"On Site Bioremediation Of Oily Ballast Waters Of Ships and Tankers"

By

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Abstract

Discharge of oily waste ballast water is a perpetual problem for most types of ships including cruise and dry cargo ships. The problem of disposal of oily ballast waters is no less for oil tankers. Even today many tankers in operation are without segregated ballast tanks.

Treatment of waste oily ballast water is through the use of bioremediation products developed on the basis of our patented biodispersion technology. Studies have shown that mixtures of oils and greases collected as waste in industrial plants have been effectively remediated using our products in a very short span of time. In trials, bilge water was effectively remediated by our products. This indicates that these products are useful for even more complex mixtures generated during operation on board ships.

Ballast water on the other hand contains a single type of oil or hydrocarbons and hence remediation is expected to be faster. Similar studies are in the process of being carried out on an experimental basis on tankers. However, field evaluations on open water spills have documented the suitability of these products even under extremes of conditions. In one instance the TPH content of wastewater was reduced by 20% in a short span of 8 hours.

Of the manifold cost savings to the operators of ships and tankers the two most important are: 1) On site treatment can be carried out during a return voyage and hence there are no disposal requirement and 2) No overheads at the port or transportation and liability costs. Cost of treatment by these products is less than 40 cents per gallon.

Treatment Options

Treatment options proposed here are ***on-site bioremediation*** of oily ballast waters of ships and tankers using patented environment friendly biodispersion technology.

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Ballast water collected by tankers and ships contribute to two major influences on local waters when discharged. One of the most important aspect is oil pollution due to discharge of oily ballast water by non Segregated Ballast Tanks (SBT's). After delivery of the cargo of oil at the terminal, the ship fills up the now empty tanks with seawater to maintain stability and navigability. The oil clinging to the walls of the tanks is collected in this water and may not exceed 0.5% of the total volume of cargo or about 500 tons.

Technology

Oil is insoluble in water and hence consumption of oil by bacteria takes place in the following four stages:

- **Dispersion**: - A physical process by which oil is broken down into smaller globules
- **Solubilization**: - A biochemical process wherein the same dispersed molecules are transformed into assimilable form
- **Assimilation**: - A metabolic process where in the assimilated molecules are transformed into glucose
- **Mineralization**: - Final stage where oil is finally broken down into carbon dioxide and water

An important property of oil eating bacteria that is not generally recognized is their ability to chemically disperse oil by breaking down the oil film. We define this property as **Biodispersion.** Biodispersion, thus is a ***biological*** process that promotes dispersion of oil and forms an important phase of remediation. In order to achieve an effective biodispersion, oil-eating bacteria are grown in a proprietary self-supporting ***oleophilic*** medium. The oleophilic nature of the medium ensures that the bacteria remain in the oil layer and are not lost in the large volumes of oily ballast water. Based on our technology, the oil-eating bacteria first disperse oil before converting the hydrocarbons into carbon dioxide and water after utilization.

Bacteria prefer a warm environment, working best at temperatures above 20° C. However, bioremediation by the biodispersion technology has been recorded even under cold conditions, but the process takes a longer time (Ganti, 2000). Once the oil has been consumed the bacteria die though lack of an available sources of organic carbon.

The consumption of oil by these biodispersion products developed on the basis of the above technology is fast and does not require supplementary addition of nutrients. These products have been designed to provide the following properties:

- Available in a ready to use (RTU) liquid form
- Non-corrosive to metal parts of Oil Water Separators
- Not toxic to aquatic life
- Not harmful to ship's staff
- Does not require addition of supplementary nutrition

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- Effective in a short time
- No residue after remediation of bilge oil
- Requires minimal human intervention
- Does not contain genetically modified bacteria
- Environmentally safe

Aims & Objectives of the project

Biodispersion products have been used for treating a variety of oils both on ships and other land based operations. The current project is being undertaken to meet the following objectives.

