NEW PROCESS FOR IMPROVEMENT OF CONTAMINATED SEDIMENTS BY SUCCESSION OF MICRO-BIOTA

Hiroshi Kishi,* Kouichiro Yamamoto**

** Rural Environment Research Association.(RERA)*
605-10-9-1,Yushima, Bunkyo-ku, Tokyo, Japan113
*** Environmental Technology Engineering Co.Ltd.*
401-9-20-3, Yuhima, Bunkyou-ku, Tokyo, Japan 113

ABSTRACT

We have developed the new process for the improvement of the contaminated sediments. The new process is based on controlled succession of micro-biota with a bioreactor.

The test results were that 1) the volume of dry solids was reduced by roughly 1%/d, 2) made odorless, 3) the number of coliform groups was reduced to less than 1/100, 4) the reduced iron in the sediment was oxidized and a large volume of contaminated sediment converted into sediment containing oxygen, 5) in release tests conducted over a period of 20 days, the nitrogen regeneration volume was reduced by 90% and the phosphorus regeneration volume by 95%, 6) and effluent quality was improved by advanced treatment.

This makes the treatment of contaminated sediments easier, and when securing a disposal site is difficult, the regeneration of nitrogen and phosphorus is suppressed even if the treated sediments was returned into lakes, marshes and the sea. Also, a large volume of oxygen can be supplied into the bottom layer to eliminate anoxyc water, oxygen can be retained in the bottom layer over a long period of time to prevent deterioration of the water environment, and recovery of poor water environments appears possible.

KEYWORD

Batch treatment; Bioreacter; Contaminated bottom sediments; Release test; Dam; Wetland; Regeneration; Succession of micro-biota;

INTRODUCTION.

In lakes, marshes and sea areas, harmful sediments(sapropel) are produced by the inflow of contaminants. These harmful sediments consume oxygen and change the ecosystem, resulting in the regeneration of nitrogen and phosphorous from the bottom sediments and leading to the worsening of water quality. Particularly, contaminated organic sediments have a high fluidity and a putrid smell, making their elimination and treatment difficult. The objective of the new process described herein is to improve these contaminated organic sediments through the controlled succession of micro-biota. The succession speed of micro-biota is very fast in general. By performing succession treatment of contaminated organic sediments in a short period of time by artificial

Rural Environment Research Association(RERA) Japan
Tel +81 3 3816 0019 Fax +81 3 3818 3140
Home Page Address http://www.rera.org E mail t-kishi@kt.rim.or.jp

operation, it is possible to transplant the self-purifying function of activated sludge into sediments. At the same time, it is possible to oxidize iron, which is an oxidation-reduction substance contained in the sediments, thus improving the contaminated organic sediments into sediments possessing a large amount of oxygen and a self-purifying function.
This report discusses the results of practical tests using a pilot plant that were carried out in Marsh Furukawa (brackish lake; water area: 9ha.; volume: 159.000m^3; mean water-level: 1.77m) in the winter of 1992 to verify the process for improvement of contaminated sediments by succession of micro-biota.

METHODS

Properties of bottom sediments
The bottom sediments sampled from the test water area in Marsh Furukawa were(muck) black without free acidity, had a putrid smell and were -500mV in oxidation-reduction potential (ORP), and 9.3 in pH value. The sediments were composed of nitrogen of 0.512% DS and phoephorus of 0.245% DS and showed an ignition residue of 23.3%. The concentration of chlorine in the sediments was 3.500 mg/l. thus indicating the properties peculiar to eutrophicated brackish lake.

Pilot plant
In this test, the batch-type activated sludge tank located in a bathing place was used. The tank measured 4 m wide. 4 m long and 2.5 m deep, and its effective volume was 40 m^3. A conceptual view of the test tank is shown in Fig.1. The controller used in this test consisted of DO, pH, ORP and water temperature measuring equipment and aeration controlling equipment. A conceptual view of the controller is shown in Fig.2.

