STUDY ON PERFORMANCE OF AEROBIC COMPOSTING OF OIL SLUDGE CONTAMINATED SOIL USING DIFFERENT BULKING AGENTS

NURAMALINA BINTI JAAFAR

CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JUNE 2010

CERTIFICATION OF APPROVAL

Study on Performance of Aerobic Composting of Oil Sludge Contaminated Soil Using Different Bulking Agents

by

Nuramalina binti Jaafar

A project dissertation submitted to the

Civil Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(CIVIL ENGINEERING)

Approved by,

____

(Dr. Amirhossein Malakahmad)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Malina

NURAMALINA BINTI JAAFAR

Study on Performance of Aerobic Composting of Oil Sludge Contaminated Soil Using Different Bulking Agents

by

Nuramalina binti Jaafar

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)
JUNE 2010

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

ABSTRACT

Major problem due to the hazardous waste in a petroleum industry is mainly coming from the disposal of oil refinery sludge (ORS). ORS consists of heavy metals and other constituents which are very dangerous to human health and also can pollute the environment. The aim of this study is to reduce the amount of oil and grease level in ORS using aerobic composting. Oil refinery sludge was taken from PETRONAS Penapisan (Terengganu) Sdn. Bhd. from Oily Float Tank (T-3006) KR1, crude tank D901, D902 and D903, and from Corrugated Plate Interceptor (CPI) compartment. Thus ratio of ORS, bulking agents and seeding material was 1:1:0.5. ORS to bulking agent was 1:1 (v/v), while ORS to seeding material was 1:0.5 (w/w). Recycle office papers were collected at the printing room academic building UTP, and the dry yard wastes consist of leaves and branches which are dry and brown in color were collected from the area near the hostel where it is filled with trees which are fully grown. Sewage sludge was taken from PETRONAS Penapisan (Melaka) Sdn. Bhd. at the waste water clarifier and was used as seeding material in the compost pile. Two different mixtures was been introduced in the same ratio amount. The composter was made in cubic containers with dimension (0.25m x 0.25m x 0.25m). Opened at the top and with small holes in the bottom and side, and been wrapping with rice bag (fabric). Oil and grease level, temperature, pH, C:N ratio and moisture content were monitored during composting. Composter 1 and 2, working under the similar condition, which recorded temperatures was between 31-35°C, and moisture content (50-60%), with optimum pH level (6.5-8.0). The maximum oil and grease reduction was 55.9 % starting from week 1 to week 14 experimental period in compost 2, using shredded papers as a bulking agent

ACKNOWLEDGEMENT

First and foremost, the author would like to thank to the supervisor of this project, Dr. Amirhossein Malakahmad for the valuable guidance and advice. He inspired the author greatly to work in this project. His willingness to motivate, contributed tremendously to author project. The author would also like to thank him for showing some example that related to the topic project. To the Final Year Research Project Coordinator, Dr Hasnain and Mrs Husna for providing the author with all the initial information required to begin the project.

To all technicians in Civil Engineering Department, thank you for assisting the author in completing her project. Besides, I would like to thank the authority of Universiti Teknologi PETRONAS (UTP) for providing me a good environment and facilities to complete this project. Finally, an honorable mention goes to my families and friends for their understandings and supports on me in completing this project. Without helps of the particular that mentioned above, I would face many difficulties while doing this project.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

COD	Chemical Oxygen Demand
CPI	Corrugated Plate Interceptor
MOG	Mineral Oil and Grease
ORS	Oily Refinery sludge
TC	Total Carbon
TIC	Total Inorganic Carbon
TKN	Nitrogen, Total Kjeldah
TOC	Total Organic carbon

CHAPTER 1
INTRODUCTION

1.1. Background of Study

Petroleum refineries are unavoidably generating waste streams of oily refinery sludge (ORS) which is produced mainly from the accumulation of waste oily material in storage tank bottoms and from the water-oil separation system [1]. Nowaday's oil refineries are experiencing problems with environmental contamination because of difficulty in the safe disposal of oil refinery sludge (ORS) generated during the refining process. A typical Malaysian refinery (manufacturing capacity, 105,000 barrels/day) produces about 50 tons/y of sludge. Disposal of this refinery sludge is a challenge to the petroleum industry because many of its constituents are carcinogenic and potent immunotoxicants [2].

Due to economics and simplicity, land farming has traditionally been the biological treatment method chosen to dispose of most oil sludge. However because of land farming often requires a large surface area, other bioremediation methods such as composting of petroleum wastes has therefore received increased attention as a potential substitute technology for land farming [3].

Composting is a biological decomposition of organic waste into a useable product called humus that is dark brown or black and has earthy smell. Oil sludge contaminated soil can be composted by additions of bulking agent, seeding materials, aeration and turning, or by combination of these practices [4].

1.2. Problem Statement

Petroleum storage and transportation facilities have often been a source of environmental pollution as they generat a number of hazardous waste during the operation [1]. The petrochemical industry generates a series of liquid effluents during the petroleum-refining process. The sludges that result from this treatment process have a high content of petroleum-derived hydrocarbons, mainly alkanes and paraffins of 1–40 carbon atoms, along with cycloalkanes and aromatic compounds, making them a potentially dangerous waste product [3]. Due to its content of harmful organic compounds, ORS has been recognized as a potentially dangerous waste product [1].

