Bioremediation is the process of cleaning the soil contamination using microorganisms (fungi, bacteria). Bioremediation aims to break down or degrade contaminants into less toxic materials or non-toxic. Bioremediation is considered as an alternative action to restore a state of the environment has been polluted. This study aims to determine the effectiveness of the differences and how Biopile and Landfarming in bioremediation process and to determine the amount of impairment Total Petroleum Hydrocarbons (TPH). Petroleum-contaminated soil used in this study comes from the waste generated from ConocoPhillips Indonesia Ltd. Banyuasin South Sumatra. The research method is experimental. The design of the experiment that used is Completely Randomized Design (CRD) factorial. The results showed biopile technique showed higher efficacy compared with Landfarming techniques; biodegradation process time to achieve the targets, which is under 1%, is faster than Landfarming techniques; bioremediation process with biopile techniques can be controlled better than Landfarming techniques.

Keywords: Bioremediation, biopile, landfarming, petroleum

INTRODUCTION

Background

Crude oil or unprocessed oil is a hydrocarbon compound which come in liquid form at normal temperature and pressure. Boiling point of this compound ranges from a low temperature to a high temperature (Margono and Amir, 1994). Oil processing as fuel and other products through the activities of oil and gas exploration activities began from exploration, production, processing, distribution, transport, until its utilization in everyday life in the society. In addition to give positive impact on social and economic development, the use of oil can also have a negative impact on the environment, especially in case of spills that can pollute the environment. Waste generated in the form of an oil refinery can come in wastewater and solid waste form. Petroleum refinery production of 1000 barrels per day would generate solid waste (sludge oil) more than 2.6 barrels, while in Indonesia, a petroleum refinery produces about 1.2 million barrels per day, which means solid waste as much as 3120 barrels per day and the period of one year produces as much as 1.3 million barrels of waste, which is 285,000 barrels of which is hazardous and toxic waste (Lasari, 2010). Soil contaminated by petroleum hydrocarbons with a high concentration can be a source of groundwater contaminants.

Petroleum hydrocarbon can move vertically or laterally and converge at wastewater piping or in the basement that can cause dangerous explosions. Petroleum hydrocarbon-contaminated soil surface is a source that can harm human health. Some constituents in gasoline that has a high vapor pressure can migrate into not saturated-areas, which can contaminate surface water and cultivated plants around contaminated areas.

Biological wastewater treatment is an alternative to petroleum waste management technologies by utilizing living things, especially microorganism, to lower the concentrations of toxic pollutants. Bioremediation is petroleum waste treatment process which process old waste or spill / oil spills on contaminated land by utilizing living organisms, including microorganisms (bacteria, fungi or protozoa) to reduce or eliminate the concentration of toxic pollutants. There are 2 (two) mechanisms in bioremediation process, the
first one is by biopile, and the second one is landfarming. The effectiveness of these two methods will determine the process of bioremediation in processing petroleum-contaminated soil.

**Problem Formulation**

Formulation of the problem in this study:
- How the two ways of bioremediation process, Biopile and LandFarming, are different?
- How much decrease in the concentration of Total Petroleum Hydrocarbons (TPH) in two ways of bioremediation process, Biopile and LandFarming?

**Research Objectives**

To evaluate the effectiveness of the two ways of bioremediation processes, Biopile and LandFarming, which will be done in the process of eliminating or reducing contaminants in petroleum-contaminated soil.
- To find out differences in effectiveness and how BiopileLandfarming in bioremediation processes.
- To determine the amount of impairment Total Petroleum Hydrocarbons (TPH) in a way Biopile and Landfarming

**THEORY**

**Hydrocarbons and Petroleum**

Petroleum is composed of 83-87% carbon with the remainder being hydrogen. In the oil also contained metals such as nickel, vanadium and iron, but in very small concentrations. Properties and chemical composition of petroleum varies depends on: the source, the oil’s age, the condition of the formation and so on. Therefore, different distillate products of petroleum will have different chemical compositions, even if the product has the same physical standards and look (Koesoemadinata, 1980)

Petroleum is generally separated in distillation fractions based on boiling point range. Petroleum components can be divided in several groups based on the structure of the hydrocarbon. There are aliphatic hydrocarbons, aromatic hydrocarbons and hydrocarbon which also contain mixture of nitrogen, sulfur, and oxygen.

