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Full Length Research Paper

An advanced treatment on coastal oil pollution

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Coastal oil pollution was hard to clean up because we lacked a powerful method. Currently, bioremediations were directly applied for the treatment of beach oil pollution. Their results, extending over a period of years, the degradations became insignificant and a huge amount of time, manpower and money is wasted because they cannot controlled the changes of weather and tides. In this study, giving up the treatment of beach oil pollution directly, the pollutants were transported to a centralized treatment plant to made degradation. The pollutants present at the fishing port of Zhuwei in Tauyuan, Taiwan, contain diesel or heavy oil over 10,000 ppm. The results of degradations were vastly improved.

Keywords: oil pollution, beach pollution, bioremediation.

INTRODUCTION

Marine accidents occur continuously throughout the oceans of the world. According to the Ministry of Transportation of R.O.C, more than 800 accidents occur around Taiwan coastal waters every year, even though Taiwan's waters consist of a small portion of the world's oceans. Marine accidents always lead to oil pollution, which impair our health, prosperity and livelihoods (Shahidual and Tanaka, 2004). Hence, the whole world is affected by this crisis of marine pollution. Governments must take pains to prevent oil pollution and adopt methods to swiftly and thoroughly remediate such pollution when it does occur. Dagmar Schmidt Etkin et al (2000) showed that the cost of preventing oil pollution is still high, and responses to spills of heavy fuels are more than ten times as expensive as spill responses to lighter crudes and diesel fuels. Most heavy oil pollution incidents were caused by cargo ship or tanker accidents resulting in oil spills, and therefore an efficient method for cleaning up oil pollution that dramatically decreases the costs and eliminates secondary pollution is vitally needed.

Marine accidents occur off the coast and sometimes near coastlines. The accidents occurring near coastlines give rise to some of the most serious pollution crises. The effects vary from coast to coast since there are many types of coastline, such as beach, rock, coral reef, fish culture field, mangroves and so on. However, the majority of coastal oil pollution incidents involve beach pollution or coastal rock pollution, although other types of seashore pollution have occurred as well.

With respect to beach pollution, in the past, the method employed was to spray the polluted beach with high temperature steam in order to melt the layer of oil, but this caused the oil-water mixture to flow out to sea. Since such mixture still contained oil, it simply became a new source of pollution somewhere else. The job of beach remediation has traditionally been given by governments to subcontractors. But those subcontractors simply collected the pollutants and buried them or washed them away. “Sweeping it under the rug” in this manner may have allowed the oil pollution to be hidden from sight, but the threat to human health and the environment still remained because the oil had not been degraded to safe levels..

Since the difficulty on treating coastal oil pollution has been a long-standing problem, it has become a matter of great concern. Experiments in biodegradation indicated that to be a safe and reliable way, gradually making it to prominence as the method currently under research today (Mathieu et al 2013). Vast amounts of literature have been generated with respect to investigation of biodegradation, resulting in application techniques that improved the viability of this approach (Mu Chien Lin, 2011). They studied the physical, chemical process as well as effects upon the environmental surroundings and found that biodegradation efficiency depends not only upon the structure of oil pollutant but also upon environmental factors (Ronald 1981) and (Leahy and Colwell, 1990).

The vast amount of literature devoted to hastening degradation has been reviewed. Gallego et al (2001) attempted degradation of diesel oil by applying fertilizer and found that phosphate or nitrogenous fertilizers are effective to hasten degradation.

In practice, currently, bioremediation is directly applied for the treatment of beach oil pollution (Wilfred et al 2004). Workers enclose the polluted beach to isolate the area and scatter microbes onto the polluted surface. They then apply fertilizer, spray on water and fork the soil, positioned there all day no matter how windy, rainy, cold or hot. Although this may be adequate for small-scale remediation, heavy oil pollution is normally on quite a large-scale when spilled form a ship or oil tanker. On-site bioremediation cannot result in complete oil degradation due to delays and complicated external reasons, such as low temperatures, which hampers microbe metabolism; rain, which dilutes the microbes; wind, which destroys the fences; tides, which washes off the microbes; and salt, which hinders microbial life. Occasionally, even humans treading on the site or animal excrement change the composition of the soil. Although large numbers of workers are employed, they are reluctant to spade the beach under strong sun, or when it's a raining or when it's a cold day. Thus, extending over a period of years (Chaerun, S. Khodijah, et al. 2004), the degradation becomes unsuccessful and a huge amount of time, manpower and money is wasted.