Land farming is becoming one of most preferred treatment technologies for oily sludge disposal [5]. Land farming also known as land treatment or land application, is an above-ground remediation technology for soils that reduces concentrations of petroleum constituents through biodegradation [6]. Simply dumping these wastes or burning them with no previous treatment has serious environmental consequences and presents a risk to both ecosystems and human health [3]. The implementation of land farming gives several disadvantages towards the environment and human health.

1. May not be affective for high constituent's concentration of hydrocarbon (greater than 50,000ppm total petroleum hydrocarbon).
2. Requires a large land area for treatment.
3. The potential of large amounts of particulate matter released by operations
4. The presence of metal ions may be toxic to microbes and may leach from the contaminated soil into the ground.
5. Dust and vapour generation during landfarm aeration may pose air quality concerns.

1.3. Objectives

The project, aerobic composting of oil sludge contaminated soil objectives are:

1. To apply aerobic composting as a low-cost treatment method for reduction of oil and grease contents in oil sludge contaminated soil.
2. To compare the effects of different bulking agents (dry yard waste and shredded paper) in the composting process.

1.4. Scope of Study

Samples were taken from PP(T)SB at crude tank D901, D902, D903 and corrugated plate interceptor (CPI). Aerobic composting was carried out by application of two composters which have been filled with ORS, bulking agents, soil and seeding materials. Oil and grease level, temperature, pH, C:N ratio and moisture content were monitored during composting.

CHAPTER 2
LITERATURE REVIEW

2.1. Composting

Composting is a biological decomposition or can be called the process of aerobic microbiological degradation [7] of organic waste into a useable product called humus that is dark brown or black and has earthy smell. It is a natural process that occurs when there is sufficient oxygen and an optimum range of moisture content. Biological decomposition begun with the first plant on earth and has been going on ever since. As vegetation falls to the ground, it slowly decays, providing minerals and nutrients needed for plants, animals and microorganisms [8].

There are two principal methods of composting which classified as agitated (windrow composting) and static (aerated static pile composting). In the agitated method, the material to be compost is agitated periodically to introduce oxygen, to control the temperature and mix the material. In the static method, the material to be composed remains static and air is blown through the composting material [9].

The composting process occurs in two major phase. In the first stage, microorganisms including bacteria and fungi decompose the composting feedstock into simpler compounds, producing heat as a result of their metabolic activities. In second stage, the compost product is finished where microorganism depleted the supply of readily available nutrients in the compost. As a result, heat generation gradually diminishes and the compost becomes dry and crumbly in texture [8].

By composting hazardous materials (ORS) was solely to convert these substances into an innocuous end-product [10]. By doing the composting give a lot of benefits towards environment, human and also the economic [11].

Pollution Remediation:

1. Absorbs odors and degrades volatile organic compounds.
2. Binds heavy metals and prevent them from migrating to water resources or being adsorb by plant.
3. Degrades, and in some cases, completely eliminates wood preservatives, petroleum products, pesticides and both chlorinated and non-chlorinated hydrocarbons in contaminated soils.

Pollution Prevention:

1. Avoids methane production and leachate formation in landfills by diverting organics for composting.
2. Prevents pollutants in storm water runoff for reaching water resources.
3. Prevents erosion and silting embankments parallel to creeks, lakes and rivers.

Economic Benefits:

1. Results in significant cost saving by reducing the need of water, fertilizers, and pesticides.
2. Produces a marketable commodity and a low-cost alternative to standard landfill cover and artificial soil amendments.
3. Extends municipal landfill life diverting organic materials from waste stream.
4. Provides a less costly alternative to conventional bioremediation techniques.

A study had been done by Ling and Isa [2], where they use the soil spiked with petroleum refinery oil sludge (10%, dry weight basis), and supplemented with grass as a bulking agent at a soil-to-grass ratio of 1:0.5 (v/v). For seeding materials, they use sewage sludge with ratios of contaminated soil to sewage sludge of 1:0.5 (w/w). It takes

9 week study period under low temperature conditions and they successfully achieve 65.5% oil and grease removal. Also other researchers examined the composting of ORS with shredded green wastes [1], straw [5], horse manure [10], wood shaving [3] as a bulking agent in their compost pile.

2.1.1. Bulking Agent

A bulking agent is a critical amendment that is added to the biosolid, primarily to reduce the bulk weight. It directly affects the composting process and the quality of the final product. The ideal bulking agent has low bulk weight, is readily degradable, and is as dry as possible. Bulking agent characteristics such as particles size, moisture content, and absorbency are also important [12] Bulking agent has intersection, which is important in providing spaces for air and water. Conceptually, sludge can be viewed as occupying part of the void volume in the bulking agent. If too little bulking agent is added the individual bulking particles will not be in contact with each other. Instead they will immerse in the sludge and no practical increase in free airspace or pore size will result [13].

Roger Tim Haug [13] also indicate that the wet feed substrates (oil refinery sludge) are difficult to compost alone because of the high moisture content. Thus it needs addition of bulking agent and amendment to overcome the problems. But, if the addition of bulking agents is more then required, it will increased the quantity of materials to be handled daily. Then it will need more spaces and higher cost.

The better aerobic conditions of the mixtures with bulking agent stimulates microbial activity meaning that microorganisms can degrade hydrocarbons better than in the oil sludge compost; this bulking agent favors fungal development and the establishment of new microbial degradation pathways, all this leading to higher respiration rates and contributing to a higher hydrocarbon biodegradation [3].