1. Fast bioremediation of oily waste water
2. To remediate oily ballast water on the ship itself.
3. Reduce the volume of oily operational discharges by tanker operators
4. Treat oily waste during the return voyage thereby saving costs in port
5. To promote a clean water discharge and waters free from oil pollution
6. Minimum overheads and peace of mind

Test Protocol & Experimental Design

Oily Wastewater At A Port Maintenance Facility

A project was undertaken to remediate oily wastewater in a sump fitted with an oily water separator (Figure 1). The regimen of separating oil is in the use of oil absorbent materials which form the Oily Water Separators. The sump receives large amounts of warm water, charged with detergent, for pressure cleaning different types of vehicles handled by the port. Water is further applied at a pressure of 3000 psi to remove grease and oils from the engines. The facility collects oily wastewater almost 3 to 4 times in a day. Water from the sump was discharged directly into the waste stream after passing through the oily water separator.

There were concerns in spite of the above regimen, that often the values of oil in the discharge exceeded permissible limits set by the town. The port authority was keen in improving the quality of wastewater to meet these requirements by seeking a means to reduce the residual oil content. The oil absorbent material in the oily water separator is changed every three weeks with a down time of two days for the facility. Bioremediation of oily wastewater was considered as one of the options to facilitate to comply with these limits.

Initial water analysis showed that the wastewater contained inorganic salts of metals often toxic to bacteria. Average values for some of these are: cadmium, 0.004 ppm;

chromium, 0.01 ppm; copper, 0.02 ppm; lead, 0.01 ppm; nickel, 0.2 ppm and zinc 0.036 ppm. Hence it was not clear if SpillRemed would work at all. Five (5) gallons of SpillRemed (Fresh Water) was added into the compartment before the water passed through the oily water separator. An addition was made a week prior to the scheduled change of the absorbent material. Initial water sample was drawn from the above compartment and subsequently analyzed for Total Petroleum Hydrocarbons (TPH).

Another sample was collected on the 8th day of the trial from the same compartment and was again analyzed for TPH. The system was then refreshed with new absorbent material. Major concerns of the protocol were as follows:

1. Will the bacteria be able to survive in the presence of toxic metals?
2. Will they be able to consume oil when water is flushed under such high pressures?
3. Will the process of bioremediation be satisfactorily completed in short period?
4. Can SpillRemed be able to clean the absorbent material free of the oils and greases?
5. Can SpillRemed clean the troughs of metal leading to the sump?
6. Will bioremediation be a complimentary process to the physical process of removal of oil?

Results

Results showed that even in the presence of metals of a toxic nature, the bacteria continued their normal activity of dispersing the oil and consuming the same.

SpillRemed is an oleophilic formulation and hence the bacterial population was expected to be concentrated in the oil layer. Even under the high pressures for cleaning of the vehicles, the bacteria remained attached to the oil layer and were not washed in the water. Bacteria breakdown the oil into smaller droplets and each one of these is surrounded by a dense population of bacteria (Figure 2). The oil-eating bacteria consumes this oil and increase their population. However, once the oil is consumed, the bacteria are unable to find any source of food and died a natural death. This is seen in the microphotograph showing the reduction in bacterial population in the water after 8 days (Figure 3).

The TPH values of the water were 286.0 ppm at the start of the trial and when analyzed after 8 days, the value was 25.8 ppm. Thus there was a 90% reduction in the hydrocarbon content due to bioremediation by the bacteria in the biodispersion products. This indicated that the bioremediation of the oily wastewater could be accomplished in a very short time required by the user. This increases its applicability to oily ballast water on tankers and also for bilge water on shore based reception facilities.

A separate experiment was conducted using heavy thick sludge oil as test oil for determining the ability of bacteria in desorbing the oil absorbed on a cotton applicator along with a control without any addition of SpillRemed. Within 48 hours, the sludge oil was found on the surface of the water in tubes containing SpillRemed and there was no

change in the control. The bacterial population seemed to be growing and the cotton base expanded owing to the absorption of water indicating that SpillRemed had the ability of cleaning the oil adhering to the absorbent material used in the oily water separator.

The entire test shows that both bioremediation and the physical process of oily water separators are complimentary and can be used for effective reduction of hydrocarbons in the wastewater entering the town waste water. They can also work independently of oil water separators in oily ballast waters.

