The Use of Bioremediation Technology on Oil-Contaminated Soil

Putri Alvernia¹, Suyud Utomo², Tri Edhi Budhi Soesilo³, Herdis Herdiansyah*⁴
¹School of Environmental Science, Universitas Indonesia, Jl. Salemba Raya No. 4, Central Jakarta, 10430, Indonesia.
putri.alvernia@ui.ac.id, suyud.warno@gmail.com, soesilo@indo.net.id,
* herdis@ui.ac.id

Abstract. The demand of oil not only has contributed the economy and foreign exchange of a country, it has also caused environmental pollution. The negative impact caused by the oil spills were due to the hydrocarbon compound or Total Petroleum Hydrocarbon (TPH) contaminates the environment. Oil contamination, despite of low concentration of hydrocarbon, affects the smell and taste of the groundwater. One of the alternatives to overcome environmental contamination from oil that is environmental-friendly is with bioremediation technology. The rehabilitation efforts of the oil-contaminated environment biologically with the bioremediation technology has an advantage as it is more environmental-friendly and the operational cost is more affordable than physics and chemical recovery techniques. This research utilizes study of literature and SWOT analysis to comprehend the strengths, weaknesses, opportunities, and threats of the use bioremediation. The outcome of analysis illustrated that bioremediation could reduce the TPH value as the bacteria could decompose the oil where it generally is difficult to be degraded. However, there is also potential use of microorganism utilized on bioremediation to mutate thus creating a new and unknown product that could harm the environment. The implementation of bioremediation technology examined by sustainable indicators still have weaknesses and threats that could be further examined so that the use of bioremediation could be implemented as one of the ways to have a sustainable oil spill cleanup.

1. Introduction
The demand for oil as a source of energy keeps increasing which causes the growth and expansion, explorations, and refining activities of crude oil. However, in addition to the contribution to the economy and foreign exchange, it also harms the environment. Environmental pollution due to oil spills continues to occur as Indonesia is an oil-generating country with a relatively significant amount along with the high oil waste. Oil contamination despite of the very low hydrocarbon still affects the smell and taste of groundwater [1]. The oil spill could reduce the soil stability and soil function degradation may occur, causing critical lands. Oil spills also has a negative effect on the marine ecosystem as well as the human activities [2]. The impacts caused are disrupting the habitat of the marine creatures, hindering the ability of the organisms to find food, reproduce and avoid predators.

The negative impacts caused by the oil spills are due to the hydrocarbon compound or Total Petroleum Hydrocarbon (TPH) that harms the environment. The level of oil contamination could be identified by measuring the TPH concentration in the soil and water. The oil spill is always on the
surface of the freshwater or sea water as a result of the difference of the density of the liquid substance type. Oil spills will be brought to the beach zone and could contaminate the surrounding waters. The characteristics of the coastal land that is suitable with the features are the sandy soil could not become a good absorbent to absorb the oil. The sand fraction has a relatively small surface area and a very big percentage of soil pores so the oil could be brought by the sea water easily intruded to the beach thus contaminating the land. According to [3], the remediation effort is required to be performed on the upper surface of the soil to further avoid crude oil percolation into the soil. Based on such study, a human intervention along with technology are necessary to overcome such contamination.

One of the alternative ways to overcome the environmental contamination caused by crude oil that is environmental-friendly through bioremediation technology [4]. Generally, bioremediation technology utilizes microorganism such as yeasts, fungi, and bacteria as an agent of bioremediatory. Biologically, remediation is consideration as the most environmental-friendly and sustainable way as it does not generate secondary pollution problems as a result of the transport of contaminant and chemical reagents used [5]. The absorption of crude oil utilizes sorbent mineral to absorb oil must meet several requirements such as hydrophilic, (compatible with water), oleophilic (compatible with oil), high level of absorption, and could release the absorbed oil. This method requires relatively inexpensive costs as the material could be easily found especially in Indonesia [6]. Biologically, the technique must be further examined as it is environmental-friendly [7].

In addition to the biological use, other oil cleanup methods are absorption, mechanic, and chemical methods [8]. The common technique used to overcome the oil spills is to use barrier buoys that are transferred with oil booms to a tank-shaped shelter and with oil-burning technique. Moreover, it could also be conducted with chemical dispersants. However, the physics-chemical methods have higher risks on the environment and require more expenses [7]. Additionally, the oil cleanup cost in the United States requires a significant amount of which the manual expense is amounting to $23,403.45 per ton. The machine-based clean-up cost is $9,611.97/ton, with dispersant is $5,633.78/ton, and In Situ Burning of $3,127.87/ton [9].