2.1.1.1. Yard waste

Yard wastes in the compost pile are widely practice by neighborhoods in their backyard composting [14]. Yard wastes are generally accepted as the best starting material for high-quality compost [8]. Yard wastes such as leaves, grass, and remains of garden plants all make excellent compost. To speed the composting process, woody yard wastes should be clipped and sawed down, or run through a shredder [15]. Some researchers had use the yard waste as their bulking agent in ORS composting such as, green waste [1] and grass [2], with the ratio approximately 1:3(v/v) [1] and 1:0.5 (v/v) [2], under the high temperature [1] and lower temperature [2] condition. The moisture content for both researchers was in the same range (50-60°C). Based on their study, they can achieve up to 62.1% and 65.6% reduction of oil and grease level. Also by using the dry yard waste in compost pile, it can reduce amount of waste to be dump at the land fill and reduce numbers of open burning.

2.1.1.2.Paper

There are a few numbers of study had been made using the paper as bulking agent in their compost pile such as study done by Van Gestel et al. [4] where the soil spiked with diesel oil was mixed with biowaste (vegetable, fruit and garden waste, paper included) at a 1:10 ratio (fresh weight) and composted in a monitored composting bin system for 12 weeks. Based on the research they achieved 85% reduction in diesel content at composting-temperature treatment.

2.1.2. Seeding Material

The addition of seeding material in the compost pile will increase volume of microbial culture sufficiently large to effect the decomposition of the receiving material at a faster rate [9]. Most of researchers had used seeding material in their composting treatment such as sewage sludge [2], poultry manure, bean cake, carbamide [5], and pig slurry [3] which adds nutrients and microbial biomass to the pile.

2.1.3. Mixing and Turning

One of the most important criteria in composting is to approximate the ratio for each material to be combining or blend together and to make sure it was sufficient enough to meet the optimum conditions. Ling and Isa [2] decided to adjust the proper C/N ratio after the experiment s were run while according to Fountalakis et al. [1] the composting can be continued well without any adjustment of C:N ratio.

Turning of the organic material during the composting process is also an important factor which helps to maintain aerobic conditions in the composting pile [9]. Fountalakis et al. [1] has mentioned that in total 13 manually turnings for one to two weeks intervals took place for period of 120 days.

2.1.4. Parameters Control

To perform the aerobic composting processes, there are some essential elements required by the composting microorganisms. Which are particles size, temperature, moisture content, pH, and C:N ratio.

a) Particles Size

It is important to shred all the bulking agents before being used for composting, because it yields a more uniform and debris-free final product [16]. The large pieces of paper or leaves and branches packed together do not decomposed quickly in a compost pile. A reduction of particles size will increase the biochemical reaction rate during aerobic composting process. For optimum results the size of solid wastes (bulking agents) should be between 25 and 75 mm [9]. Shredding material also makes it more uniform in size, aerates it, and makes it easier to handle and keep moist. Shredding all the bulking materials had been done by previous study [1], [2] and [17].

b) Temperature

Temperature is directly proportional to the biological activity within the composting system [18]. To maintain microbial activity thus will break down the organic material. The ideal temperature range is needed, the mesophilic, 30 to 38°C, or the thermophilic, 55 to 60°C temperature regions [8]. Within certain limits the rate of this biochemical reaction will about to double for each 10°C rise in temperature [13]. If the temperature gets too high, more than 60°C, it can kill most of desirable microorganism responsible for decomposition. Changes in temperature are commonly used as a measure of microbiological activity underlying the composting process and the temperature profile of composting can be used to determine the stability of organic material [19].

However, composting also can be done well in a low range temperature, which is 23-25°C, lower than the normal temperature of composting pile (55-65°C), due to heat produced from biodegration of organic matter [2]. These also supported by another study done by Van Gestel et al. [4], where their compost pile operate in low range temperature. He found that more hydrocarbons were degraded through composting when the temperature profile was kept at 23°C rather than imposing a 5 -day thermophilic plateau (50°C).

On the previous study also done by Fountalakis et al. [1], the temperature present can become fluctuation in the core of the mixtures with time because there are different thermal behavior between compost containing bulking agent and other.

c) Moisture Content

Achieving the correct moisture content is an important factor in keeping a compost pile working efficiently [20]. Thus, it must be controled between 50% to 60% wet basis. If the moisture content more than 65% of wet basis, water begins filling the pore space and compost becomes saturated with water and begins an anaerobic decomposition process increasing the chances of odor problems, also can reduce composting temperatures. Sludge also tends to compact under its own weight which further reduces the void volume [11].

Also been stated by Chemisinoff [11]. adding water (when needed) at the start of composting is very important to ensure adequate moisture throughout the pile at the time of its formation and thereafter. It is better to start with a pile that is too wet than to risk dryness [10].

Moisture loss is prominent throughout the composting as expected for open windrow system. It is indicated by numerous researches that moisture content to be monitored weekly in a compost pile by adding water [1], [2], [17] and [20].

d) pH

Control of pH is another important parameter in evaluating the microbial environment and waste stabilization. It varies with time during the composting process [9]. The composting works the best when the pH stays between 6.5 and 8.0. The pH level can influence the availability of nutrients, activities and nature microbial populations. The pH level can be changes with lime to raise pH and sulfur to lower pH. A high pH, above 8.5, encourages the conversion of nitrogen compounds into ammonia gas, resulting in nitrogen loss from the compost, with losses of nitrogen in the form of ammonia to the atmosphere not only causes nuisance odors, but also reduces the nutrient value of the compost [21].