Discussion

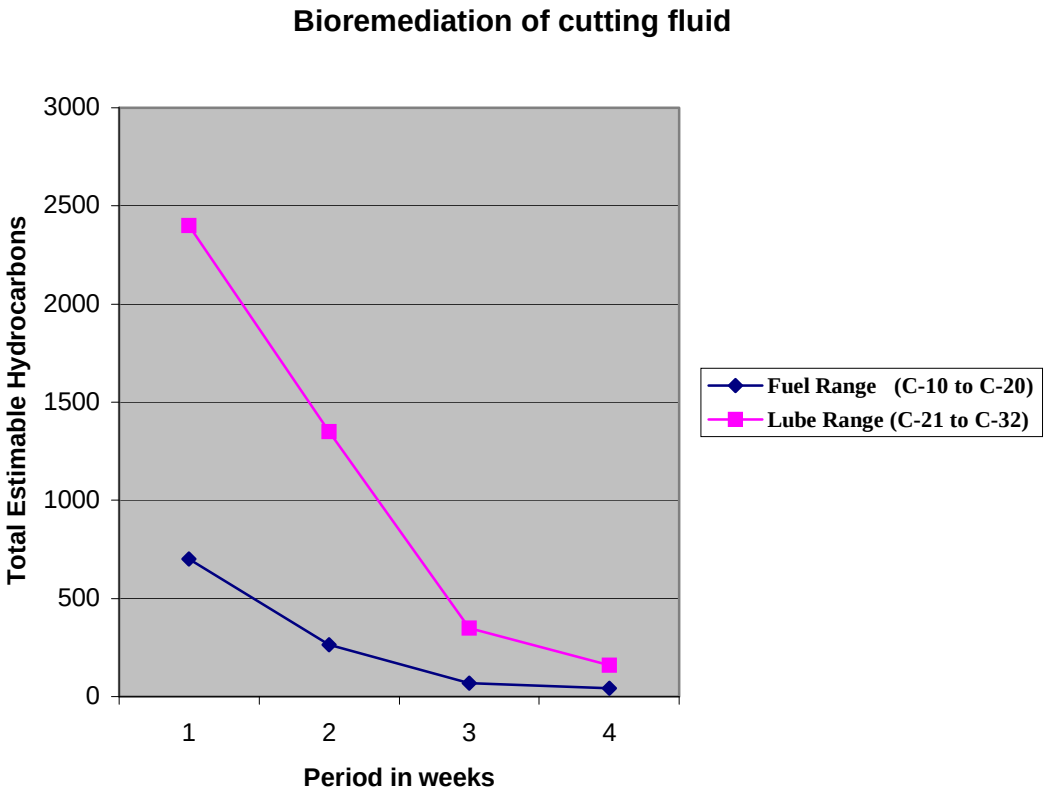
Bioremediation has been defined as a process of stimulating growth and activity of indigenous microorganisms which naturally feed on spilled hydrocarbons which is achieved by addition of fertilizer compounds. The process takes a very long time and hence it is an accepted practice for shoreline clean up after a major oil spill (Bragg et al, 1992). This is the first report demonstrating the utility of bioremediation approach for the remediation of oily wastewater at source. In addition the results indicate that the bioremediation using biodispersion technology occurs in less than 8 days which is a distinctive advance over the earlier bioremediation approaches. The entire project cost less than $200.00 for the product and one hour of operator time for application. This equates an estimated cost savings more than $2000.00, based on the 2 days of lost operation time due to the standard practice of shutting down the facility.

In an earlier studies bioremediation was carried out on waste cutting oil, an emulsion of different fractions of hydrocarbons emulsified using strong detergents. Results indicated that biodispersion products (SpillRemed) are effective against both the fuel oil range and lube oil range of hydrocarbon oils present in cutting fluid.

Table 1. Analysis of values recorded at weekly intervals

Day	Lube oil TEH*	% Reduction	Fuel oil TEH*	% Reduction
0	2500	0	500	0
7	1350	85.18519	265	47
14	350	86	68	86.4
24	160	93.6	43	91.4

* Total Estimable Hydrocarbons.



Results of the chemical analyses show that there was a steady decrease in the values of Total Estimable Hydrocarbons and more than 90% of the values of hydrocarbons in both the ranges were consumed. The results are interesting that an oleophilic bioremediation agent like SpillRemed was selective in utilizing hydrocarbons in emulsion form.

Statistical interpretation of these findings indicates that the underlying mechanism responsible for the rate of reduction of TEH content is strongly correlated with the known exponential doubling rate of the oil-eating bacteria added at the start of the experiment. This is evident from an approximate two-fold decrease per unit time in TEH reduction derived from the slopes of the above data (Ganti & Wille, In press).

