

Research and Development of Biodegradation Disposal for SBS (Sugi Bark Sorbent)

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The research on the practical applications of SBS (Sugi Bark Sorbent) which was initiated in 1997 realized a waste material recycled product using 100% natural materials with reduced environmental loads which is comparable to commonly used petroleum products in terms of performance and cost, and reached the stage of commercial production in 2000. For the purpose of reducing total environmental loads in the oil recovery, we investigated biodegradation treatment as a disposal method of SBS after use (after adsorbing oil). It was confirmed that the oil content was reduced from 10000 ppm to 2000-5000 ppm after 1 to several week-period in a biodegradation experiment using Bunker C in the bark compost.

I. INTRODUCTION

Oil sorbent is one of the effective resources for land and marine oil spill responses. In contrast to polypropylene (PP) which has been frequently used in the existing oil sorbent, we developed the practical application of an oil sorbent using sugi (*Cryptomeria japonica* D. Don) bark¹⁾ as a starting material which is a natural product of which there is an excess supply in Japan so the development of its uses has been in demand. We gave permission to Bungo Yuki Hiryo Inc. (Taketa, Oita), to proceed with patent filing procedures for SBS's commercialization²⁾.

A. R & D of SBS

There were 3 objectives in this R & D.

(1) Lower environmental load.

In terms of its production, the resources are waste products and the process is simple. During its use if the responder fails to recover the sorbent itself the environment will not be unduly harmed due to the fact that it is made entirely of organic materials. With respect to disposal, SBS does not discharge toxic

materials.

(2) Lower total costs.

It is thought from the ease of disposal after use and its processing expense that it is advantageous with the possibility of total cost reduction of oil spill response.

(3) Equivalent absorption of conventional pp products.

The main volume of their Sorbency Ratio (g/g) is 10-15 in low viscosity and 15-20 in high viscosity. We aimed to realize these absorbency with less water absorbency than 0.2.

We have tried to make an oil sorbent from sugi bark and test its basic absorbency under dry/wet conditions. The oil absorption function is as efficient as that of the test piece, which is in a state of dryness. Concerning the size of fiber, a tendency is clearly observed that the oil absorbing function improves when the fiber size is larger. Controlling fiber size and the state of dryness made the Sorbency Ratio the highest 13.4 (Bunker A), which is an equivalent absorption of PP products. From the viewpoint of the practicality in the spill site, we suggest about appropriate form for its use in real spills through the water tank experiments. After all, they were improved into commercial products (Fig. 1), which started to be released in 2001 at Japan.



Fig. 1 SBS (right) and used SBS (left)

B. R & D of Biodegradation Disposal

As the next step, we conducted a study regarding a biodegradation treatment technology in an attempt to propose a non-incineration treatment method for the used organic oil sorbent such as sugi bark which has been greatly requested by users.

In addition to the concern about 3 items, (1) harmful substances generated during incineration such as dioxin which has attracted recent attention, (2) the resistance to the emission of carbon dioxide which causes global warming, and (3) the generation of incineration heat, an expectation of the biodegradability is a part of the background when requesting a non-incineration treatment. The biodegradability is a characteristic of SBS, which has been emphasized as a product made of 100% natural material.

In comparison with PP products which have over 90% of the domestic share, the SBS has the following advantages:

- (1) The starting material during manufacturing is a natural waste (in contrast to the fact that PP products are virgin petroleum products).
- (2) It is biodegradable in use so that it is decomposed in a short time and its environmental loads when its recovery fails are low (in contrast to the fact that PP products require a long time to be decomposed).

However, in terms of a treatment method, there are no other choices but an incineration method now. Although the SBS generates less heat than the PP products, it is handled in the same way as the PP products from the aspect that it can be safely incinerated under specified conditions.

Another treatment method besides incineration is the biodegradation. Environmental remediation by the biodegradation (bioremediation) has recently been applied increasingly to contaminated shores due to oil spill accidents, and the conditions and procedures have been discussed actively. The application of a method of spraying a bio formula containing oil decomposing bacteria is questionable when considering the ecosystems around the area. For this reason, the common method is to activate oil-decomposing bacteria which originally live on the polluted shores by fertilization with nitrogen and phosphorus or supplying oxygen by tilling the land surface in order to shorten the time required for decomposition. However, due to the environmental conditions including atmosphere or seawater temperature, it generally requires long time such as several months to years for remediation.