Crude oil contains a complex mixture of hydrocarbons and small amounts of compounds containing nitrogen, sulfur, and oxygen, asphalt and various metals. Based on the chemical structure, hydrocarbons can be divided into two groups: aliphatic (normal-alkanes, branched, and cycloalkanes) and aromatic compounds, which generally are often found in the form of poliaromatic hydrocarbon.

**Petroleum and hydrocarbon biodegradation by bacteria.**

Petroleum degradation can also be mentioned as hydrocarbon degradation. Degradation can take place through a process of transformation or metabolism. Petroleum degradation by bacteria takes place in a series of processes that result in a number of intermediate compounds (intermediates) that have very different toxicity and recalcitrant compounds from the original. Those toxic intermediate compounds can affect the metabolism process of degradation bacteria, and make the transformation failed. To avoid that, controlling biodegradation of oil is required in order to achieve optimum results.

Petroleum biodegradation can be described as follows: initially, hydrocarbon is oxidized to make liquid alcohol, subsequently followed by the formation of aldehydes and/or organic acids that begin with β-oxidation. After going through the Krebs’s cycle, the release of carbon dioxide, water and new cells occurs. In the biodegradation process also produced an intermediate compound. Intermediate compound that come as results of oil recast can often be found in the form: hydroxyl, carboxylic acid or aromatic compounds derived from original compounds. Hydroxyl compounds often have bigger toxic response, because the polarity and solubility.

A complete biodegradation of organic substrates will change those substracts to form CO₂, H₂O and other organic compounds. Some research indicates that petroleum can be degraded by microorganisms such as bacteria, fungi, yeast and microalgae. From studies that have been done in subtropical countries, noted that petroleum degradation by microorganisms is a complex process. A major factor inhibiting biodegradation of petroleum, among others, petroleum components that are toxic and resistant, low temperature, lack of mineral nutrients, especially N and P, dissolved oxygen limitation and scarcity of local microorganisms which are able to degrade petroleum in places that were previously not been contaminated.
Factors that supporting biodegradation

Microbial growth and activity of enzymes that determine the degree of biodegradation of petroleum hydrocarbons influenced by abiotic factors, namely:

1. Physical properties of hydrocarbons, include: solubility in water, ability to absorb, toxicity or recalcitrant and temperature. Several studies have shown that bio hydrocarbon degradation can occur in a wide temperature range. At 25 °C hydrocarbon degradation occurs more rapidly than at 5 °C. Temperature also provide different effects, depending on the composition of the oil mixture. Low temperature slows the rate of evaporation of low molecular weight hydrocarbons and in some cases gave rise to the toxic properties of microorganisms. According to Atlas (1981) at low temperature kometabolisme plays an important role in determining the rate of disappearance of hydrocarbons in the mixture.

2. Nutrition. Nutrient absorption process is the process of absorption of nutrients. Nutrients that have been absorbed into the cells will be used through a process called metabolism.

3. Oxygen. Oxygen is basic materials of water in cells and can be found in all cell materials. The role of oxygen in the growth of microbes is as the last oxidizing agent in aerobic respiration. If oxygen is the only final electron acceptor that can be used by the cells of the organism, then the bacterium is an obligate aerobic bacterium. Obligate anaerobic organism is an organism that gets its energy from reaction that does not involve the use of oxygen. Facultative anaerobic organism is an organism that can grow with or without oxygen. Most fermentation can be respiration if oxygen is available. Microaerophilic organisms are obligate aerobes that grow well in very low oxygen concentrations.

4. The degree of acidity (pH). Petroleum biodegradation speed is higher at slightly alkaline conditions. In the sea environment, the pH in alkaline conditions gives the advantage to the growth of petroleum degrading bacteria.

5. Salinity. Brock (1991) studied the biodegradation of hydrocarbons in high-salinity environments and found that the metabolic rate decreases with increasing salinity. The limited metabolism seem unrelated to the low oxygen levels or organic nutrient availability.

Generally, Capone and Bauer (1992) describe several ways to increase petroleum degradation by bacteria, namely:

1. Optimization of environmental conditions in order to make bacterial decomposers work in maximum condition, for example through the addition of nutrients and control factors that limit the growth of hydrocarbon decomposition.