Practicability

With regards to issue of practicability, it should be emphasized that the use of biodispersion products in ballast water does not interfere with the day to day operations of the tanker. Further the bioremediation does not leave any residue and hence there is no follow up on recycling of the waste. Dispersion is carried out without the need for harmful and harsh chemicals. There is no learning curve and thus saves on performance time of the ships personnel, no specialized storage requirements and nor any dosing equipment, further there is no loss of time at the port since the treatment can be carried out during the return voyage of the vessel.

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Cost Benefit

Tankers are benefited in a dual manner by employing these biodispersion products. A tanker of approximately 70,000 dwt converts black oil (dirty) to white (clean) oil and produces 'dirty' ballast water in the range of 2000 to 3000 metric tones. Employing physical process of decantation, the volume of slop can be reduced to 500 metric tones depending on the availability of time. In the U.S.A cost for disposal at the current rates is about US $140.00 for every metric ton of the slop. This works out to be US$ 70,000.00 for the ship of the above size.

Cost of On-site use of bioremediation products on the other hand works out to be US$ 90.00 per M/T or US$ 45,000.00 for decanted slop of 500 M/T, a savings of $25,000. In addition to slops, the tankers generate large quantities of oily bilge/sludge. Cost of disposal of the oily bilge is much higher and ranges between US$ 250.00 to $350.00 M/T, which can also be taken care of by the biodispersion products. Figure 3 shows the effect of biodispersion product on release of sludge from absorbent material and in a form that can be more readily bioremediated. Biodispersion products have been designed to consume oils and mixtures of oils generated on ships or elsewhere in the industry. Hence, they can be classified as "Multi use products" for different applications on the ships.

Based on the above available information, advantages of biodispersion products are given below.

1. Treatment is on site itself.
2. Can be carried out during return voyage hence, no port costs.
3. Offers cumulative benefits by constant remediation in between ports and also at the ports.
4. Saving of off-loading time since there is no batch process involved.
5. Of critical importance in bad weather since the tanker will not need to find a nearby port for disposal of oily waste outside the plan.
6. Multi use product and can be employed to meet any contingency.
7. No disposal costs and no insurance overheads.

It is our projection, that the effectiveness of on-site bioremediation demonstrated in the results above will readily carry over to the treatment of oily ballast water. This assumption is encouraged by the earlier results reviewed below. The biodispersion products have been tested for pathogenecity and toxicity to aquatic life by independent laboratories and have been found to be safe in both these aspects.

The results obtained in the above project indicate that oily waste water can be employed for bioremediation of a range of hydrocarbon oils likely be carried by tankers.

Conclusions

The above results of the project fulfilled the major concerns expressed by the user while netting both time and cost. The most important conclusion is that the bacteria remained attached to the oil droplets throughout the course of the treatment, a consequence of a proprietary oleophilic matrix - the core of our technology. Additionally, bioremediation was not hampered by emulsions formed by the prior addition of detergents to the wash water. In summary:

1. Biodispersion products can even be used under dynamic flow conditions.
2. Bacteria are not lost under high pressure cleaning procedures.
3. There is no reduction in the bacterial activity in the presence of metals of a toxic nature.
4. Oil is broken down into smaller droplets indicating biodispersion.
5. Bacteria remain attached to the oil droplets till oil is consumed.
6. Reduction in the bacterial population occurs along with reduction of oil.
7. 90% reduction in TPH value was recorded in 8 days time.
8. Compatible with industrial oil water separators.
9. Bacteria are non-pathogenic and the products have no toxicity to aquatic life
10. Cost effective solution.

Recommendations

The short term project has shown effective use of bioremediation of oily waste water generated in large volumes under pressure. The following proposal is submitted for in-depth evaluation of this technology. Specific research goals are listed below.

1. Trials to be continued for at least one year to determine the reduction in TPH values over a period of time to determine the environmental impact.
2. To pressure spray SpillRemed along with the wash water for examining the influence on the walls of a trough.
3. To examine the possibilities of extending in-between period of change of absorbents in the oil water separator.
4. We are seeking funding in the amount of $300,000.00 for one year to conduct ship board studies on oily ballast water in tankers.

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