Based on previous study [1], mostly compost pile pH level were at range 6.5 to 8.0. Some studies have shown that the acid level at the beginning due to the nitrogen and phosphorus contents which are very low, but towards the end of composting all the compost pile will turned in neutral pH [2].

e) Carbon-to-Nitrogen ratio

The optimum range of carbon-to-nitrogen ratio (C:N) for most organic waste is from 20:1 to 25:1 [9]. This shows that the microorganisms need more carbon than nitrogen. The microorganism uses carbon as a source of energy and nitrogen for building cell structure. If the C:N ratio is below than 20:1, the excess nitrogen will leave the compost as ammonia which contributes to odor problems. But if it is greater than 40:1 it will takes much longer to compost. Carbon materials are usually dry and brown such as straw, paper, fall leaves, and hay, and nitrogen materials are usually green and wet such as grass clippings, and freshly pulled plants) [22].

CHAPTER 3
METHODOLOGY

1.5. Introduction

Figure 3.1 shows the activities and plan during this study which have been divided as activities during last semester (FY1) and this semester (FYP2). Appendix 1: Project *Gantt Chart*

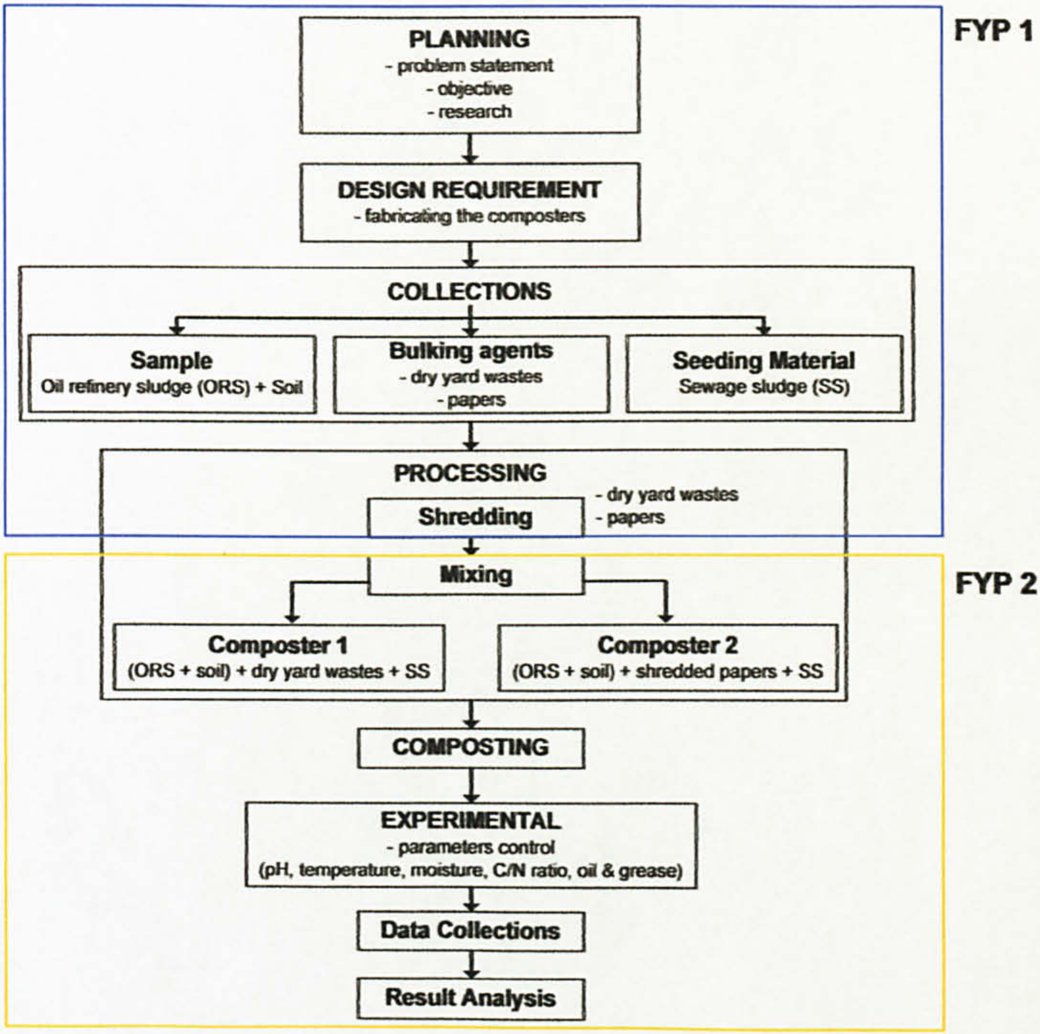

Figure 3.1: Project Planning

3.2. Project Activities

3.2.1. Composter

To achieve the objectives of this project, a cubic composter with the dimension of (0.25m x 0.25m x 0.25m) were used as illustrated in Figure 3.2. Two cubic shape composters were design as same as Fountoulakis et al. [1], but smaller in scale due to limitation of samples and cost of fabrication [1]. The boxes had door at the top and small holes were punctured at all sides of walls for the air circulation. The boxes were located on the top of a bricks that can allow air enter from the bottom through the holes. Rice pack (made from jut) was used as additional padding around the composters which allow passive aeration through the holes.