2. Equating the polluted environment with tolerant bacteria which are able to quickly reorganize certain types of pollutants and thus expand the natural microbial population.

3. The addition of natural populations of bacteria that have been genetically engineered to open up the development of certain metabolic pathways.

Petroleum-degrading microorganisms

Microorganisms such as bacteria, fungi and algae are a living catalyst that can affect a large number of chemical processes that occur in water and soil. Bacteria with fungi are classified as decomposers. Remodeling and deciphering the chemical compounds into the types of compounds which are simple and therefore require energy for growth and metabolism (Saeni, 1989).

Mechanism of decomposition by microorganisms to a chemical waste through the chemical process with enzymes found in microorganisms and suitability of substrates, so that environmental factors play a very important accompanying there in (Citroreksoko, 1996). On petroleum biodegradation process, decomposers use hydrocarbons as a source of carbon and energy.

Atlas (1981) recorded more than 100 species; representing 30 genera of microbes have demonstrated the ability to use hydrocarbons. In general, the most important genera that use hydrocarbons in aquatic environments (based on the frequency of isolation) were Pseudomonas, Achromobacter, Arthrobacter, Micrococcus, Nocardia, Vibrio, Cinetobacter, Brevibacterium, Corynebacterium, Flavobacterium, Candida, and Sporobolomyces Rhantoula. Seen from the source, petroleum degrading microbes may originate from sea water habitat, fresh water or soil contaminated by petroleum. Types of microorganisms that will appear later as degrading microorganisms influenced by the temperature and composition of petroleum.

Bioremediation is the process of cleaning the soil contamination by using microorganisms (fungi, bacteria). Bioremediation aims to break down or degrade contaminants into less toxic materials or
Bioremediation is the use of microorganisms to reduce pollutants in the environment. When bioremediation occurs, the enzymes produced by microorganisms modify toxic pollutants by changing the chemical structure of the pollutant, an event known as biotransformation. In many cases, biotransformation leads to biodegradation, where toxic pollutants degraded, its structure becomes not complex, and finally into metabolites that are harmless and non-toxic.

There are 4 basic techniques commonly used in bioremediation:

1. Stimulatory activity of indigenous microorganisms (in contaminated locations) with the addition of nutrients, regulation of redox conditions, optimization of pH, etc.
2. Inoculation (planting) microorganisms in contaminated locations, i.e. microorganisms that have special abilities in biotransformation
3. Application of immobilized enzymes
4. The use of plants (phytoremediation) to eliminate or modify contaminants.

Bioremediation field is now supported by a better knowledge about how pollutants can be degraded by microorganisms, identification of the types of microbes that are new and useful, and the ability to improve bioremediation through genetic technology. Molecular genetic technology is very important to identify the genes that encode enzymes related to bioremediation. Recombinant microbial strains or types that are created in the lab can be more efficient in reducing pollutants. Recombinant microorganisms that first invented and patented were bacteria "oil-eating". These bacteria can oxidize hydrocarbons that are commonly found in petroleum. The bacteria grow faster than other types of bacteria that naturally or not created in a laboratory that has been tested. However, these findings have not been successfully commercialized because this recombinant strain can break down harmful components only in limited quantities. Strains also have not been able to degrade the molecular components that are heavier tending to persist in the environment.

**Waste Treatment Techniques of Oil Contaminated Soil by Bioremediation**

**Land Farming**

Land farming is designed to optimize the biological process of degradation by applying premises using soil as inoculum and supporting media for the growth of bacteria. Contaminated soil is spread in a thin layer (12 inch). Occurring biodegradation processes are optimized by periodically aerating the soil with nutrients and appendes plowing techniques in agriculture. Nutrients, pH, and soil moisture content should also be maintained and periodically arranged. The process of land degradation in farming in principle takes place biologically.

