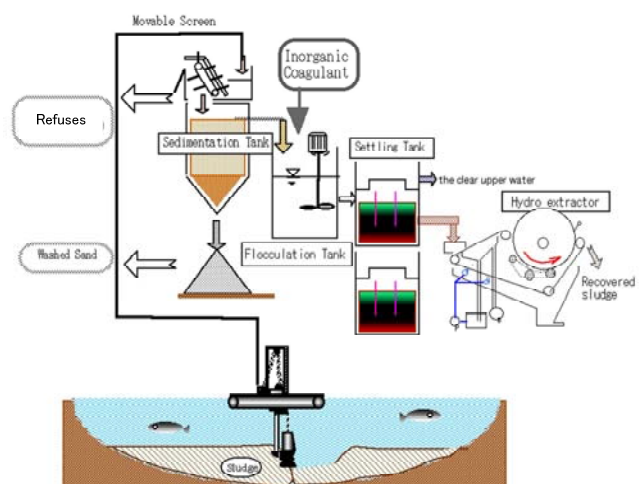


Figure 3 An outline of the dredging method [10]

A concentration of material, TS (total solids) was analyzed. Samples of the deposits were collected from each location (Figure 3), burned in a muffle furnace (600°C, 1 hour) and VS (Volatile Solid: indicates organic matter volume) was determined.

2.5 Recycling sediment from the creek, reservoir

We confirmed the performance of the equipment at the Yaba river in Tochigi pref., and the agricultural reservoir 'Saiko' located on the premises of Gunma National College of Technology (Saiko officially known as Shoukan Swamp, surface area of 6,900 m²). The dyeing plant is located upstream of Yaba river.

Fertilizer analysis of dredged sediments from Saiko and Yaba river in Tochigi pref. were analyzed by specialized agencies. Figure 1 shows these places. Elemental analysis of the recovered sludge was conducted using X-ray Fluorescence Analysis (SEA2120E, Seiko Instruments Inc.) for sludge flocculated using inorganic coagulant from Saiko and Yaba River. In addition, a germination test using rape was conducted conforming to the germination test prescribed by the Fertilizers Regulation Act. Furthermore, a test was conducted on the black soil as a control test. The test was conducted for 10 days under conditions of 12 hours of light and darkness, utilising a plant cultivator (temperature 25°C, lighting 3,500 lux) and a bottom-covered pot with an inside diameter of 11 cm and depth of 6.5 cm. Twenty rape seeds were sown and germination status was observed daily. After 10 days, seven quickly-grown plants were collected in order of their growth, and the leaf length and wet weight were measured.



Figure 3 Sediments were got from Saiko and Yaba River located in Gunma Pref. and Tochigi Pref.

3 RESULTS AND DISCUSSION

3.1 The performance of the improved dredging system

The sediment in Saiko is deposited approximately 80cm to 1m deep. Dredging was carried out continuously using the developed special pump. Table 1 shows ss (sediment) concentrations of each process in the improved dredging system. The average sediment concentration was 56.6 g/l (5.7%) after passing through the automatic screen. The average concentration of the sediment in the supernatant water was 58.6 mg/l, and the average concentration of the sediment was 332 g/l (33.2%) in the settling tank.

The rate of inflow by a special pump used was 160 L/min.

Flocculation time was about 5 minutes in the separation tank. These results showed that we got the dredged sediment in a short time. Sediment sent to the dehydrator was 540 kg/h approx. Before improvement of the system, this was 197 kg/h (Table 2 shows). The results revealed remarkably improved capacity.

Furthermore, the flocculation tank and the sedimentary sand tank were made one for a small space technology. As a result, all parts of this technology can be transported by one truck (a medium truck in Japan, Figure 4).

3.2 Component analysis

Table 3 shows the results of fertilizer analysis of dredged sediments and black soil. Significant differences in nitrogen content of sediment dredging were not observed. Dredging of sediment phosphate (P₂O₅) content was three times in the black soil. Further dredging of sediment potassium (K₂O) was similar in content between the regular soil and dredged sediment from West Lake. The dredged sediment in the



Figure 4 All parts of the partial dredging system in a truck

Table 1 SS concentration of each process in the improved dredging system

	flow rate	the concentration of sediment	supernatant water in separation tank	the sediment in settling tank
No.	m ³ /h	g/l	mg/l	g/l
1	10.9	126.9	85	294.7
2	10.2	58.3	46	255.8
3	8.6	15.9	64	395.2
4	9.4	73.7	52	287.8
5	8.8	8.4	46	423.8
average	9.6	56.6	58.6	331.5

Table 2 SS concentration of dredged sediment

	flow rate	the concentration of sediment
No.	m ³ /h	g/l
1	7.2	16.8
2	7.7	20.4
3	8.2	44.7
4	7.8	38.3
5	8.0	34.4
6	10.0	29.4
7	7.0	24.4
8	6.0	23.8
9	6.2	15.9
10	7.7	11.5
average	7.6	26.0

Yaba river was about 2.5 times. These results show that dredged sediments have a rich fertilizer ingredient.