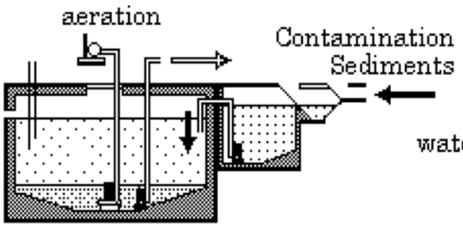

Figure 1 Test Tank

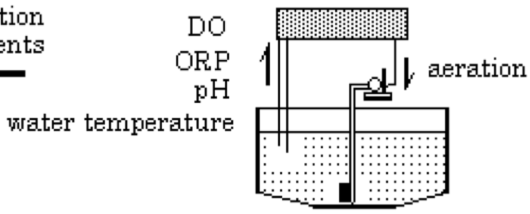

Figure 2. Controller

The activated sludge produced in the above-mentioned facility was used as species sludge in this test, and acclimatization operation was carried out by adding the bottom sediments of Marsh Furukawa. The ratio of species sludge to contaminated sediment was 1:5 in volume percent. The period of acclimatization was 30 days, and acclimatization judgment was made based on DO wave characteristics and pH values.
In the test, the activated sludge having nitrifying and denitrifying functions was added to the contaminated organic sludge excluding sand; then, aeration and anaerobic stirring were repeated, and the anaerobic biota of sediments was succeeded to the aerobic micro-biota, thereby transplanting the self-purifying function of the activated sludge into the sediment. The test was conducted fully automatically using programmed computers. The optimization of aeration and judgment on the succession of micro-biota were made based on DO wave characteristics, pH values and ORP values.
Batch running was performed under the following conditions: aeration time + stirring

time = 8 hours/cycle x 3 cycles/day. The test methods specified in the "Sediment Monitoring Methods" of the Environment Agency of Japan were used. Also, the methods of analysis specified in the Japanese Industrial Standards and the Sediment Monitoring Methods of the Environment Agency of Japan were used.

RESURUTS AND DISCUSSION.

The results of the tests are described below.

Reduction in the volume of sediments
The concentration of sludge, 63,100 mg/l at the time of commencing the test, dropped to 50,600 mg/l after the lapse of 25 days. The results of this test are shown in Table 1.
The table shows the percentage changes % and DSkg/m3 taking the value at the time of commencing the test as 100.

Table 1 Changes of sludge concentration in test tank

Day		Starting day		25days		
Item	(Unit)	DSkg/m3	%	DSkg/m3	%	%/day
MLSS		63,1	100	50,6	80.2	-0.79
MLVSS		15,9	100	16,2	101.9	
MLSS-VSS		47,2	100	34,4	72.9	

Changes in the composition of sludge.
The tendencies of changes in the composition of sediments and improved sludge in this test are described below. Changes in the composition of sediments are shown in Table 2.

Table 2 Change of sludge composition in test tank

Item	Starting day (Unit) gr/m3	25days gr/m3	%	%
C	4,382	3,850	87.9	−12.1
N	323	290	89.8	−10.2
P	154	154	100.1	+0.1
S	791	45	5.7	−94.3
Si	9,591	6,927	72.2	−27.8
Fe	2,618	2,646	101.1	+1.1

(1) Sulphur (S) in the sediments rapidly decreased with the succession treatment.
(2) Silicon (Si) in the sediments greatly decreased with the succession treatment. A similar tendency was also observed in reducing the volume of sludge.
(3) Carbon (C) in the sediments decreased a little with the succession treatment. Carbon is a substance that may be increased by bio-treatment (carbon dioxide assimilation). It was an interesting behavior in comparison with the behavior of other substances such as silicon.
(4) Nitrogen (N) in the sediments decreased a little with the succession treatment.
(5) Phosphorous (P) and iron (Fe) underwent no change with the succession treatment.

Fig 3.1 shows the quantitative changes(mg/l) of the composition in sludge and Fig 3.2 shows the changes(%) of the sludge composition in the test tank.