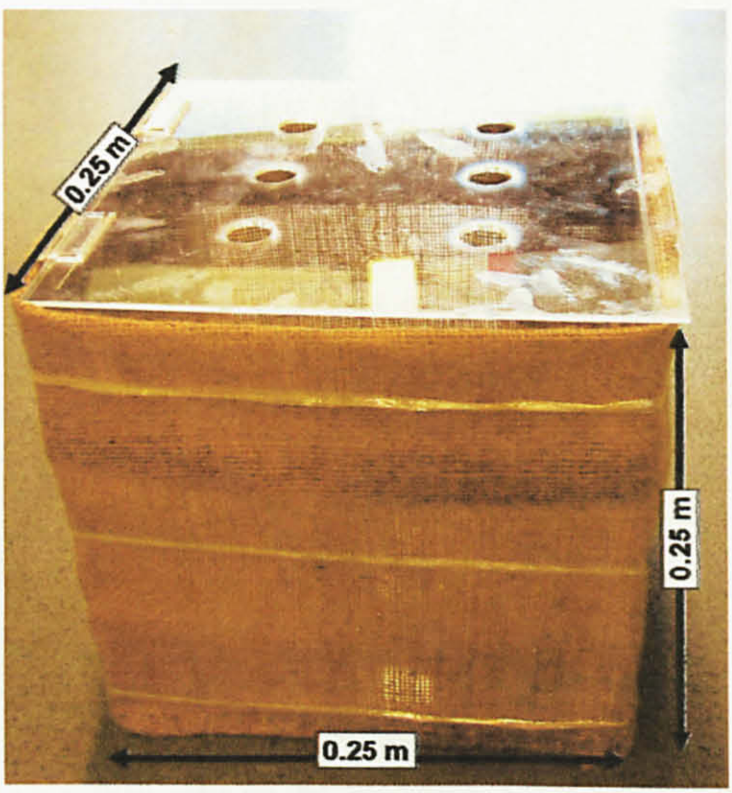

Figure 3.2: Composter

3.2.2. The Sampling

The ORS was collected from the PP(T)SB plant at the Oily Float Tank (T-3006) KR-1, crude tank D901, D902 and D903, and Corrugated Plate Interceptor (CPI), before it enters the Sludge Treatment Plant, transferred by vacuum truck. The ORS was collected in the 20-L bottle and stored in the cool storage. The ORS characterization was shown in Appendix 2, prepared by PP(T)SB. The ORS sample was mixed together with the soil with ratio 1:5 (w/w), approximately 0.4 kg of ORS and 2.2 kg of soil.

3.2.3. Bulking Agents

Recycle office papers and dry yard wastes were used as a bulking agent (Figure 3.3). Recycle office papers were collected at the printing room academic building UTP. The dry yard wastes consist of leaves and branches which were dry and brown in color collected from the green area of the campus. The leaves were collected and stored in plastic bags every week. Then both dry yard wastes and recycle office papers were shredded manually into a small particles size, approximately 25 mm in order to facilitate faster reactions due to more surface area that were exposed and increase the porosity of the compost to allow the air circulation.

Figure 3.3.: Shredded dry yard wastes and recycle office papers

3.2.4. Seeding Material

The refinery sewage sludge had been selected as the source of seeding materials in compost pile. It was collected from the PETRONAS Penapisan (Melaka) Sdn. Bhd at their wastewater clarifier.

3.2.5. Mixing

Initially, the mixing ratio were determined based on proper C:N ratio (20-30:1). Based on the calculation (Appendix 3) the ratios of each material are not really efficient in order to achieve the main objective. Because it required a huge amount of bulking agent instead the ORS. Therefore, regardless to the initial proper C:N ratio, the mixtures in composters were set up and C:N observation and possible adjustments were referred to the efficiency of system. Thus ratio of ORS, bulking agents and seeding material was 1:1:0.5. Which is ORS to bulking agent was 1:1 (v/v), while ORS to seeding material was 1:0.5 (w/w).

Two composters were used, one was filled with 2.6 kg of ORS, 0.4 kg of yard waste and 1.3 kg of sewage sludge is called compost 1. The other was filled with 2.6 kg of ORS, 0.4 kg of shredded paper and 1.3 kg of sewage sludge is called compost 2. The composter 1 and 2 were turning once a week to supply the oxygen to the bacteria and water was occasionally added in the mixtures manually to maintain the moisture content.

3.2.6. Parameter Analysis

The following parameters were measured according during the project according to HACH standard method [21].

3.2.6.1. Moisture Content

Moisture content was measure by weighing the container with some amount of samples and dry it for 24 hours in a 105°C oven. Then reweight the samples by subtract the weight of the container and determine the moisture content using the equation 1.

$$M_n = \frac{W_w - W_d}{W_w} \times 100\ \% \qquad (1)$$

M_n = moisture content (%)

W_w = wet weight of the sample

W_d = dry weight of the sample

3.2.6.2. pH analysis

Compost was spread into a thin layer in a pan, and dried for 24 hours in 105 – 110°C in the oven. 5g of sample of over-dried compost was weight and put into small containers and distilled water was added, it was mixed and stands for 10 minutes before measured using pH paper or calibrate meter. For digested sample of oil refinery sludge the measurement were done using calibrate pH meter.

