Journal of Coastal Zone Management

Lin, J Coast Zone Manag 2016, 19:2
DOI: 10.4172/2473-3350.1000424

Research Article Open Access

A New Method for Rapid Treatment and Management of Coastal Oil Pollution

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Received date: March 17, 2016; **Accepted date**: April 01, 2016; **Published date**: April 08, 2016

Abstract

Coastal oil pollution was hard to clean up because we used biodegradation directly on beach, but lacked a significant method. This study investigates a centralized plant method on treating oil pollution associated with heavy oil by a treatment plant. Giving up the treatment of beach oil pollution directly, the pollutants, which were from the marine accidents occurring in Penghu or Taitung County, Taiwan, were transported to a centralized treatment plant to wash out and made photo degradation. Such treatments were finished in 4 days, which were more powerful than years that made biodegradation directly on beach. This technology will sufficiently find application in prevention of marine pollution with many advantages without secondary pollution, and can generally applied to the prevention of oil pollution on rocky coast and beach coast.

Governments take necessary steps to treat oil pollution by the present method will probably shorten the coastal remediation period and minimize losses.

Keywords: Coastal oil pollution; Centralized plant; Marine environmental Protection

Introduction

Marine accidents occur continuously throughout the oceans of the world. According to the Taiwan Ministry of Transportation, 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 [1]. 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. Etkin et al. [2] 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 may be beach pollution or coastal rock pollution, although other types of seashore pollution have occurred as well.

With respect to beach pollution, 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.

Oil pollution on rocky coastlines, moreover, is also a series problem. This is illustrated by in the accident that occurred off Taiwan's coast involving the Greek cargo vessel M/V AMORGOS, which ran aground off the coast of southern Taiwan and caused extremely serious marine pollution. Putting aside the direct economic loss, the Taiwan government used more than 35 thousand workers and much material, but the methods employed did not yield good results. The oil stains on the coastal rock was very difficult to clean up and took a long time. Essentially, no one could conceive of an efficient method to solve beach and rocky coast pollution problems concurrently.

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 cheap, safe and reliable way, gradually making it to prominence as the method currently under research today [3]. Vast amounts of literature have been generated with respect to investigation of biodegradation, resulting in application techniques that improved the viability of this approach [4]. 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 [5,6].

Recently, much research has given further consideration in this field. Zahed et al. [7] focused their attention on the study of dispersants. 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.

The vast amount of literature devoted to hastening degradation has been reviewed. Gallego et al. [8] attempted degradation of diesel oil by applying fertilizer and found that phosphate or nitrogenous fertilizers are effective to hasten degradation. They focused on the degradation of diesel or petroleum hydrocarbon whereas little research focused on the degradation of heavy oil.

Wu et al. [9] developed a method utilizing a system of ponds to treat palm oil mill effluent. Such a centralized system can also be used to treat coastal oil pollution. Unquestionably, a vast area of polluted beach is beyond our control with respect to weather, tides, and destruction by mankind. The idea of a centralized treatment facility eliminates these variables, and optimizes the coastal oil pollution treatment method presented in this paper.

More recently, an application of the nanometer photocatalyst method on decomposition of benzene has been successfully used in the treatment of coastal oil pollution. Lin [10] studied and found that using this method could completely decompose the benzene or gasoline within hours [11]. This initial success found a new path in the treatment of oil pollution [12,13].

The present study is the first attempt to investigate the treatment of coastal oil pollution in a centralized facility. Since the method of bioremediation or nanometer photocatalyst used in this study is thoroughly explored elsewhere, it does not fall within the scoped of the present article.

Physical model

Putting aside river shores, seashores are largely divided into beach, rock coast, soil coast, aqua-culture zone, coral reef, or marine leisure areas and so on. Most often, the coastline is mainly beach or rock coast as mentioned in the last section. No matter what kind of coast, however, the polluting oil should be enclosed by an oil boom as soon as possible to prevent the oil from diffusing into the sea. The only disadvantage is that marine oil pollution enclosed by oil boom in the past has gotten out of control due partly to the accident occurring in an adverse climate [14], partly to mutual shirking of responsibility between governments, and partly to delays in negotiations between the government and the culpable shipping company. Therefore, these factors must be mitigated as much as possible. Otherwise, oil pollution will continue to be exacerbated by natural processes or human errors in judgment that will transform otherwise trivial matters into a catastrophe again and again.

