

PERFORMANCE OF A CIRCULATION TYPE PURIFICATION SYSTEM DURING THE TREATMENT OF SLUDGE FROM MANILA BAY AND TWO PORTS IN JAPAN

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ABSTRACT: Ocean sludge seriously exerts significant environmental load to local sea areas and has a negative effect on the marine ecosystem. In this study, the use of fine-bubble technology for the purification of sludge is being investigated. The principle behind this technology is that the bacteria that can degrade sludge are activated by the aerobic conditions induced by the fine-bubbles. Fortunately, one of the authors successfully developed a fine-bubble decomposition system (circulation type) for ocean sludge. Hence, to verify and check the system's performance it was used and tested in the treatment of sludge that was obtained from Manila Bay and from Funabashi and Hidaka ports, in Japan. Interestingly, the results of the study showed that the system performed very well in treating the sludge. It is noteworthy to mention that through this study, potentially beneficial bacteria isolated from the sludge sample was successfully identified using 16S rRNA gene sequence analysis.

Keywords: Fine-bubbles, Purification of Sludge, Circulation Type Purification System, Manila Bay

1. INTRODUCTION

Ideally, it is important to reduce and control the formation of sedimentary sludge in the ocean. Plans to reduce the sludge are usually based on dredging or sand covers. Dredging is a simple method whereby the sludge is physically removed. However, the dredged sludge needs to be treated after removal. Sand covers, in general, reduce contamination from ocean sludge, but they too can stress living organisms and ecological systems and are not ideal in places where navigation is a major concern. Hence, better and more efficient sludge management options are needed.

In this study, the use of fine-bubble technology to promote sludge degradation is being explored. Fine-bubbles can change the conditions from an anaerobic state into an aerobic state. Fortunately, one of the authors has developed a method for decomposing sludge by using microorganisms activated by the aerobic state induced by the micro-bubbles. Consequently, very good results were achieved using this method [1-3]; as a matter of fact, utilizing the said method hastened the treatment time and reduced it to 5 days. In this study, the purification system was used to treat the sludge from the following three areas: Funabashi Port in Tokyo Bay, Japan Hidaka Port in Wakayama Prefecture, Japan and Manila Bay, Philippines. The primary objective of this study was to assess the performance of the purification system.

The ports of Funabashi and Hidaka are regarded as two of the most important ports in Japan. On the other hand, Manila Bay is a natural harbor that is located in the capital city of the Philippines. Historically, it has served as a key area for socio-economic development in the country and has helped in facilitating commerce and trade between the Philippines and other nearby countries. Unfortunately, due to the high level of human activity and industrialization around Manila Bay, the water quality within the bay has continuously deteriorated [4].

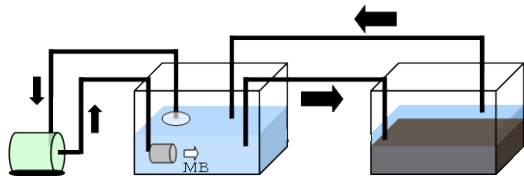
2. EXPERIMENTAL SYSTEM

2.1 Experimental Devices

Figure 1 shows the experimental devices composed of two parts. Specifically, the water circulates through the two tanks in the purification system. In one of the tanks, fine bubbles are generated. These fine-bubbles have a micro-size diameter and high solubility. This allows water with high concentrations of dissolved oxygen to circulate readily through the tanks. The fine-bubble generator was based on an earlier study [5-6]. The other tank serves as an experimental tank. In this tank, sea water

and sludge were combined.

The device is shown in Fig. 1 was set-up in one of the laboratories of the Integrated Research and Training Center (IRTC) of the Technological University of the Philippines (TUP), Manila, Philippines.



Fine-Bubble Generator Experimental Tank

Fig. 1 Purification System of the Circulation Type

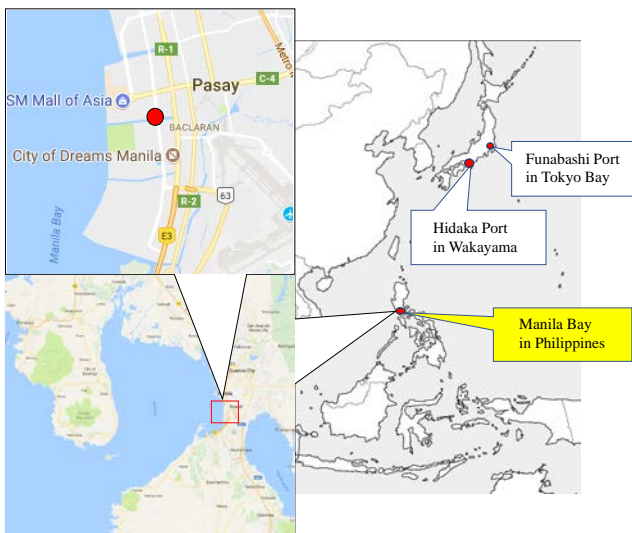


Fig 2. Locations of the study sites in Manila Bay, Philippines, and Funabashi and Hidaka, Japan