3.2.6.3. TOC and TKN measurement

TOC and TKN measurements were done according to leaching test [23]. A portion of the sample was taken out to conduct leaching test. The leachate then was used to determine the TKN and TOC. Figure 3.4 shows the leaching test procedure

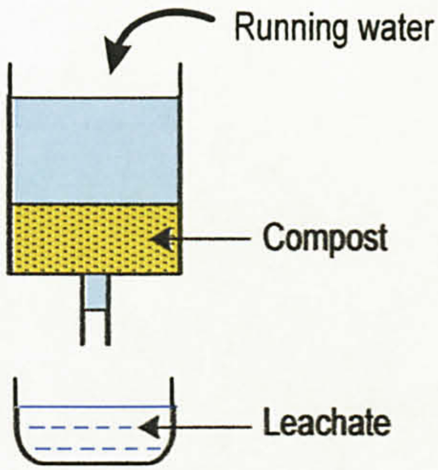

Figure 3.4: Leaching test

Total Organic Carbon (TOC)

Total organic carbon (TOC) provides a speedy and convenient way of determining the degree of organic contamination. A carbon analyzer using an infrared detection system is used to measure total organic carbon. The TOC was calculated using equation 2 and 3.

$$\text{Total Carbon} = \text{Inorganic Carbon} + \text{Organic Carbon} \quad (2)$$

$$\text{Total Organic Carbon} = \text{Total Carbon} - \text{Inorganic Carbon} \quad (3)$$

Nitrogen, Total Kjeldahl (TKN)

Total Kjeldahl Nitrogen was determined using BUCHI Auto Kjeldahl Unit K-370 after the 15-mL of samples was digested with 20-mL of sulfuric acid (98% pure) and 10 tablets of catalyst for 1 hour. The result was calculated using equation 4 {24}:

$$TKN = \frac{V_1 - V_2}{V_0} \times C \times 14.01 \times 1000 \qquad (4)$$

TKN = TKN in mg N/L

V_1 = volume in mL of the acid used for titration of the sample

V_2 = volume in mL of the acid used for titration of the blank

V_0 = volume in mL of the sample

C = molarity of the acid

Mineral Oil and Grease (MOG)

Mineral oil and grease was determined by a gravimetric method. The moist sample was dried for 2- 3 hours at 103±2 °C in a drying oven after been weight in the extraction thimbles. The extraction thimble was close with wipe-tissues then inserts it into the Soxhlet extractor. 100 mL of petroleum ether was filled into the solvent vessel. It was extracted at a temperature of *110 – 130°C* for *20 – 30* extraction cycles (4-6 hours). The solvent was drained into a suitable container. Then oil and grease (hydrocarbon) is extracted from the samples using tetrachoroethylene (C_2Cl_4) and were measured quantitatively by a non-dispersive infrared (NDIR) method using NIC Model OIL-20A Oil Content Meter [25].

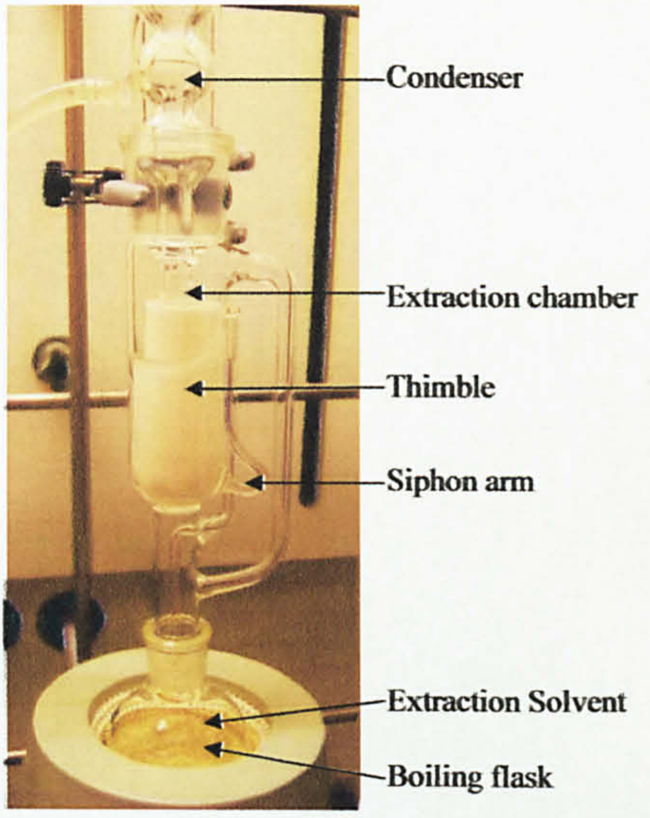

Figure 3.5: Soxhlet Extraction

CHAPTER 4
RESULTS AND DISCUSSION

Material Characterization

Table 4.1 contains characterization of the oil refinery sludge, soil, dry yard waste, paper and refinery sewage sludge. For ORS the physiochemical parameters are within the expected margins compare to others studies [2] and [17] which are high in carbon sources. For the dry yard waste it seems that there is a significant presence of dirt and soil in the collected dry yard waste since the low C:N ratio shows high amounts of nitrogen.. For refinery sewage sludge, a high source of nitrogen was expected, because sewage sludge generally rich in nitrogen content and has a high microbial diversity, with the total microbial population being higher than soil [2]. While the physiochemical parameters for soil was within the expected margins for fertilizer soil.