Effects of beach oil pollution on ecology

Beaches can be separated into two principal types: those which are formed by erosion or by deposition. The erosion beach, forming a steep beach coast beaten by surf, is composed of large particles that develop a simple ecosystem in which water does not accumulate. The tides are precluded from extending to a large area. For this reason, little serious oil pollution occurs here. Conversely, a deposited beach consists of vast smooth, fine sand on a flat plane so that water percolates into subsoil year after year, and therefore attracts many species (crabs, gulls, microbes, etc.) that symbiotically organize into mini-ecosystems. When oil pollution occurs, layers of oil cover the beach surface, completely cutting off air, water and sunlight. Crabs, gulls and microbes bath together in oil. The chain of symbiosis is cut. The miserable scene, no matter whether macro or micro, is quite hellish. The beach cannot recover unless the oil pollution is completely cleaned up [15].

Failures in treatment on beach oil pollution

As mentioned above, the treatment of beach oil pollution by steam is not acceptable. Apparently, a beach cleared of oil by steam leads to microorganisms being entirely destroyed, making it harder to regenerate than if steam was never used. Additionally, the mixture swept away from the coast becomes a new source of pollution. And the oil that remains never vanishes.

Recently, governments sent excavators to scrape the pollution oil layer off and burry it. But in any event, both the use of steam or excavator scrapping produces the same result. The polluting oil is never degraded.

Currently, bioremediation is directly applied for the treatment of beach oil pollution [16]. 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, the degradation becomes unsuccessful and a huge amount of time, manpower and money is wasted.

Pollution of coastal rock

To investigate oil adhesion on rock, Lin [14] made a simple study with three stones. The author immersed the first one (stone A) in water, then picked it up and dropped oil on it. When this stone was put into water again, the oil drop appeared to tenuously adhere to the stone because of the incompatibility between oil and water. The oil drop on stone A was removed easily at low water pressure. It shows that oil cannot adhere onto wet stone.

The second stone (stone B) was dried, given a drop of oil and immersed in flowing water. The oil drop on stone B could not be washed away unless high water pressure was used. The viscous force acting on stone B is attributable to the magnetic force in the four basic universal forces. The magnetic force between stone surface and oil is larger than between stone surface and water. In order to destroy the

larger magnetic force between stone and water by using the smaller magnetic force with water, one must entirely rely on an extra force of impact upon it. The oil drop cannot be removed except through applying a stronger impact. Therefore it is difficult to wash out polluted rocks naturally by the action of sea water.

Furthermore, the third (stone C) was a wet stone, like stone A, which also got a drop of oil, but was exposed under the sun long enough to dry. Stone C grew black because the oil drop remained on the stone's surface while the water evaporated, making it similar to stone B in that water could not wash away the oil drop.

In light of this, we know that oil floats on the sea when oil pollution occurs on coastal rock. The flood and ebb tides alternately work to carry oil over the rocks with the rising tide where it immediately catches onto the rocks' surface at low tide. If the pollutant is cleaned up early enough when the tide is going out, the clean-up would be easier. Conversely, it is difficult to clean up once, due to human delay, the rocks have dried under the sun.

The initial treatment of coastal rock is by manual application of absorbent sheets to clean the thicker layer of oil residue. Even after such cleaning, however, oil remains in polluted coastal rock, producing an unnatural black or brown coloration difficult to remove, which is left for natural degradation to recover over many years.

Material and Methods

The centralized plant 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. It seems feasible that a perfect biodegradation can remedy this flaw.

Recently, some researchers studied the biodegradation of petroleum on beach. But the quality of degradation was not adequate because bad weather or other factors common at polluted sites was hard to control, as mentioned above. Moreover, extreme conditions such as typhoon, hurricane or cold temperatures can make such remediation last for years.

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 plant, set up with a multistage washing line, degradation ponds, filtering mechanisms, a furnace and degradation system, can intensively degrade the oily pollutant to safely levels relatively quickly. The process as below:

- Send excavators to the polluted beach to scrape the polluted oil layer off.
- Transport the oily pollutant to a centralized treatment plant.
- With the oily sand removed, make good and reinstate the now unpolluted beach immediately.
- Wash out the oily pollutant by multistage line, and then carry back the cleaned sand to the beach.
- Filter the oily waste water by multiple layers of oil absorbent sheets.
- Dry the oil absorbent sheets and incinerate them.
- Degrade the residual oil.

The system for a centralized treatment plant is shown as Figure 1.