The biodegradation treatment of oil in a closed space is relatively safe since there is only a small effect on the surrounding ecosystems. Since environmental factors such as temperature and water content can be controlled easily to achieve stable results, it has been applied to a variety of applications including grease traps in kitchen drains. On the other hand, a study on the decomposition of waste vegetable oil in the process of fertilization of livestock feces has been conducted at certain research institutions. Additionally, some institutes researched the microbial decomposition of fuel/diesel oil after compost addition to oil-contaminated soil⁽³⁾⁽⁴⁾.

We primarily focused on the fact that a part of the heavy oil such as Bunker C, which can be the subject of recovery at many oil spill accidents, and lignin constituting Sugi bark (approximately 52% in the external bark) have relatively similar chemical structures. We reached a concept of a biodegradation treatment for the used SBS after adsorbing oil, utilizing the process of the biodegradation at the bark compost plants where composts are manufactured by fermentation of Sugi bark. In addition to a drastic reduction in the environmental loads by the application of a non-incineration treatment, the product obtained after the decomposition treatment may serve as compost, with the safety that the treatment is carried out in a closed space. If the process is applicable in practice, we expect the establishment of a superior oil recovery system using SBS.

II. EXPERIMENTS

A. Field Preliminary Experiments

In an attempt to seek the possibility of the present concept, the following simple preliminary experiments were conducted.

1) Experimental Methods

A bark compost material containing active microorganisms in the process of fermentation (one year after combining Sugi bark, cow feces and water content) was piled in an amount of about 5m³ on a concrete foundation and the used SBS as a sample was placed on the top. Subsequently, the bark compost material was piled in an amount of about 3m³ on the top of the sample and the interior of an experimental chamber was determined such that a sufficient temperature environment (60 to 70°C) for fermentation can be maintained. The sample used was a mat-shaped (45cm x 45cm) commercial product (about 200g/sheet) of SBS containing

Sugi bark and perlite in a cotton unwoven fabric. 200 g of Bunker A (light oil), Bunker C (heavy oil) and motor oil were adsorbed respectively (Fig. 2). Another set of the same samples was also set at a location slightly away from the experimental location.

The experiment was conducted at Bungo Yuki Hiryo Inc.

2) Results

After an 8-week period, the bark compost material covering the samples was removed and the samples were examined. In Set 1 as shown in Table 1 and Fig. 3, the amounts of residual oil were reduced to levels that could no longer be detected by the naked eyes in all kinds of oils. On the other hand, in Set 2, the presence of oil was detected in all kinds of oils, indicated a significantly slow progress.

The conditions applied to these two sets were almost the same except that the location of the bark compost material (a small mountain shape) containing the samples was in a



Fig. 2 SBSs after absorbing oil set on the bark compost material



Fig. 3 Samples after an 8-week period (Set 1)

slightly shaded area.

Although it was assumed that a decomposition treatment could proceed at a relatively high speed if all favorable conditions are available, the speed was assumed to slow down significantly if any of the conditions are missing.

Table 1. Results of decomposition of oil sorbent after use in the bark compost material (after an 8-week period)

No.	Types of Oils	Conditions Observed	Detection of Oil Smell
Set 1	Bunker A	No oil detected Raw bark partially remained Perlite remained Cotton was almost degraded	Not detected
	Bunker C	No oil detected Raw bark partially remained Perlite remained Cotton was almost degraded	Not detected
	Motor Oil	No oil detected Raw bark partially remained Perlite remained Cotton was almost degraded	Not detected
Set 2	Bunker A	Oil partially remained Raw bark partially remained Perlite remained Cotton partially remained	Almost not detected
	Bunker C	Oil partially remained Raw bark partially remained Perlite remained Cotton partially remained	Partially detected
	Motor Oil	Oil partially remained Raw bark partially remained Perlite remained Cotton partially remained	Partially detected

B. Experiments in a High-temperature Aerobic Fermentation Apparatus (small)

We assumed that it is desirable to perform an experiment using equipment having a large-sized fermentation tank with a stirring device to disperse sufficient oxygen supply and to be able to control temperature and moisture contents as such that stable data can be obtained. The next experiment was conducted in a commercial high-temperature aerobic fermentation equipment (industrial garbage disposal equipment).

1) Experimental Methods

It is desirable that the high-temperature aerobic fermentation equipment for this experiment has;

- (1) Closed fermentation tank.
- (2) Controlled temperature and humidity for fermentation.
- (3) Sufficient function to stir.
- (4) Sufficient function to ventilate.