Table 4.1: Characteristic of the ORS, soil, dry yard waste, paper and sewage sludge.

Parameter	Oil Refinery Sludge	Soil	Dry Yard Waste	Paper	Refinery Sewage Sludge
pH	6.61	7.70	7.34	7.12	7.33
TKN	0.16 %	0.83 %	0.84 %	0.30 %	1414.08 mg/L
TOC	22.12 %	20.75 %	0.82 %	43.40 %	116.94 mg/L
C:N ratio	138.3 : 1	25 : 1	0.97 : 1	144.7 : 1	0.083 : 1
Moisture Content	83.84 %	41.04 %	60.00 %	7.00 %	95.00 %

Composting Process

Figure 4.1 present the temperature fluctuation in the two mixtures with time within week 1 to week 4 of composting. The temperature of the composting mixtures (30-36°C) was lower than the normal temperature of composting piles (55-60°C). Where the maximum temperature reached in the composting process did not exceed 36°C, means that the composting was operate in mesophilic conditions. This situation was similar to previous study done by Ling & Isa [2], and Van Gestel et al. [4]. However, the temperature of the composting mixtures remained low as the temperature maintained at the outdoor site under the roof was affected by the rainy weather mostly every evening. Thus, it is expected that under normal conditions, where the temperature would be higher, and the increased the availability of microorganism of organic matter would increase the reduction level of oil and grease. From week 7 to week 14 of composting, there is fluctuation in the temperature values due to the changing location of composters. However, this fluctuation does not affect so much in oil and grease reduction, because the temperature was varied between 25°C to 40°C.

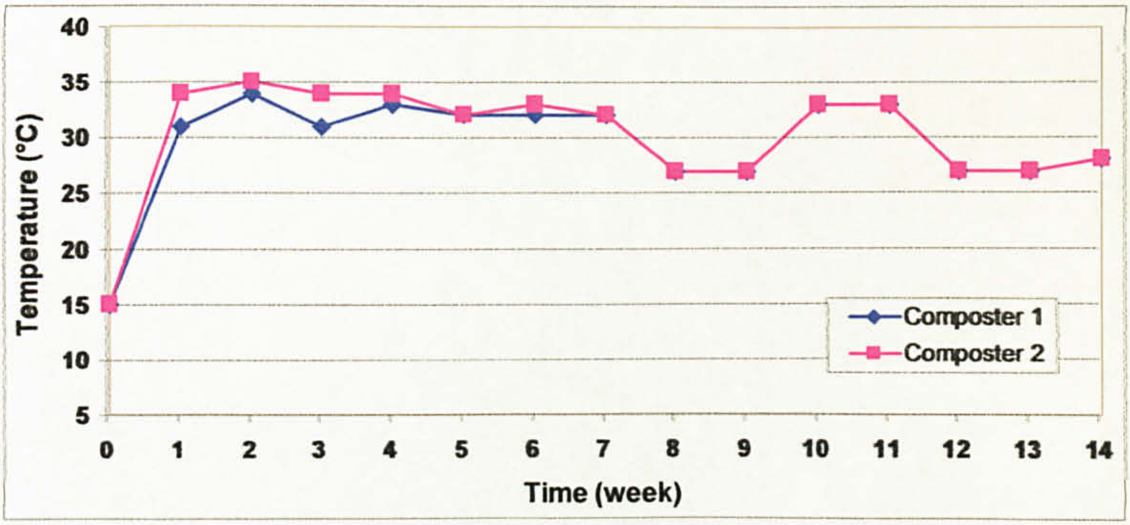

Figure 4.1: Temperature in composters at different weeks of composting

Figure 4.2 present the moisture level for both mixtures. Adjustment of the water content performed and the moisture losses during experiment resulted to moisture content fluctuations among 50.89 – 59.65% and 54.55 – 59.14% for composter 1 and composter 2, respectively. It shows that both composters were in suitable environment for efficient composting (50-60%), some research showed that as moisture content increased from 30% to 60% the metabolic and physiological activities of microorganism were enhanced [1].