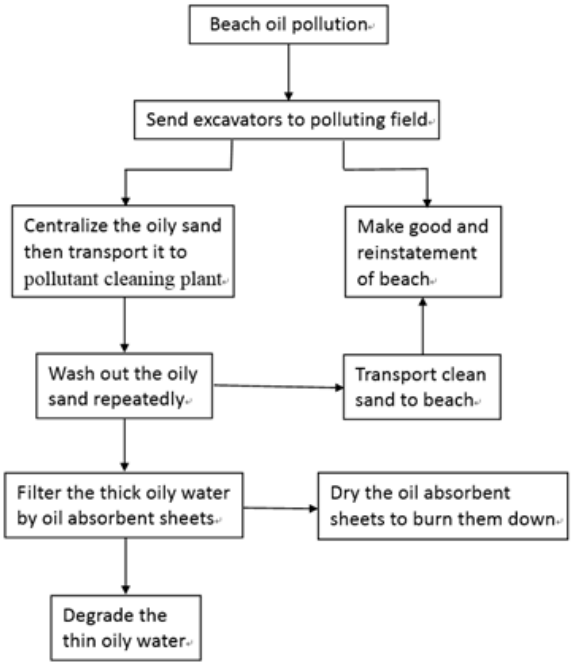

Figure 1: The flow chart of treatment Plant of beach oil pollution.

Most of oil will be separated from pollutants from step (1) to (6), therefore, entirely the residual oil can be degraded in step (7), no matter by biodegradation or photo degradation [11]. Marine accidents usually lead to hundreds of tons of oil spills. The Coast Guard should save pollution immediately by oil booms, oil absorbent sheets, skimmers or other equipment. If an oil spills coincide with high tide, most of oil will be removed by Coast Guard and the residual spreading oil is stranded on the beach when the tide ebbs. Although this pollution is not serious, it may cause a large area of pollution. Under the circumstances, the presented method can be used for remediation *in situ*.

Method

In 2014, two marine accidents occurred in Penghu and Taitung (Taiwan) causing diesel oil pollution on beach. The pollutants were taken to a centralized plant for each 10 kg. Washing out the oily pollutant twice, the sand was fully washed out, and analyzed in Double-Shot Py-GC system in order to make sure the sand was clean or not. So return the clean sand to beach. The washed oily water was filtered by multiple layers of oil absorbent sheets. Then dry the oil absorbent sheets and incinerate them. By this way most the oil was successfully separate out from pollutants. Finally the tiny oil floating on water was photo degraded by TiO2 nanometer photo catalysis [11].

The photo degradation system used a light with ultraviolet wavelength of 360 nm, which illuminate the photocatalyst to produce peroxide ions. Residual diesel oil was completely decomposed and became CO2 and H2O.

Results

The pollutants, presented at the beaches in Taitung (sample 1) and Penghu (sample 2), originally containing diesel oil at 56,000 ppm and 100,000 respectively. Undergo a process of washing out and photo degradation [11]. The residual concentration was only at 56 ppm and 600 ppm respectively. Table 1 shows the results of present method.

The washing time was 1 day, whereas the photo degradation time was 4 hours. The entire treatment period was not more than 4 days. From Table 1, it shows that the present method is more powerful than years that made biodegradation directly on beach [17,18].

Sample	Original Concentration (ppm)	Final Concentration (ppm)	Removed oil (%)
1	56,000	56	99.9
2	100,000	600	99.4

Table 1: The results of treatment.

Discussion

The advantages of centralized treatment plant

The present scheme of centralized treatment plant has many advantages:

- Elimination of adverse environmental factors from the remediation process, such as the cold, waves, tides and human foibles. Because the oily pollutant has been transported to a centralized treatment plant where all conditions, such as temperature, pressure, humidity, fertilizer, water or air supply can be controlled, degradation becomes quite simple.
- Dramatic cost reduction, the cost of employees, transportation, material and utilities can be reduced because the working site is confined within the plant. Workers need not haul equipment and material to the beach, exempting it from corrosion, destruction and burglary.
- 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. Treatment efficiency is greatly enhanced because progress and information are all controlled in the plant, minimizing the likelihood of mistakes.
- Rapid beach recovery, currently, the site for applications of the traditional method of degradation is the polluted site itself. The beach is closed and the oil stays there for years until (unacceptable) degradation is finished. However, where a beach is polluted by oil, the thickness of the oil layer is general not greater than 20 or 30 cm. Excavators could easily scrape the oil layer off beach. In this manner, the beach landscape is immediately restored and returned to local tourism and the marine fish culture industry can resume their actions as soon as possible. Therefore, the treatment of oil pollution through utilization of a centralized treatment plant is far better for trade than the traditional on-site degradation method.
- Sharply reduced time for achieving degradation to safe levels. It's important to emphasize that the period of degradation in a plant is considerably shorter than the period of degradation at a beach. The period of degradation at a beach takes years because of the impediments caused by weather, temperature or the human foibles that caused or extend the deterioration. Workers are often repulsed by the work of having to clear away the rubbish or animal bodies left by the retreating tide, the excreta of birds and dogs, and by having to keep the environment clean during the degradation period. Where degradation is done in a centralized plant, however, operating efficiency will be high because all these factors are removed and degradation is insulated from external disturbances. All the factors such as temperature, pressure, fertilizer, water or air supply can be controlled in the plant.
- Elimination of secondary pollution, almost certainly, there is no secondary pollution because the oil is degraded to safe levels and is not buried or rushed into the ocean to cause a pollution problem elsewhere.
- This presented method also can be applied for large area 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.