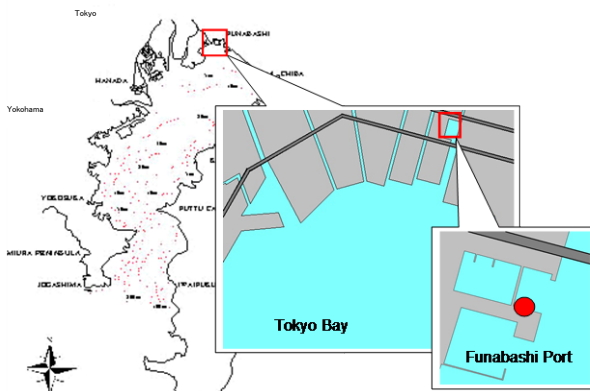


Fig.3 Sampling Point at Funabashi Port in Japan

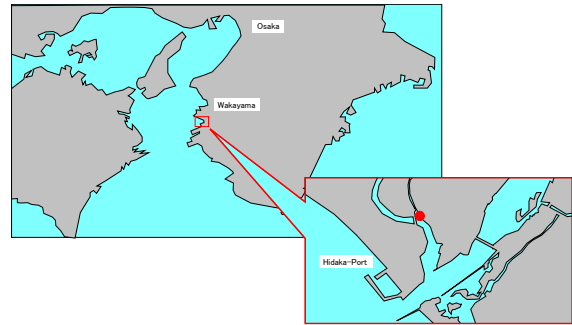


Fig.4 Sampling Point at Hidaka Port in Japan



Fig. 5 Sediment Sampler

2.2 Collection Points for Sludge and Sea Water

To investigate the efficiency of the purification system, sea water and sedimentary sludge samples were collected from Manila Bay in the Philippines at the sites marked with a red circle as shown in Figure 2. The other samples were collected from the Ports of Funabashi and Hidaka specifically at the sites marked in red circles as shown in Figs. 3 and 4, respectively.

2.3 Experimental Procedure

The sedimentary sludge was collected using the sediment sampler as shown in Fig. 5. The collected samples were then placed in the tanks (Fig. 6). Commencing the operation of the fine-bubble generator signals the start of the sample measurements. After 6 hours of fine-bubble generation, a microbial activator was added consists of kelp with some nutrients and enzymes in liquid form. The amount of the microbial activator added was 100mg/L. The water quality was assessed by taking measurements of the water temperature, chemical oxygen demand (COD), and concentrations of dissolved oxygen (DO), ammonia nitrogen (NH₄-N), nitrite nitrogen (NO₂-N), nitrate nitrogen (NO₃-N), total nitrogen (T-N). Measurements were conducted after 24 hours, 48, 60, 72 hours from the time the micro-bubble generator has started to operate. Dissolved oxygen and water temperature were

measured using a multi-parameter water quality meter (portable fluorescent dissolved oxygen meter). Ammonia nitrogen, nitrite nitrogen, nitrite nitrogen and total nitrogen were measured by using a Digital Pack Test (Kyoritsu Chemical-Check Lab, Corp.). Additional specifications of the experimental device are shown in Table 1.

Table 1 Specifications of the Experimental Devices

Water = 25 L, Sludge= 0.1875 kg
Size of Water Tank = 200x270x370 mm
Flow Rate for Fine Bubble Generator = 43 L/min
Flow Rate for Circulation Water Pump = 10 L/min
Microbial Activator = 100 mg/L



Fig. 6 Photograph of the Actual Experiment

3. EXPERIMENTAL RESULTS

3.1 Water Temperature and Dissolved Oxygen

The measured water temperature and dissolved oxygen results are shown in Fig. 7. The water temperature was stabilized at 30 degrees C, and the DO stabilized at around 7.5 mg/L. The stable water temperature and DO concentrations are desirable because this facilitates proper interpretation of the results for the other parameters to be measured. The above data also demonstrates that aerobic conditions were present in the sample experiments.