**Biopile**

In biopile technique, biological treatment performed after mechanical preparation in which the soil that will be cultivated are separated from other materials that may interfere, filtered, and refined, so that it becomes homogeneous. With this homogenization, the soil structure will be tenuous that will facilitate the supply of oxygen to the soil particles. To activate the biological degradation of the contaminants, nutrients, water, and kosubstrat can be added. In addition, microorganisms or substances that can improve the soil structure can be added. Organic additives such as compost or husks can serve as kosubstrat or nutrient source for microorganisms and as a structural material. In the static biopile process, biopile is built almost like composting organic waste. Trapezoidal or pyramid shape is the form that most commonly used. The height of biopile varies between 0.8 m to 2 m.

**METHODOLOGY**

**Materials and Equipment**

The materials that are used as samples in this study including: Waste-contaminated soil that generated from ConocoPhillips Indonesia Inc. Ltd. activities which has been running. The main tool in this study is the area Biopile, LandFarming and TPH measuring instruments and total microorganisms.

**Stages of Research**

Bioremediation techniques applied are biopile and landfarming. Treatability of this study was observed for 2 months (8 weeks) with sampling every 2 weeks.

**Procedure:**

1. Predetermined locations are cleared from existing vegetation on it.
2. Install the liner that has been provided, so that all cells are provided properly covered.

3. Pour the soil that has been mixed with all the necessary ingredients in bioremediation.

4. The addition of 4 liters of microorganisms was done by using the spray. The process of mixing or stirring is done regularly and periodically to optimize the treatment process.

5. The process of mixing or stirring is done regularly and periodically 2 times a day to optimize the treatment process.

Pilot cells of bioremediation Biopile manufacturing

Equipment: a predetermined location; liner cells; piping which has been prepared; blower; gravel; land that has been mixed.

Procedure:
1. Predetermined locations are cleared from existing vegetation on it.
2. Install the liner that has been provided, so that all cells are provided properly covered.
3. Installation of piping that has been available as well.
4. Gravel is sprinkled around the piping that has been installed.
5. Pour the soil that has been mixed with all the necessary ingredients in bioremediation.
6. Add microorganisms in liquid form using a spray

Treatment / experiment

Bioremediation techniques applied are biopile and landfarming. This study were observed for 10 weeks with sampling every 2 weeks with treatment, among others:
- Adding mixing ingredients to the waste with the goal to optimizing the decomposition process of petroleum waste by microorganisms with the ratio between waste and maximum mixing ingredients is 1:1. The mixing ingredient that will be used is soil which is not contaminated and has no economic value.
- Adding a bulking material (bulking agent) to increase the porosity of the mixture of petroleum waste by using materials that are available around the processing location.
- Perform aerobic treatment process, thus required the supply of oxygen (aeration) which is done by supplying oxygen through pipes to BioPile and stirring manually with a hoe for LandFarming method.
- Optimum humidity of the process needs to be maintained with water that is sprinkled or sprayed on a regular basis or at any time if the results of the monitoring showed reduced soil moisture.
- The process of decomposition of petroleum waste is enhanced by the addition of nutrients and optimizes environmental conditions. Urea as a nutrient and rice husk as a bulking material.
- Decomposition process can be improved and accelerated by the addition of petroleum waste decomposing microorganisms that has been tested for its ability. This microorganism is obtained (isolated) from the location of the processing unit.
- The process of mixing or agitation (mixing) is done regularly and periodically to optimize the biological treatment process.

Calculation of the number of colonies Living Microorganisms

The success of bioremediation in achieving objectives is influenced by the presence of microorganisms that can degrade the target contaminants. The growth of microorganisms is measured as the change in the cell or cell mass quantity (Atlas & Bartha, 1985).

Method Total Plate Count (TPC) has been widely used in measuring the growth of microorganisms in terms of quantity because of the ease of application / workmanship and also a fairly high level of economy (Eweis et al., 1998).

Processing and Data Analysis

The experimental design used in this study is the method completely randomized design (CRD) factorial. According Gaspersz (1991) mathematical model factorial completely randomized design are as follows:

\[ Y_{ij} = \mu + T_i + \Sigma_{ij} \]

\[ Y_{ij} \] being any observation for which \( X_i = i \) (i and j denote the level of the factor and the replication within the level of the factor, respectively)

\( \mu = \) the general location parameter
\( T_i = \) the effect of having treatment level i
\( \Sigma_{ij} = \) random error

RESULTS AND DISCUSSION

Concentration of Oil in Contaminated Soil With Biopile Technique Based on Remediation Time

Concentration of oil in the soil by using the Biopile techniques at various times of remediation
prove the results decreases with increasing time of remediation.