The quick treatment for rocky coast oil pollution

As for coastal rock pollution, the common treatment was to recover the oil floating on the water. But helplessly, governments always took a passive attitude toward confronting the dried oil stains, or oil that lay in the crevices of the rocks. Some strong governments sent workers on mission rubbing the oily rocks, but at a snail's pace. Moreover, they washed out the oily debris into the sea, which caused the oil to return to the coast as a new source of pollution. It was all nonsense.

On the face of it, the characteristics of coastal rock pollution and beach pollution are quite different. Governments suggested spraying dispersant onto the polluted rocks to clean them up. It seemed that the oil stains on the rocks were disappearing but part of the oil-water mixture simply drifted to sea as fish food to enter the food chain. Part of the mixture sunk down into the sea as a pollution source. Nonetheless, in practice the treatment of beach pollution can be extended to coastal rock pollution. In other words, by utilization of a centralized treatment plant we can treat coastal rock pollution the same way as we treat beach pollution. The treatment is as follows.

First, people recover the floating oil on the water where coastal rock pollution has occurred. Second, clean the heavy oil from the rocks by oil absorbent sheets. Third, brush away the dry oil stain standing on the underside of a rock by electric brush. Finally, gather the oily dust and transport it to centralized treatment plant to be degraded just like the oily sand mentioned above. In this manner, the reinstatement work of a rock coast could be completed much faster.

In short, the treatment of beach and rocky coast oil pollution can be united by the method of a centralized treatment plant.

Choice of Schemes

There are two available schemes to be chosen by governments for treating coastal oil pollution:

- Governments could establish cooperation with environmental remediation companies. The advantage of such a policy is that it is easy to manage by governments. The disadvantage is the difficulty of close supervision. Environmental remediation companies only show governmental supervisors photos as evidence of environmental recovery, but pollutants are still always buried to decrease costs, causing secondary pollution. Governments must face the challenges with respect to adequate supervision.
- A large country could establish an environmental organization and pollutant cleaning plants. The organization, consisting of professional and full time members, is responsible for treating all serious polluting accidents in the country. For a small contrary, governments could establish pollutant cleaning plants as well as a pollution treatment group. The members of the group, forming a part time committee in the nature of a task force, should have regular training in pollution treatment to raise their skills, and be called up for emergency remediation whenever oil pollution occurs. They should be immediately dispatched to polluted sites and convey pollutants to a plant to affect biodegradation. The benefits of this management method are low cost, less manpower required, higher efficiency, shorter recovery and minimal secondary pollution. The drawbacks are the complexity of management and difficulty in maintaining the plant.

Conclusion

Coastal oil pollution is a major issue in marine ecology and economy. The most important aspect of the environmental remediation is the workflow design. The importance of the design presented in this paper is that oily pollutants from an open site can be transported to a centralized treatment plant where all factors are easy to control. The present scheme of a centralized treatment plant has many advantages:

- Elimination of adverse conditions, degradation is made quite simple and stable.
- Dramatic cost reduction with respect to employees, transportation, material and utilities.
- Managerial control, the workers focus their attention on the tasks at hand within the plant, minimizing the likelihood of mistakes.
- Rapid beach recovery.
- Sharply reduced time for achieving degradation to safe levels.
- Elimination of secondary pollution.

The procedure for treating beach oil pollution is described as follows. First, wash out the pollutant at a centralized treatment plant. Second, return beach sand to the beach. Third, filter the oily waste water by multilayer oil absorbent sheets. Forth, incinerate the sheets. Finally, degrade the residual oil in the waste water.

The procedure for treating coastal rock oil pollution is similar to treating beach sand pollution.

The ideas for governments to establish cooperation with environmental remediation companies or establish an environmental remediation organization have both advantages and disadvantages. If governments would actually put these supervisory and managerial recommendations into practice, the coast will be kept clean and beautiful.

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