Recently, much research has given further consideration in this field. Mohammad Ali Zahed et al focused their attention on the study of dispersants (Mohammad et al 2010). Theoretically, dispersants are a kind of surface-active agent that contains both hydrophobic groups (their tails) and hydrophilic groups (their heads). That is, a surfactant contains both an oil soluble component and a water soluble component, which will diffuse in water and at interfaces between oil and water. In experiments, as the area of contact between oil and water expands, the rate of degradation accelerates. However, in a real-life marine pollution environment, it is unknown whether the microbes stay around the dispersants or not due to the vast expanse of ocean. In reality, combinations of oil and dispersant flow with the tides, ride the waves, sink down into the sea, get ingested by fish and enter the food chain, and kill corals or poison farming areas. The result is dire consequences. Accordingly, in the interests of environment protection, it is suggested that the use of dispersants should be avoided whenever possible.

Mu-Chien Lin et al (2014) developed a highly inefficient theorem of centralized treatment plant to treat marine pollution. Such a centralized system can also be used to treat beach or rocky pollutions (Mu-Chien Lin and Jui-Chung Kao 2014). The idea of a centralized treatment facility eliminates external variables, especially weather and tildes, and optimizes the coastal oil pollution treatment method presented in the following terms.

Treatment by centralized treatment plant

The quick treatment method

Governments have simply left environmental remediation up to corporations to manage the problems of oil pollution. Such corporations, signed up with government, sent excavators to the polluted site to scrape the pollution oil layer off and transport it to their plant. Nevertheless, most of these corporations were not well set up to deal with the practical exigencies of achieving degradation to within safe levels. Being not able to degrade the pollutant completely, they opted to simply burry the polluted scrapings in order to cut costs. Unfortunately, this caused secondary pollution to the environment. In the final analysis, this faulty policy and ineffectual method led to a detrimental result. Recently, the biodegradation directly applied for the treatment of beach oil pollution was not insignificant enough. Therefore, it seems feasible that a perfect biodegradation can remedy this flaw.

To remedy of these flaws, a simple and quick process can now be employed. The authors combined the ideas of scraping the polluted oil layer with off-site biodegradation and developed a method for a centralized treatment plant. The plan can intensively degrade the oily pollutant to safely levels relatively quickly. The process as below:

1) Send excavators to polluted beach to scrape polluted oil layer off.
2) Transport oily pollutant to a centralized treatment plant.
3) Wash out oil pollutant.
4) Degrade oily water.

The advantages of centralized treatment plant

Although the idea of present scheme of centralized treatment plant is simple, it has many advantages: (1) Elimination of adverse environmental factors from the remediation process, such as the cold, rain, waves, tides and human foibles. (2) Dramatic cost reduction. The cost of employees, transportation, material and utilities can be reduced because the working site is confined within the plant. (3) Managerial control. In a plant environment, workers efforts are focused upon the tasks at hand, thus saving them from wasted trips to and from beach. (4) Rapid beach recovery. (5) Sharply reduced time for achieving degradation to safe levels. (6) Elimination of secondary pollution.

Irrespective of whether the organization that does the remediation and pollutant degradation is private or publicly owned, the polluted beach would be restored to original appearance in a few days if the centralized treatment plant system was adopted to treat beach oil pollution.

METHODS

Equipment

The equipment and consumables includes steel ponds, microbial agent, air feeder, water feeder, thermometer, dry oven, autoclaves sterilizers, cross-beam agitator, double-Shot Py-GC system, microbalance, magnetic stirrer, clean bench, pure water, inorganic nitrogen and phosphorus.

Method

First, the four cases of oily sand were dumped into four separate steel ponds (Case A of diesel oily water was dumped into the pond A and so on, respectively). The pond A and B contained diesel-water in which microbes were not added into pond A as control set. Conversely, microbes were added into B as an experimental set. Similarly, the pond C and D contained heavy oily water in which microbes were not added into pond C as a control set, whereas microbes were added into pond D as an experimental set. All equipment was sterilized and baked. Two bottles of 500 g microbial agent with inorganic nitrogen and phosphorus were put into a cross-beam agitator, agitated for 24 hours, and then were poured into the pond B and D.

The actions for making microbial bottles were done weekly during the first month of the experiment. Subsequently, the actions of making bottles were done once monthly repeatedly until all oil was fully degraded. During the degradation process, temperature was controlled at or near 30℃.