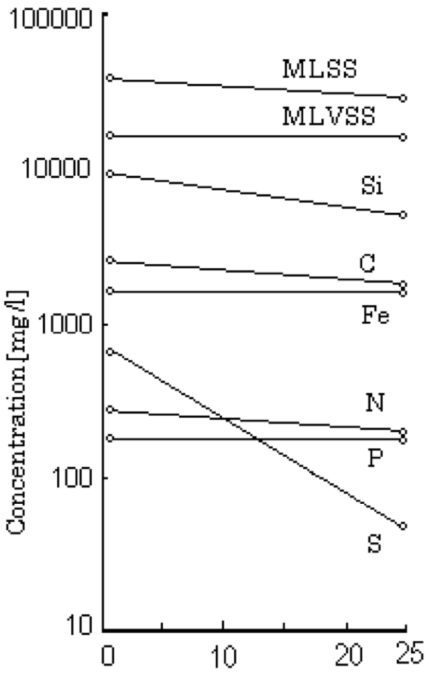

Figure 3.1 Change in the component of the improved bottom sediments[mg/l]

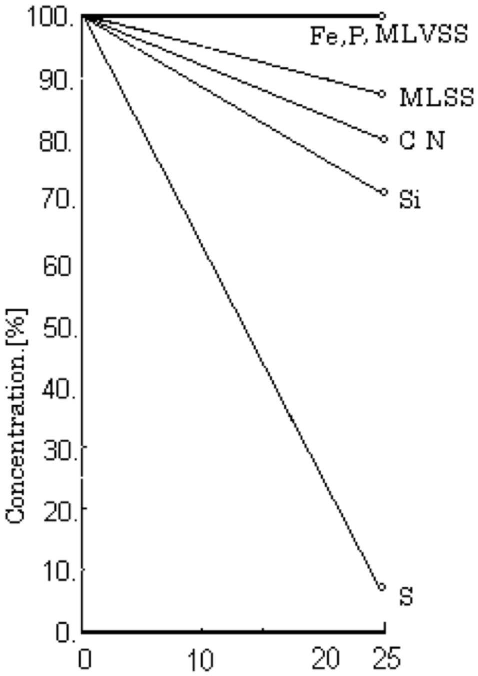

Figure 3.2 Change in composition of the improved bottom sediments[%l]

Results of nitrogen. phosphorus and COD release tests

Tests were conducted on the release of nitrogen, phosphorus and COD from the sediment in Marsh Furukawa and the improved sediment. As a result, differences in the release characteristics (release rate and volume) between the sediment in the marsh and the improved sediment were clarified. Particularly, as for nitrogen, a tendency contrary to the release was observed, and a conspicuous difference was seen in the release characteristics of the sediment in the marsh and the improved sediment. The results of these tests are shown in Table 3.

Table 3 Release test results from the bottom sediments and improved bottom sediments

Item	(Unit)	Bottom sediments mg/m2/day	Improved sediments mg/m2/day	Improvement effect %
COD		45.1	−0.8	101.8
Nitrogen		89.2	−5.4	106.1
Phosphorus		39.3	1.2	96.8

Nitrogen

The results of the release test are shown in Fig. 3.3.

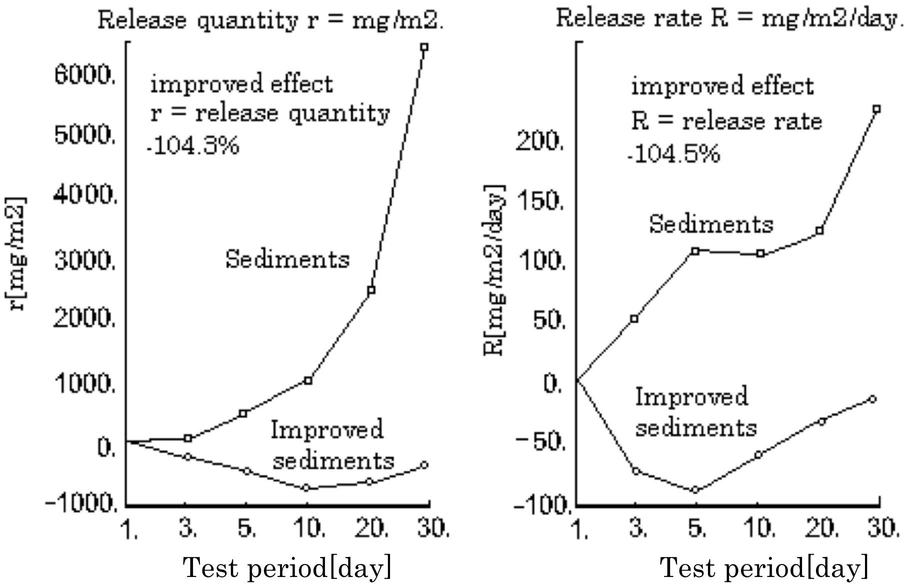

Figure 3.3 Release test results of nitrogen from bottom sediments and improved bottom sediments

Making the sediments odorless

The results of the gas generation test are shown in Table 4 .