We used 4 same machines, garbage disposal equipment (Toshiba GO-S20A, Fig. 4), in which the samples were placed and controlled under the same condition (Table 2). Samples consisted of a bark compost material in the process of fermentation (Bungo Yuki Hiryo Inc., 1 year after the beginning) and Bunker C.

In tank No.1(Fig. 5), oil content was 5000ppm, in tank No.2, oil content was 10000ppm, and in tank No.3, there was no oil as the control. Additionally, we put the same sample as No.1 into 105°C atmosphere for 24 hours in order to kill the microbes, which was called "No.4".

The moisture contents of samples were analyzed once a week and kept at about 50-60% by adding the water (0.7-2kg). Samples were collected from more than 10 locations in each tank using spatula, they were analyzed by gravimetric method using carbon tetrachloride extraction (analyzed by Sumika Analysis Inc.).

As the machines we used did not show the sufficient performance in keeping temperature, the water tank was held outside the equipment. The experiment was executed Nov.11, 2002 to Jan. 6, 2003.

Table 2 Specification of Samples (at the Beginning)

Sam ple	Bunker C (kg)	Compo st (kg)	Total (kg)	Oil Cont. (ppm)	
No.1	0.2	3.8	4.0	50000	
No.2	0.4	3.6	4.0	100000	
No.3	0.0	4.0	4.0	0	
No.4	0.2	3.8	4.0	50000	After 24h at 105°C

2) Result and Discussion

Showing at Fig. 6, there seemed be no significant inclination in the data of oil content in any samples. The reasons were possibly related to:

- (1) The sampling from each tank for analysis of oil content.
- (2) The issues of microbes' activities such as temperature, moisture content, heating method,

ventilation, stirring frequency and the scale of equipment.

- (3) The division among the samples.

In sampling mentioned (1), the spatula may picks up "oil ball" or "compost ball" because viscous oil like bunker C is not easily inclined to be distributed uniformly. It is necessary to check the margin caused by instability of distribution and sampling. Table 2 and Fig. 6 show the difference between theoretical data and real analysis data of oil content at the beginning. It suggests the problem in this sampling method.

The temperature of fermentation tank was about 50°C through the experiment even using the outer hot bath, much lower than 70°C, usual temperature of fermentation in bark composting factory. However it may mean the low activities of microbes, Table 3 shows the more number of microbes than usual garbage disposal equipment. This issue would be concluded after further experiments and discussions. Although there may be a way to keep the tanks' temperature



Fig. 4 High-temperature Aerobic Fermentation Apparatus (small) (Toshiba GO-S20A□



Fig. 5 Compost in the tank (Sample No. 1)

at 70°C using some items, the microbes phase necessarily would not be same as the case in natural rising up in usual fermentation.

Additionally, as this equipment stirs the compost only for 2 minute every 30-90 minutes, which may not be sufficient for bark compost fermentation, the possibility is pointed out that the aerobic microbes in it do not always aerobic activities. The small scale such as 4 kg of the equipment inclines to cause the lack of stability of fermentation, which may not be a good environment for microbial activities.

Table 3 shows that there was almost same number of microbes in No.4 after 8 weeks as other samples, despite of the sterilization (mentioned (3)). All the apparatuses were placed in one atmosphere that may allow the air including microbes to come in through the ventilation.

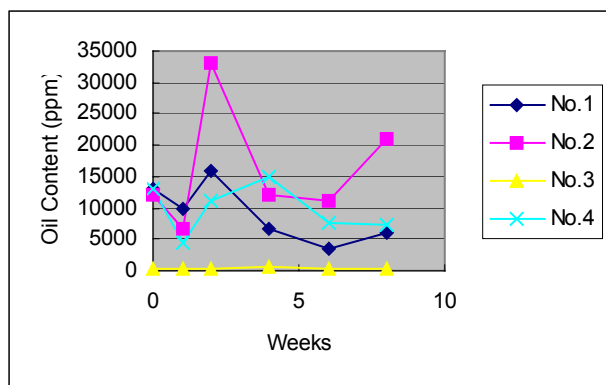


Fig. 6 Changes in the oil content

Table 3 Microbial counts after 8 weeks [cfu/g wet weight]

	Aerobic Thermophiles	Aerobic Mesophiles	E. coli Bacteria
No.1	2.80×10^4	6.40×10^4	1.20×10^4
No.2	4.60×10^4	2.60×10^4	6.40×10^4
No.3	4.40×10^4	3.40×10^4	5.40×10^4
No.4	1.50×10^4	2.00×10^4	7.72×10^4

C. Experiments in a High-temperature Aerobic Fermentation Apparatus (middle)

1) Experimental Methods

The experiment was executed using the high-temperature aerobic fermentation apparatus (middle) satisfying the conditions mentioned “B. 1)”. The apparatus was Eco-up T-25S (Fig. 7), in which 8 sheets of SBS (15cmx15cm) including

bunker C (0.6kg) and the bark compost were placed (Fig. 8). The oil content at the beginning of this experiment was 50000 ppm in whole of the tank. The bark compost and bunker C were the same as the experiment of “B. 1)”.