At low temperatures, the viscosity of oil increases, the volatilization of toxic short-chain alkanes is reduced, and their water solubility is increased, delaying the onset of biodegradation. Rates of degradation are generally observed to decrease with decreasing temperature; this is believed to be a result primarily of decreased rates of enzymatic activity (Haritash, A. K., and C. P. Kaushik, 2009). Higher temperatures increase the rates of hydrocarbon metabolism to the maximum. But in an overheated environment, the cell membrane of microbes soon breaks down, decreasing the rate of degradation. This shows that temperature can dramatically influence the rate of degradation. Furthermore, air should be fed to the microbes adequate to carry out their metabolism.

RESULTS

The results of degradation are shown as the Figures 1 and 2. Figure 1 denotes the degradation of diesel. Similarly, Figure 2 denotes the degradation of heavy oil. The horizontal axis denotes time of degradation (days), and the vertical axis denotes diesel residuals. From Figure 1, the initial concentrations of diesel were both 10,000 ppm in sets A and B. The diesel in set B had

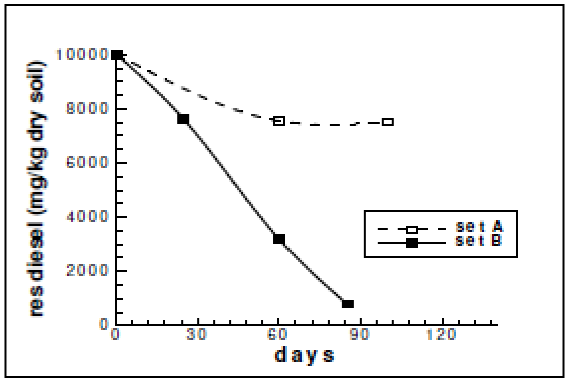

Fig 1. Diesel degradation diagram. When it is below 1000ppm, it can be considered complete.

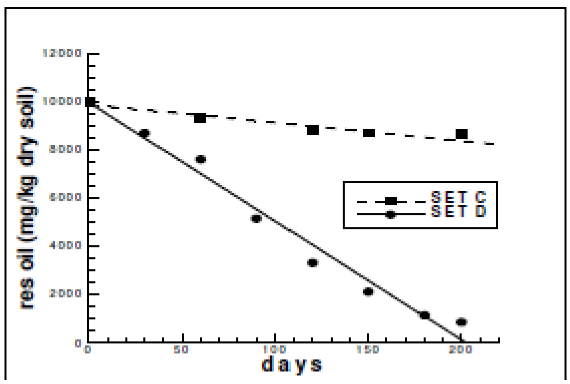

Fig 2. Heavy oil degradation diagram. Heavy oil residuals below 1000 ppm can be considered complete.

added microbes and degraded to less than 1,000 ppm, the value considered to be unpolluted according to Environment Protection Administration standards. Conversely, set A had no microbes added, being a control set. The behavior in set A shows that the original microorganisms had little ability to affect degradation. Although it occurred at the initial stage, this ability gradually vanished after 60 days. These figures specify that where no additional microbe is supplied, the initial microorganisms applied to beach sand had little ability to affect degradation.

The results of degradation of heavy oil are also shown in the Figure 2 with 10,000 ppm in initial concentrations. The curve of set D, similar to the degradation of diesel degraded to less than 1,000 ppm, demonstrates a strong decay. The degradation trend is quite stable. Additionally, the degradation of heavy oil by the initial microorganisms shown in set C of Figure 2 was more difficult than the degradation of diesel shown in set A of Figure 1, in which the initial microorganisms (shown in set C) did not degrade heavy oil at all. In other words, we cannot rely on only burying of pollutant or nature remediation, an insignificant degradation is essential when an oil pollution accident occurs. Obviously the

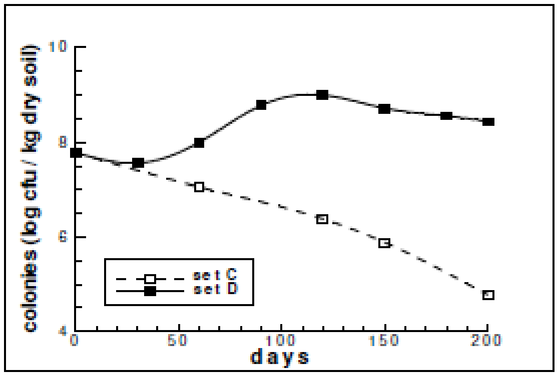

Fig 3. The bacterial colonies diagram (heavy oil).