Table 4. Gas generation rate and improved effect

Item	(Unit)	Sediments μl／DS kg	Improved sediments μl／DS kg	Improved effect %
Sulfide		87.3	N D	100
Methane		982.0	9.2	99.1
Ammonia		34..0	18.9	44.4

Change in the bacterial phase

To verify the safety of the sediment in the marsh and the improved sediment, ordinary bacterial count and coliform group number were measured. The results of this test are shown in Table 5.

Table 5 .Change in the number of the bacteria.

Bacterial phase	Sediments	Improved sediments	Removal rate
Bacteria〔number / cc〕	75.100	890	98.8%
Coliform group〔group number / cc〕	512,000	15	99.9%

Iron

Iron is an oxidation-reduction element contained in the sediments.Under oxidation-free condition, it becomes reduced iron and can be used as an index of the environment in which the sediments are placed. Simultaneously with the succession treatment of microorganisms, the iron contained in the sediments is oxidized. The change in the composition of iron in the sediments is an index showing succession treatment and also the volume of oxygen contained in the sediments and the capacity to retain oxygen. The results of this test are shown in Table 6.

Table 6 . Change in the iron contained in sludge

test period Item／	(Unit)	starting day g/KgDS	%	25days mg/KgDS	%
Fe^{2+}		35300	85	7400	14
Fe^{3+}		6200	15	44900	86

In this test, the harmful sediment became a brown sludge and its ORP was +300 mv and pH was 6.5.

(1) The putrid contaminated organic sediment was odorless.
(2) The sediment decreased by 0.79% DS/day.
(3) Changes in the composition of the sediment were different, depending on substances. Sulfur decreased greatly. The decrease in silicon was large, and agreed with that of the sediment. The decrease of nitrogen and carbon was small and showed the same tendency. A decrease of phosphorus and iron was not recognized. It is therefore possible to estimate the increase and decrease of sediments from the variations in the concentration of which substance.
(4) The regeneration of substances (nitrogen and phosphorus) causing eutrophication from sediments was greatly reduce. Particularly, nitrogen showed a self-purifying tendency, indicating that the function of activated sludge was transplanted. The same tendency was also observed in COD.
(5) The coliform bacilli contained in the sediments decreased.
(6) 85% of iron contained in the sediments changed into oxidized iron, and harmful sediments were improved into sediments possessing a large amount of oxygen.

The results of these tests showed the same tendency as those of basic tests conducted in Marsh Furukawa (brackish lake, 1988-89) and those of continuous tests conducted in Lake Biwa (freshwater lake, 1991-92), thus demonstrating the reproducibility of succession technology. From the tests and actual examples, this process proved to be effective in improving the harmful contaminated organic sediments found in the freshwater, brackish water and sea areas.

CONCLUSIONS

These practical tests proved that a new process for improving contaminated sediments by artificially controlling the succession of micro-biota is effective in improving the quality and quantity of highly-suspended organic contaminated sediments.
The new system will make it possible to return to the bottom of water the improved sediments which have an activated-sludge self-purifying function and contain a large amount of oxygen, and to supply oxygen into a seabed where aeration is impossible. Also, using the improved sediments, it will be possible to create a beach or marsh and to restore a variety of ecosystems and self-purifying functions. This process will permit the environment in water areas (sea, lake, wetland, dam, marsh, fishing ground, etc.) to be restored without using chemicals, without producing wastes and without changing the natural Submarine/water bottom topography.

EXAMPLES

Farming pond (*Penaeidea* culture pond)

The contaminated sediments in the *Penaeidea* culture pond located in Ishigaki Island, Okinawa Prefecture were given succession treatment with a bioreactor in 1990, thus successfully preventing marine pollution, 1990.