The results of each sample from X-ray Fluorescence Analysis reveal that these dredged sediments don't contain

Table 3 The results of fertilizer analysis of dredged sediments and black soil

	N	P ₂ O ₅	K ₂ O	VS
black soil	0.39	0.18	0.93	20.2
Dredged sediment from Saiko	0.33	0.64	2.32	12.3
Dredged sediment from Yaba river	0.43	0.63	1.07	13.1

(dry %)

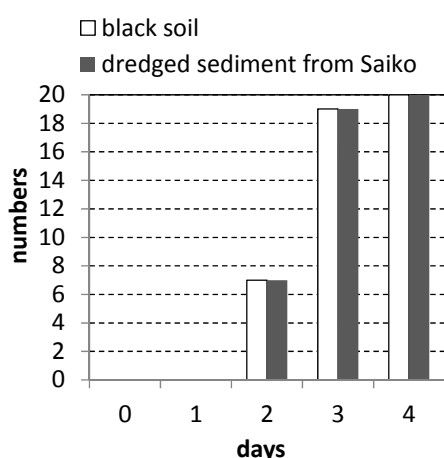


Figure 5 The result of germination test

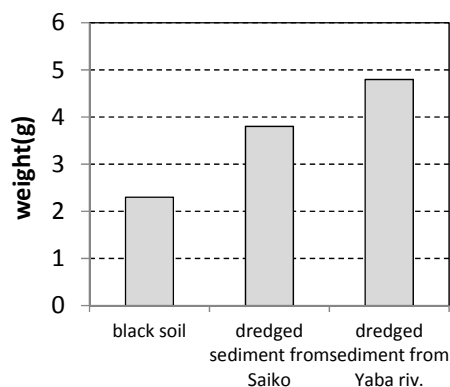


Figure 6 The wet weight of seven leaves

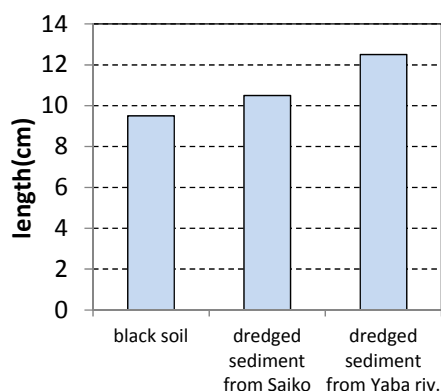


Figure 7 The leaf length of seven leaves average

Cr, Ag, Pb and As, but the content of Al is small. These components will not impede the growth of plants. This result indicated that the reservoir sludge can be used for agricultural applications.

3.4 The results of germination test

The starting time of sprouting and the number of sprouts are shown in figure 5. This result shows the starting time of sprouting in the dredged sediments is similar to the black soil. The leaf length and wet weight are shown in figure 6 - 7. The dredged sediments showed a higher figure for the length of leaves. It is believed that growth by the dredged sediment is favourable.

4 CONCLUSION

We have proposed sediment dredging technology using a special pump with an inorganic coagulant for conserving the ecosystem and recycling the sediment. In this research, we reported about the improvement of this technology and the cases of application. Consequently, these things are recognized as follows,

- 1) The flocculation tank and the separation tank were made one for small space. As such, all parts of this technology can be transported by one truck.
- 2) The special pump developed was fitted with an inverter. This ensures that by changing the frequency, the number of special pump motors can be changed.
- 3) The dredged sediments were applied to fertilizer analysis. As a result, they have sufficient amounts of P₂O₅ and K₂O. X-ray Fluorescence Analysis showed that dredged sediment did not contain Cr, Ag, Pb and As.
- 4) Germination test showed that the growth by the dredged sediment is favourable.

We propose that such dredging technology can be used at lakes in parks, small ponds, and other locations. The dredging sludge can be used for agricultural applications.

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