The clean-up efforts with chemical approach could be done through solidification, which is a process of compaction of hazardous substance with the addition of additives. However, this method contributes to the environmental problem as it may generate another environmental problem from the addition of such chemical materials. The biological treatment and bioremediation technology have an advantage of being more environmental-friendly and operational cost is relatively cheaper than the physics and chemical recovery techniques [4]. This research aims to study the use of bioremediation on oil-contaminated soil based on the sustainable indication (environment, social, and economy). This research is important to be conducted as based on the sustainable indication, the oil contamination would have and adverse effect to the living standards of the people and environment.

2. Methods
This research utilizes study of literature about the use of bioremediation to remove crude oil content on the oil-contaminated environment. Moreover, the data utilized is secondary data based on previous researches regarding the use of bioremediation implemented to absorb hydrocarbon compound. The SWOT analysis is conducted which is an analysis of strengths, weaknesses, opportunities, and threats from the implementation of bioremediation as an effort to overcome the crude oil. SWOT analysis is generally used to form a strategic planning, though in this research the SWOT analysis is only used to evaluate the feasibility of the use of bioremediation and zeolite on oil-contaminated soils.

3. Result and Discussion
Bioremediation is one of the technologies that could be utilized to recover the soil and water contaminated by the oil hydrocarbon with a relatively inexpensive cost [10]. Bioremediation utilizes the biodegradation capacity by microorganism on hydrocarbon by changing them into residues that is not toxic so that they could be utilized for agriculture. Bioremediation has been used for the past ten
years and is considered as an alternative for rehabilitation efforts due to hydrocarbon experiencing biodegradation by microorganism. The presence of hydrocarbon biodegradation is seen from the rising number of bacteria on the earth mounds. The number of microbes on a contaminated soil usually could rise to 90% from the total population that experienced the hydrocarbon degradation.

One of the bacteria used to absorb the oil content is Pseudomonas bacteria. Pseudomonas bacteria is a bacteria that generates biosurfactant that could be found in its wide distribution in the contaminated environment, quick growth, easy to be isolated and for filtering, as well as having a high level of oil degradation capacity [11]. Pseudomonas bacteria has a high capacity of degradation namely 81.54% with the optimal temperature of 35°C, value of pH 8, and salt tolerance of 6% [12]. The research outcome of [13], also illustrated that Pseudomonas bacteria could reduce oil content despite of the salinity. However, in some cases, Pseudomonas bacteria caused the Bacterial Red Stripe (BRS) disease or red stripe disease and bacteria blight. Moreover, the characteristics of BRS disease is seen from the leaves and there are no roots, stems, and panicles. For bacteria blight, the characteristics that appear are when the spots appear on the leaves, stems, petioles, and pods [14].

The success of using bioremediation technology is generally measured through the reduction of the total crude oil content. Bioaugmentation with bio-stimulation in desert soil reduces the TPH level of 77% in 156 days [15]. The research outcome conducted by [10] showed that the use of Aspergillus niger mushrooms could reduce the TPH value from 48,300 ppm to 33,600 ppm in 96 days. In addition, the use of bioremediation could remove the oil hydrocarbon content up to 61% in 12 weeks [16]. The hydrocarbon content decrease on the soil is also affected by the temperature and generally the decline of the biodegradation rate is in line with the decline of the temperature. The rise oil viscosity and the volatility of low molecular toxic hydrocarbons is reduced by the low temperature that delays the biodegradation to occur. Based on figure 1, the highest degradation level by a microorganism occur at 30–40°C in the soil environment, at 20–30°C in freshwater environment, and at 15–20°C in the sea.

The temperature of environment affects the spilled oil and microorganism activities. According to [17], the crude oil contamination affects the physical nature and soil chemicals so the development of an effective land recovery is needed.