Photo 1 Bio-reacter in *Penaeidea* culture pond 1992

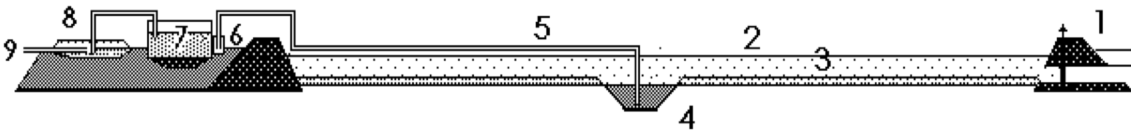

Figure 4 The cross section of the *Penaeidea* culture pond

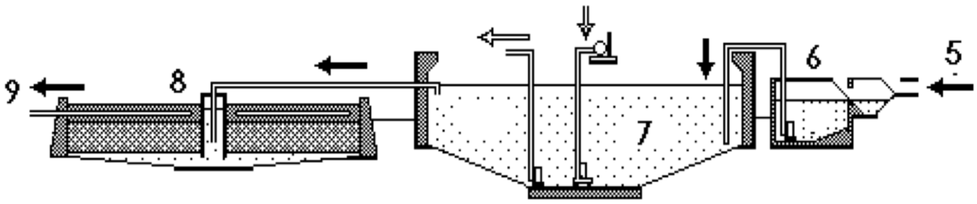

Figure 5 The flow of the succession establishments.

1:bulkhead and intake gate 2:Seawater 3:Sand bed 4:Groove 5:Organic contaminated sediments 6: Sand pit 7:Bioreater 8:Sand filter 9:Out flow

On-site treatment (sediment control dam)

The contaminated sediments accumulated in the sediment control dam located in Togi Town, Ishikawa Prefecture ran into the sea owing to rain in 1985, causing marine pollution. As a countermeasure against this pollution, an aerator and other devices were installed in the dam from sediment control and the physical properties of the contaminated sediments were changed within the dam, thus successfully preventing marine pollution downstream, 1985-1990

Photo 2 The establishments in sediment control dam, 1985

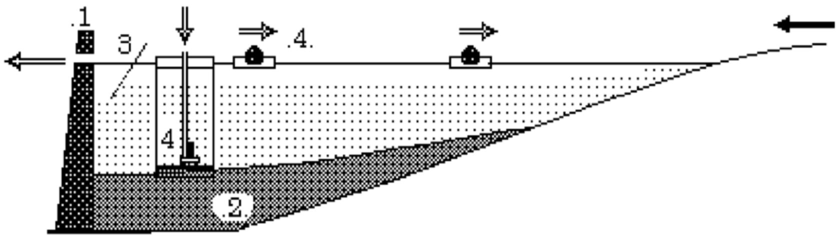

Figure 6 The image figure of the establishments in the dam

1:Sediment control dam 2: Contaminated sediments 3:Baffle plate 4:Aeration

ACKNOWLEDGEMENT

We thank the following organizations for proving the opportunity to conduct the contaminated sediment treatment tests and for providing funds to publish this paper: Fisheries Agency, Fishery Infrastructure Development Center, Gyokou Senkaieng Consultants Corp., Rikuzen Takada City, Ishigaki City, the Society for Protecting Marsh Furukawa.

REFERENCES

A. J. Kluyver and C. B. Von Niel (1956):*The Microbe's Contribution to Biology* Harvard University Press, Cambridge Massachusetts USA. (in Japanece, and English)

The Environment Agency (1985):*The way of researching the bottom quality and commentary* Japanese environment analysis society Tokyo, Japan(in Japanece)

Hiroshi.Kishi (1985) *Hy-brid Lagoon System* ,Rural Environment Research Association, Tokyo, Japan(in Japanece)

The Ministry of Construction (1987): *The development of the water control technology that a lake is synthetic* Japanese construction center Tokyo, Japan(in Japanece)

Hiroshi.Kishi, and Makoto. Natori (1991):*The Experimental Report of Bottom Sediments Purification in Marsh Furukawa,* Ministry of Transport.15th US-JAPAN Expert Meeting. (in Japanece, and English)

Rural Environment Research Association(RERA) Japan
Tel +81 3 3816 0019 Fax +81 3 3818 3140
Home Page Address http://www.rera.org E mail t-kishi@kt.rim.or.jp