There were 3 stirring bars, one of the bars has the hole for the air flowing for ventilation, which activate the fermentation. The stirring rate was set at 1 rotation per minute. The experiment was executed Nov.11, 2002 to Jan. 6, 2003.

2) Results

The oil content during the experimental term is showed at Fig. 9. This experiment is in near concept expected as the



Fig. 7 High-temperature aerobic fermentation apparatus (middle) (Eco-up T-25S)



Fig. 8 Compost and SBS with oil in the tank

real SBS disposal, for the target of decomposition is very SBS with bunker C. It means that the oil content in the tank would not be uniform while the shapes of SBS remain. (The theoretical oil content was 50000 ppm.) In this context, the basis of the discussion would be 10000 ppm, oil content after 1 week, and after 2-8 weeks, it was reduced to less than 5000 ppm. The microbial counts in the tank had been kept at high

level through the experimental term (Fig. 10).

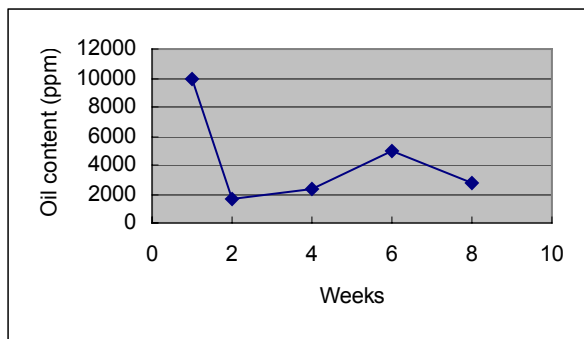


Fig. 9 Changes in the oil content

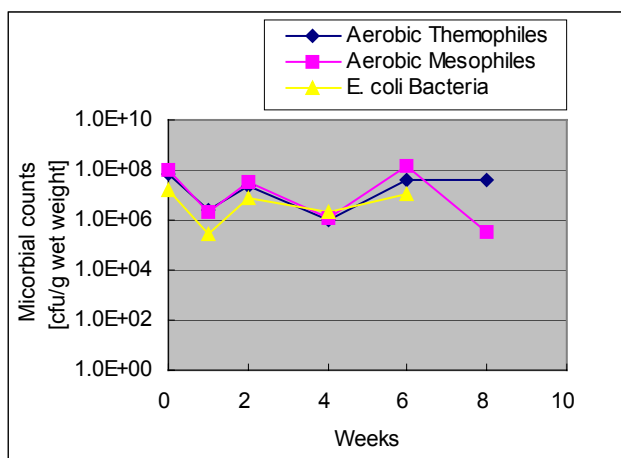


Fig. 10 Changes in the microbial counts

III. CONCLUSION

The following points were clarified in the present study.

- (1) After one to several months, oil was not perceptible from the sample of SBS and absorbed bunker C.
- (2) In experiments in a high-temperature aerobic fermentation apparatus (middle), the oil content of bark compost and bunker C was reduced from 10000 ppm to 2000-5000 ppm after 1 to several week-period.

Additionally, using the compost made from SBS with bunker C, there was not any problem to grow the grasses for a month. To use the compost as fertilizer, we must execute further experiment carefully and confirm its safety in detail.

On the other hand, in experiments in a high-temperature aerobic fermentation apparatus (small), we have not got the significant and stable results of this technology yet. We must discuss and research with the experts of this field including the experimental method.

Although there are still several questions, this technology is expected to be the technology with low environmental load appealing the biodegradability, which is the specification of SBS.

ACKNOWLEDGEMENT

We are deeply grateful for the support by the Nippon Foundation, for the advice by Prof. Hajime Yamaguchi, Tokyo Univ., Prof. Ryuichiro Kondo, Kyushu Univ. and Dr. Takeshi Naganuma, Hiroshima Univ., and for the material supply by Kyushu-Sekiyu Inc.

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