Table 1. The relation between the timing of remediation with the decreasing of oil concentration (%) by biopile technique

<table>
<thead>
<tr>
<th>Replication</th>
<th>Remediation time (weeks)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.104 11.104 9.604 6.004 0.802 0.675 0.613</td>
<td>16.104</td>
</tr>
<tr>
<td>2</td>
<td>11.104 11.104 9.604 6.004 0.802 0.675 0.613</td>
<td>16.104</td>
</tr>
<tr>
<td>3</td>
<td>11.104 11.104 9.604 6.004 0.802 0.675 0.613</td>
<td>16.104</td>
</tr>
<tr>
<td>Total</td>
<td>33.294 24.111 27.573 52.605 20.822 14.604 84.312</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>11.104 11.104 9.604 6.004 0.802 0.675 0.613</td>
<td>16.104</td>
</tr>
</tbody>
</table>

By using biopile techniques, the relation between the timing of remediation with the decreasing of oil concentration is described by the regression equation $Y = 6.7534 - 0.8139X$, where $Y$ is the concentration of oil and $X$ is time of remediation with biopile technique. This relationship is shown with correlation coefficient $r = -0.8511$ and a correlation coefficient of determination $R^2 = 0.7244$. This means that the increasing of each unit’s remediation time will result in decreased concentrations of oil in the soil for 0.8511 units. In another sense, that the decrease in the concentration of oil in the oil-contaminated soil is 72.44% due to the effect of remediation time, while other factors that influence is evaporation (27.56%). Decrease in proportion of the concentration of oil in the soil with biopile technique (consecutively) : 84.05%, 92.01%, 92.91%, 94.04% and 94.59%.

In the remediation process with biopile technique, the role of microorganisms in the soil will determine oil degradation process. Development of microorganisms during remediation processes has increased from $1.10^8$ at the beginning to $7.10^{11}$ at the time of remediation for 10 weeks.

Microorganisms are grown well with adequate and complete supplies of nutritional needs as nitrogen, sulfur, phosphorus, carbon, and so on. Aeration factor plays an important role; this condition is obtained from the addition of urea, composted chicken manure (litter) and aeration treatment so that the circulation of air or oxygen goes well. In forming cells of microorganisms, nitrogen elements obtained from urea, carbon skeleton, sulfur phosphorus and other elements derived from chicken manure.
Concentration Of Oil In Contaminated Soil With Landfarming Technique Based On Remediation Time

Concentration of oil in the soil by using the landfarming techniques at various times of remediation prove the results decreases with increasing time of remediation.

Table 2. The Relation Between The Timing Of Remediation With The Decreasing Of Oil Concentration (%) by Landfarming Techniques

<table>
<thead>
<tr>
<th>Replication</th>
<th>Remediation time (weeks)</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.2800</td>
<td>2.4650</td>
<td>3.1000</td>
<td>1.0458</td>
<td>0.6210</td>
<td>0.5246</td>
<td>15.564</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10.3700</td>
<td>2.4060</td>
<td>3.1000</td>
<td>1.0470</td>
<td>0.6200</td>
<td>0.5380</td>
<td>15.677</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10.2390</td>
<td>2.4070</td>
<td>3.1040</td>
<td>1.0420</td>
<td>0.6220</td>
<td>0.5300</td>
<td>15.970</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10.700</td>
<td>2.7200</td>
<td>3.1090</td>
<td>3.1330</td>
<td>1.1844</td>
<td>1.6940</td>
<td>47.031</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>10.260</td>
<td>2.4070</td>
<td>3.1090</td>
<td>1.0444</td>
<td>0.6210</td>
<td>0.5360</td>
<td>15.970</td>
<td></td>
</tr>
</tbody>
</table>

Statistical analysis of the data obtained in table 2, shows the oil concentration in the soil is very different (p <0.01) due to the time difference in the remediation. Improved remediation time (0-10 weeks) results in decreased concentrations of oil in the soil 23:46%, 10.74%, 10:18%, 6:05% and 5:22% or rate of oil degradation that become higher (76.54%, 89.26%, 89.82%, 93.95% and 94.78%).