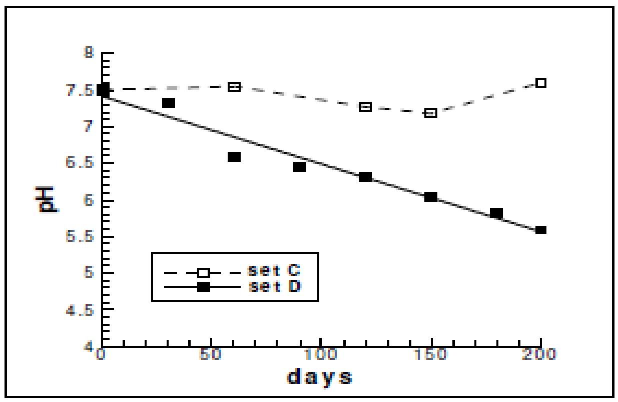

Fig 4. The pH values during the experiment process

results of degradation by method of centralized treatment plant are powerful than those the bioremediations directly applied for the treatment of beach oil pollution which extend over a period of years (Chaerun, S. Khodijah, et al. 2004).

The Figure 3 denotes the bacterial colonies diagram. The vertical axis denotes logarithm value of bacterial colonies per unit weight in set C and D. In the process of degradation, the bacterial colonies in set C decreased rapidly from 10^8 to 10^5. This indicates a conclusion beyond question: that the degrading ability decays rapidly due to reduced bacterial colonies in the control set. Conversely, the bacterial colonies in set D always maintained a level at 10^9 to carry out degradation.

The pH of the heavy oil set (set D, Figure 4) still decayed during the whole process of degradation. It represents that microbes undergoing a process of metabolism heavily convert to acidic materials, whereas pH did not vary in pond C due to stagnation in degradation.

DISCUSSIONS

In order to make the degradation smooth, the operators should sterilize all the equipment and operate on a clean bench to eliminate any adverse factors during degradation. An interesting question was: in what should the oily-sand be taken from polluted beach (Zhuwei) to advance degradation? It seems like it would be easy to mix clean-sand with diesel oil or heavy oil and dumped them into the ponds, doesn't it? Although the procedural steps were quite roundabout, there were different consequences between polluted sand and mixed sand. (1) The mixed oil, dumped into the ponds, was real oil in a laboratory, not the polluting oil found at the coast. The degradation results would be questionable. (2) The polluted sand, the water contained in the oil-sand mixture was sea water (not freshwater), which includes microorganisms, salts, minerals and so on. Accordingly, the work flow designed into these experiments was as close to real coastal pollution conditions as possible.

Beside, for the sake of removing obstacles in weather, sea conditions, animal or human disturbance, it was necessary to scrape polluted sand and take such sand to open ponds in a factory to degrade. The work field was changed from open coast to a plant so that the work flow was both easy to control and to decrease costs, especially in manpower, consumables, and management control. Most importantly, this work flow rapidly recovered the polluted coast in a few short days. Having the advantages of reducing cost, manpower and time, such scheme will not cause secondary pollution.

The control sets, shown in Figures 1 and 2, in which microbes were never added, degradation basically relied upon indigenous microorganisms, and thus obtained poor results. In other words, the polluted coast cannot be degraded naturally without any support. Thus, scraping polluted sand up and burying it somewhere is nonsense, at best, just like the cat shuts its eyes when stealing cream.

CONCLUSIONS

Bioremediation is a popular approach to cleaning up coastal pollution because it is simple to maintain, cost-effective, applicable over large areas and leads to the complete destruction of the contaminant. The design of work flow is quite important. One may transport the contaminant from polluted coast, an open region, to a plant where all factors are easy to control. In this manner, the adverse factors and the other problems such as secondary pollution may all be eliminated, enabling a smooth biodegradation to occur.

The necessary materials for biodegradation, for example, fertilizers, are added. Keeping the ponds at constant temperature maintains biodegradation at higher efficiencies. Oxygen and fresh water recirculation are also important for microorganism metabolism. It is recommended that each batch of microbes should be added one at a time into the decontamination ponds, so as to maintain bacteria count.

The method of centralized treatment plant is a significant method which can be widely applied in treatment of coastal oil pollution. Whether governments establish cooperation with environmental remediation corporations, or a pollutant treatment group, both have advantages and disadvantages. Nonetheless, if supervision of environmental remediation corporations or management of a pollution treatment group is well done, our environment will be protected and the beauty of our coast maintained.

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