3.2 Dissolved Inorganic Nitrogen, Total Nitrogen and Chemical Oxygen Demand

The level of dissolved inorganic nitrogen (DIN) represents the total amount of ammonia nitrogen (NH₄-N), nitrite nitrogen (NO₂-N), and nitrate-nitrogen (NO₃-N). Fig. 8 shows the results for the DIN. The DIN concentrations abruptly decreased within 24 hours and thereafter remained at almost undetectable levels for the 48 hours and 72 hour time interval. These data indicate that the denitrifying bacteria are present in the system.

The T-N results are shown in Fig. 9. The T-N concentrations first decreased and then slightly

increased by about 20% within the first 48 hours. However, after 72 hours, T-N was not detected in the system, which implies that the purification system performed very well. The temporary increase of T-N between 24 hours and 48 hours may be attributed due to the delayed effects from the addition of the microbial activator.

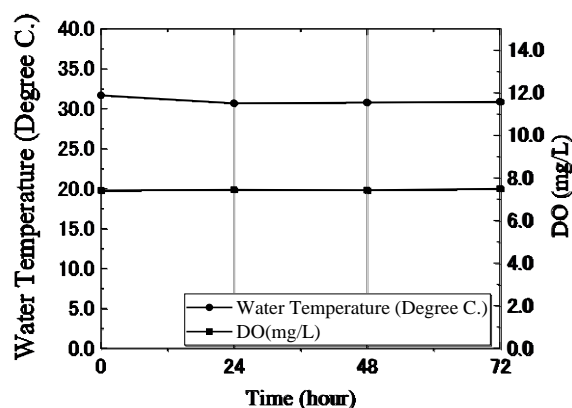


Fig.7 Changes in Water Temperature and Dissolved Oxygen (DO)

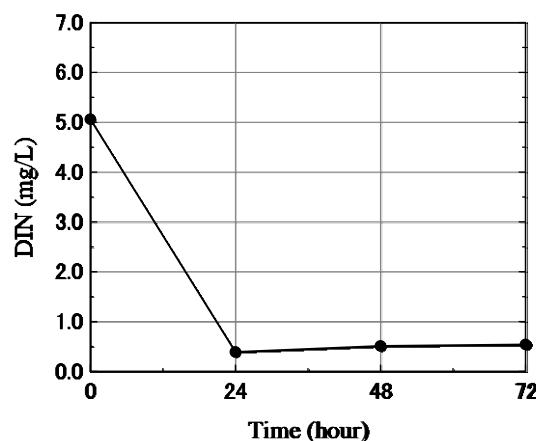


Fig.8 Changes in Dissolved Inorganic Nitrogen (DIN)

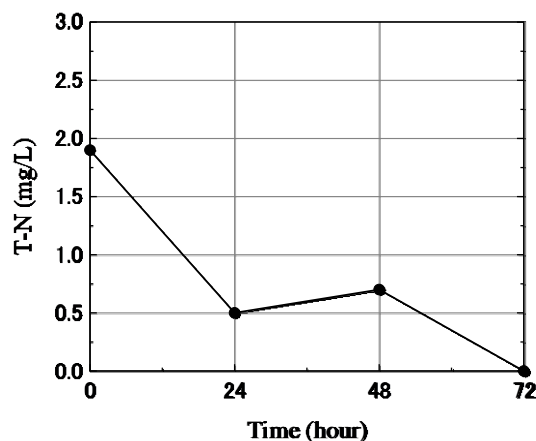


Fig.9 Changes in Total Nitrogen (T-N)

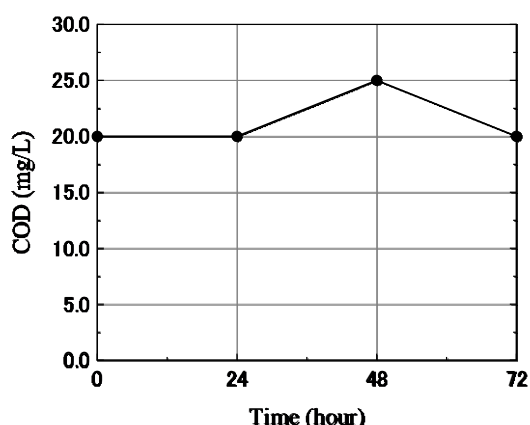


Fig.10 Changes in the Chemical Oxygen Demand (COD)

The results for the COD are shown in Fig. 10. The COD remained constant at 20 mg/L for 24 hours and then increased to 25 mg/L at 48 hours which can be attributed due to the microbial activator. Subsequently, the COD returned to 20 mg/L at 72 hours. These results confirmed the efficiency of the system.