Decrease in the concentration of oil in the soil with landfarming technique is follow the regression equation \( y = 6.5214 - 0.7719x \) where \( y \) is the concentration and \( x \) is the time oil remediation, which means increased remediation time lead to lower unit oil concentration in the soil. The closeness of the correlation between the time of remediation with concentration of oil in the soil is quite significant (p <0.05), which is described \( r = 0.7636 \) with a coefficient of determination \( r^2 = 58.31 \). It means that the decrease in the concentration of oil in the ground with landfarming techniques is 58.31%.

Decrease in the concentration of oil in the ground as a result of increase of the length of remediation time is shown in figure 3.

Figure 3. Decrease oil concentration in soil-Landfarming

Development of microorganisms in the soil with landfarming technique is well enough. At the beginning, it is \( 7.10^7 \) and after remediation for 10 weeks it become \( 2.10^9 \). Enough supply of nutrients in the soil from compost, chicken manure, urea and sufficient aeration helps the development of microorganisms. Oil degradation in soil by microorganisms resulting in lower hydrocarbon compounds.

Figure 4. The growth of microorganisms – Landfarming

Effectiveness of Biopile and LandFarming Technique in Oil degradation in the Soil

Results of oil analysis in soil contaminated by oil shows the difference between the two techniques in degrading oil in the ground.

Table 3. The relation between the timing of remediation with the decreasing of oil concentration (%) by biopile and landfarming techniques

<table>
<thead>
<tr>
<th>Replication</th>
<th>Remediation Time with Biopile technique (weeks)</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.23</td>
<td>1.10</td>
<td>0.90</td>
<td>0.80</td>
<td>0.78</td>
<td>0.61</td>
<td>10.28</td>
<td>2.41</td>
</tr>
<tr>
<td>2</td>
<td>11.23</td>
<td>1.10</td>
<td>0.90</td>
<td>0.80</td>
<td>0.78</td>
<td>0.61</td>
<td>10.28</td>
<td>2.41</td>
</tr>
<tr>
<td>3</td>
<td>11.23</td>
<td>1.10</td>
<td>0.90</td>
<td>0.80</td>
<td>0.78</td>
<td>0.61</td>
<td>10.28</td>
<td>2.41</td>
</tr>
<tr>
<td>Total</td>
<td>33.23</td>
<td>3.21</td>
<td>2.41</td>
<td>2.21</td>
<td>2.01</td>
<td>1.84</td>
<td>30.74</td>
<td>6.72</td>
</tr>
<tr>
<td>Average</td>
<td>11.23</td>
<td>1.10</td>
<td>0.90</td>
<td>0.80</td>
<td>0.78</td>
<td>0.61</td>
<td>10.28</td>
<td>2.41</td>
</tr>
</tbody>
</table>

Based on statistical analysis, biopile technique showed higher efficacy (P <0.01) in comparison to LandFarming technique. This difference can be caused by different microorganism activity...
although there are no differences in nutrient supplies.

Figure 5. Decrease Oil Concentration In Soil—Biopile and Landfarming

In Biopile technique, aeration process is more secure than LandFarming technique in which the Biopile technique, aeration process is done perfectly (with the machine), while in the LandFarming technique, aeration process was done manually (stirring). Microorganisms thrive in the ground if air circulation especially oxygen is always available. Oxygen is needed by microorganisms in the oxidation process of nutrients to produce energy in the form of ATP (Adenosine triphosphate) and ATP require the phosphate compounds to be formed.

Figure 6. The growth of microorganisms—Biopile and Landfarming

CONCLUSIONS AND RECOMMENDATIONS

Conclusion
1. Biopile technique showed higher efficacy compared to LandFarming technique.
2. Time of biodegradation process to achieve the target of below 1% is faster than LandFarming technique.
3. Bioremediation with biopile technique can be better controlled than LandFarming techniques. This is possible because biopile technique has an active aeration system.

Recommendations:

Both techniques of bioremediation, landfarming and biopile showed similar overall performance to be applied in a larger scale of processing.

BIBLOGRAPHY
14. Muller, R. & F. Lingens., 1983. Oxygenation Pathways in Bacteria. In Biological...