In this paper, it is examined that the use of bioremediation based on strengths, weaknesses, opportunities, and threats to comprehend the feasibility of the technique. The internal environment analysis consists of strengths and weaknesses whereas the external environment analysis are the external factors that consist of opportunities and threats from bioremediation (Table 1). The analysis results show the use of bioremediation technology could reduce TPH value because the bacteria could decompose the oil which is generally hard to be degraded. Bacteria is easy to decompose crude oil content because of the alkanes that is more soluble in water and diffused into bacterial cell membrane. Substrate that is commonly found in crude oil causes the abundant number of bacteria to degrade such components. In addition, physics and chemical techniques are seen to be more harmful due to their immediate effects such as causing smoke due to the burning and environmental damage due to the additional chemical substance, whereas bioremediation is safer as it does not have direct effect on environment damage.
In addition, the weakness from the bioremediation implementation is for removing the hydrocarbon content, it requires longer time compared to the other methods as it needs incubation time to activate the microbes. Moreover, the use of bioremediation has yet to be seen to give job opportunities for the people who have lost their jobs due to the oil contamination. This is due to the lack of resources and technology to develop this technology. The analysis outcome showed that the use of bioremediation by the people as one of the efforts to clean up the oil that is environmental-friendly so that it is well-accepted by those who use it. Based on the result of the analysis, there is a threat of bioremediation use in which there is a microorganism that could potentially mutate, generating new product that is unknown and could potentially damage the environment. Additionally, bioremediation with the use of \textit{Pseudomonas sp.} bacteria in some cases cause plant diseases such as bacterial blight and red striped leaves. The idea of threat surely needs further studies so that it could identify the sustainability of the use bioremediation especially in the environmental aspect.

The social aspect of the bioremediation is relating to the perception, knowledge, and view of the people on the use of bioremediation. The general public’s perception on the bioremediation technology is as a green technology or environmental-friendly. This is different from the technique which is not natural such as in chemical and physics methods to clean the environment, like energy [19]. However, on the other side, there is also a view that bioremediation could cause problem or danger because the genetically-modified microorganism which was released to the environment. There are also public concerns and perceptions about the risks of using bioremediation that could be harmful to the environment or even could cause bigger environmental problems than before.

![Diagram](image)

**Figure 1.** Hydrocarbon Degradation Rate in Soil, Freshwater and Seawater (Source: [18])

| Strengths | Weaknesses | Opportunities | Threats |
|-----------|------------|---------------|---------|
| 1. Able to reduce TPH content up to 91.04%.  
2. \textit{Pseudomonas sp} | 1. Requires a slow recovery time compared to the physics and chemical | Bioremediation and zeolite are efforts that are environmental-friendly thus it | 1. A microorganism potentially mutating so that it could harm the |

Table 1. Analysis on Internal Environmental Factors
bacteria create biosurfactant that functions to reduce crude oil content.

| 2. Does not give any job opportunities to the people who have lost their jobs | is accepted by the local people. | environment and the human health. |
|---|---|---|
| 3. Safe for the environment and is relatively affordable compared to the physics and chemical methods. | 2. Bioremediation using *Pseudomonas* bacteria could cause plant diseases. |

Based on the study above, there are several matters that need to be addressed in overcoming crude oil contamination. Firstly, there needs to be oil management so that crude oil does not spill and damage the environment. Regulations about the oil spill management must be enforced so that the industry could be responsible in case of oil spill. One of the ways to show responsibility to be willing to compensate the environmental recovery caused from the damage or also known as polluter pays principle. Oil spill management aims to reduce the amount of oil spills that damage the environment so that bioremediation could be used effectively especially in the area exposed by the oil spills. Based on the analysis of this research, another research is needed especially in the aspects of environment, social, and economics about the bioremediation technology so that there could be efforts to avoid oil spill thus making it acceptable in three of those aspects.

4. Conclusion

Bioremediation could reduce TPH value as the bacteria could decompose oil which is generally difficult to be degraded. The decline in the hydrocarbon contents on soil is affected by the temperature and generally the decline of biodegradation rate along with the decline of the temperature. The use of bioremediation technology is seen to be safe for the environment with relatively affordable price compared to the other methods thus its use is well-received by the people as one of the ways to clean up the oil. However, there is also a microorganism used that could potentially mutate thus creating a new product that is unknown and could harm the environment. In addition, the biological method requires longer time to reduce TPH than the physics-chemical methods. The bioremediation technology examined by sustainable indicators is seen to still have weaknesses and threats which could be further examined as one of the sustainable ways oil spill cleanup.

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