3.3 Comparison of the Purification Results for Total Nitrogen in Manila Bay Samples with Those from the Ports of Funabashi and Hidaka in Japan

Figure 11 shows the results for the T-N concentrations versus time for the three experiments conducted on the sludge from three different places, namely, Manila Bay and the ports of Funabashi and Hidaka. The T-N concentrations decreased dramatically in all three experiments. The T-N concentrations reached undetectable levels within 72 hours for the samples from Manila Bay and Hidaka, whereas the T-N concentrations only reached undetectable levels after 120 hours for the samples obtained from Funabashi. Based on the results, the purification system of the circulation type showed a good purification performance.

3.4 Comparison of the Purification Results for Elemental Compositions in Manila Bay Samples with Those for Funabashi and Hidaka Port in Japan

Figure12 shows the comparison of the EDX (Energy Dispersion type X-ray analysis device) results from the obtained in Manila Bay and those from the ports of Funabashi and Hidaka, Japan.

By comparison, S (sulfur) decreased in each treatment at the end of the test. Interestingly, it was observed that Na (sodium) slightly increased by a small amount in the samples obtained from Funabashi.

The other components showed similar trends. In addition, the largest decrease in Si (silicon) was observed in the samples obtained from Funabashi.

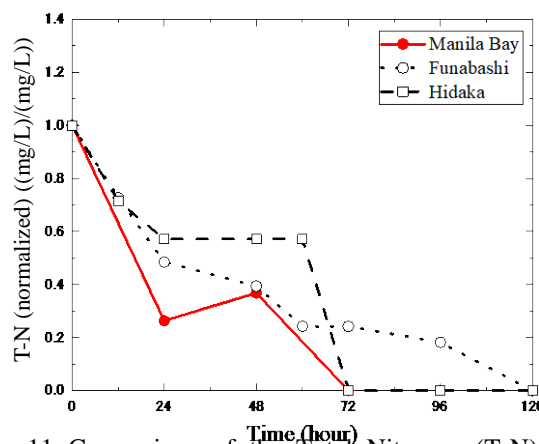


Fig. 11 Comparison of the Total Nitrogen (T-N) Results for Manila Bay Samples with Those from the Ports of Funabashi and Hidaka

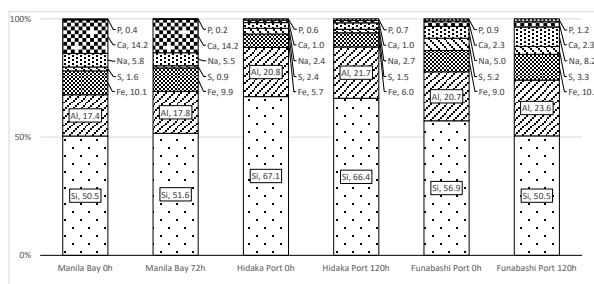


Fig. 12 Results from the EDX (Energy Dispersion Type X-ray Analysis Device) for Manila Bay and the Ports of Hidaka and Funabashi

3.5 Microbial Analyses

Microbial analyses were performed to identify the useful bacteria in the fine-bubble treatment of Manila Bay sludge. Bacteria were isolated from the sludge experimental samples and identified by 16S rRNA gene sequence analyzer according to methods described in earlier work [7].

The six species of bacteria that were identified from the sludge at 0, 24 h are as follows: *Rhodococcus* sp., *Bacillus* sp., *Exiguobacterium* sp., *Serratia* sp., *Pseudomonas* sp., and *Marinobacter* sp. (Table 3).

It was concluded that *Rhodococcus* sp., *Exiguobacterium* sp. and *Marinobacter* sp. are uniquely valuable for the breaking down of the sludge. Previous studies have shown that *Rhodococcus* sp. has the ability to participate in fossil fuel *biodesulfurization* reactions and *Exiguobacterium* sp. have been detected in a unique environment with temperatures ranging from -12 to 55 degree C [8], and that *Marinobacter* sp. can degrade hydrocarbons [9].

Table 3 Sequence Analysis Results for the Six Isolated Stains

Strain No.	Length (bp)	% similarity
1	1624	98 % <i>Rhodococcus</i> sp.
2	1005	95 % <i>Bacillus</i> sp.
3	1075	92 % <i>Exiguobacterium</i> sp.
4	593	93 % <i>Serratia</i> sp.
5	453	79 % <i>Pseudomonas</i> sp.
6	1509	97 % <i>Marinobacter</i> sp.

4. CONCLUSIONS

The results of the study showed that the performance of the purification system was very good in the treatment of the sludge from Manila Bay Philippines and those from the Ports of Funabashi and Hidaka, Japan. In particular, DIN and TN concentrations decreased markedly during the treatment process in just a very short period of time. This was clearly manifested by the significant improvement on the quality of water obtained from the samples.

Interestingly, six species of bacteria were isolated from the sludge from Manila Bay. One of the identified bacteria (*Pseudomonas* sp.) has the same species similar with the one reported in an earlier study [7].

For future experimental works, the researchers would like to check the efficiency of the system for treating sludge samples by exploring other places such as the Pan Pacific area to extend possible use and adoption of the system.

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4. REFERENCES

[1] Okamoto, K., Komoriya, T. and Toyama, T., Comparison of Purification Performance against

Ocean sludge in Two Sea-Area by Using Purification System of Circulation Type, Proc. 6th International Conference on Civil Engineering, 2017.

- [2] Okamoto, K. and Hotta, K., Purification Experiments on Sedimentary Sludge by Microorganism Activation, Recent Advances in Marine Science and Technology 2010 -PACON International, 2010, pp.151-166.
- [3] Okamoto, K., Hotta, K., Toyama, T. and Kohno, H., Experiments on Purification of Ocean Sludge by Activating Microorganisms, The International Offshore (Ocean) and Polar Engineering Conference, 2011.
- [4] Jacinto, G.S., Azanza, R.V., Velasquez, I.B., and Siringan, F.P., Manila Bay: Environmental Challenges and Opportunities, In Wolanski, E. (Ed.), The Environment in Asia Pacific Harbors, 2006, Springer, pp. 309–328.
- [5] Matsuo, K., Maeda, K., Ohnari, H., Tsunami, Y., and Ohnari H, Water Purification of a Dam Lake Using Micro Bubble Technology, Progress in Multiphase Flow Research I, 2006, pp.279-286.
- [6] Okamoto, K., Hotta, K., Toyama, T., and Kohno, H., Purification System of Ocean Sludge by Activating Microorganisms, International Journal of GEOMATE (Geotec, Const. Mat. & Env.), Vol.6, No.1, 2014, pp.791-795.
- [7] Komoriya T., Okamoto K., Toyama, T., Effect of adding of bacteria on the removal of radioactive cesium from ocean sludge in a circulation type purification system, Int. J. of GEOMATE, Vol. 12, 2017, pp. 121–126
- [8] Vishnivetskaya T.A., Kathariou S., Tiedje J.M., The *Exiguobacterium* genus: biodiversity and biogeography, *Extremophiles*, Vol. 13, 2009, pp. 514–555
- [9] Brito E.M.1., Guyoneaud R., Goñi-Urriza M., Ranchou-Peyruse A., Verbaere A., Crapez M.A., Wasserman JC, Duran R., Characterization of hydrocarbonoclastic bacterial communities from mangrove sediments in Guanabara Bay, Brazil, *Res Microbiol.* Vol. 157, 2006, pp. 752–762
- [10] Okamoto, K., and Hotta, K., An Experiment on Purification of Water Quality by Coagulants and Micro Bubble, Book of Recent Advances in Marine Science and Technology, 2008.
- [11] Matsui, R, Okamoto, K, and Hotta, K, Water Purification Experiments by Micro Bubble, Book of Recent Advances in Marine Science and Technology, 2006, pp. 119-126.
- [12] Mizoguchi, M., Observation of Water

Purification Process in a Moat by Microbiological Treatment Technique, Proceedings of Biological Resource in Mie University, No.16, 1996, pp.25-37.

- [13] Sone, T., Yamashita, K., and Okamoto, K., Identification of Microorganism in Purification Process for Ocean Sludge by using Purification System with Circulation Type, Japan Association for Coastal Zone Studies, 2014,

CDROM.

- [14] Okamoto, K., and Komoriya, T., Purification Experiments by Directly Throwing Microorganisms by from Ocean Sludge Using of Decomposition System with Circulation Type, Japan Association for Coastal Zone Studies, 2015, CDROM.

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