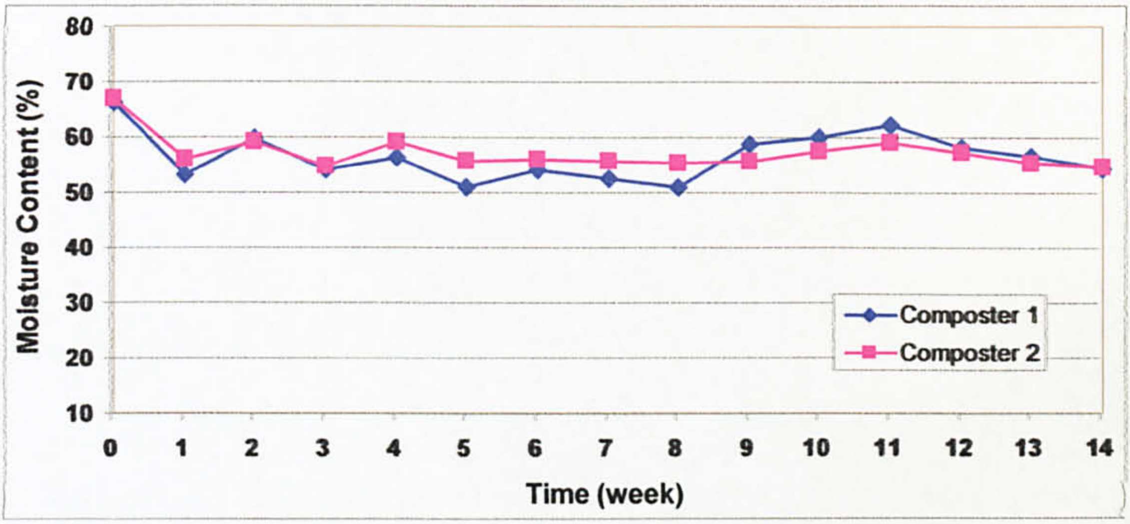

Figure 4.2: Moisture content in composters at different weeks of composting

pH level in the two mixtures with time within week 1 to week 14 illustrated in Figure 4.3. In composter 1, the pH level from week 1 until week 4 were slightly decreasing from 7.17 to 6.55 in week 4, but it still within the optimum range (6.5 – 8.0). Then it goes up again to 7.36 in week 9. While in composter 2, a sudden drop of pH was occurred, from 7.32 to 5.71 in week 1 and week 2. However, from week 3 onwards, the pH level was start increasing to 7.44 in week 9. Within week 10 to 14, the pH fluctuate due to changing location of composters, however the reduction of oil and grease does not really affected because the pH value was still varied 6 to 8.

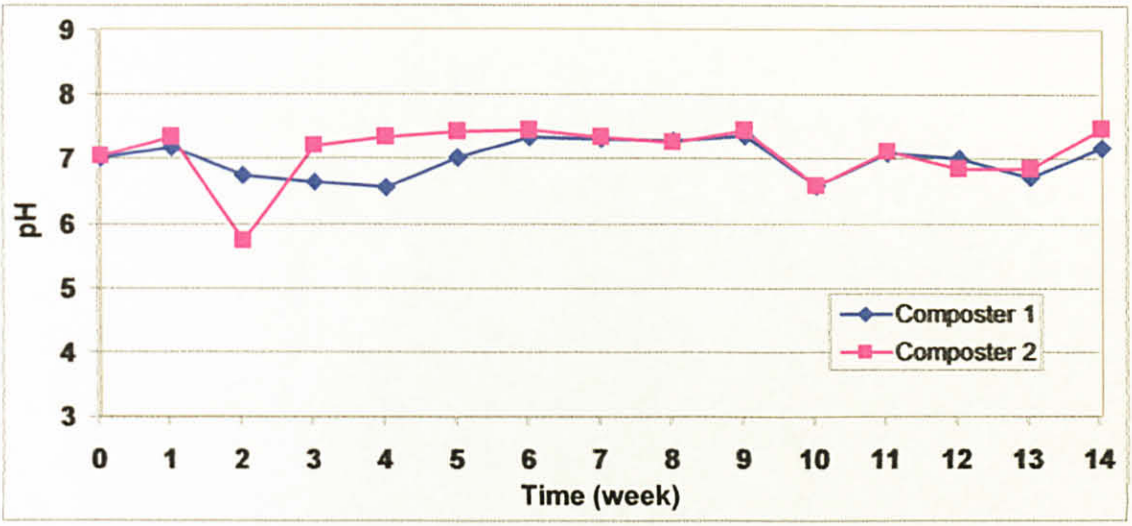

Figure 4.3: pH in composters at different weeks of composting

Figure 4.4 shows the effect of bulking agents on the biodegrading rate of oil and grease. Concentration reduction of oil and grease shows fluctuating pattern mainly due to the heterogeneity of composting pile similar to Ling & Isa [2]. In order to reduce the fluctuation of data, efforts was taken by obtain a homogenized sample by collecting a sample that was composed of several materials after a uniformly mixing the whole pile. As stated by Ling & Isa [2], there still lies a possibility that the collected sample may contain oil and grease significantly more or less than a pile average.

In composter 1, the concentration of oil and grease was reduced from 310.7 ppm to 179 ppm, and drop to 77.4 ppm in week 3. A sudden drop in week 3 can be explained due to heterogeneity of the sample. From week 3 to week 5 the oil and grease concentration was rise from 77.4 to 183.3 ppm.

While in composter 2, the concentration of oil and grease in week 0 to week 2 was reduced from 366.7 ppm to 194.5 ppm. Then, the oil and grease concentration were keep reducing until it reach week 5 which had reduced to 171.9 ppm, but it slightly rise in week 6 with concentration of 189.8 ppm.

Overall, the oil and grease removal seemed to have stabilized after the 6th week of composting for both composters. Total oil and reduction for composter 1 and composter 2 was 44.1% and 55.9%. The remaining hydrocarbon in the contaminated soil is considered as non-removable biologically even for long duration of treatment [2]. From the highest removal of oil and grease (55.9% for composter 2), it may conclude that the remaining (44.1%) are hydrocarbons that are recalcitrant as they stubbornly adsorb onto organic soil constituents an onto soil organic matter.

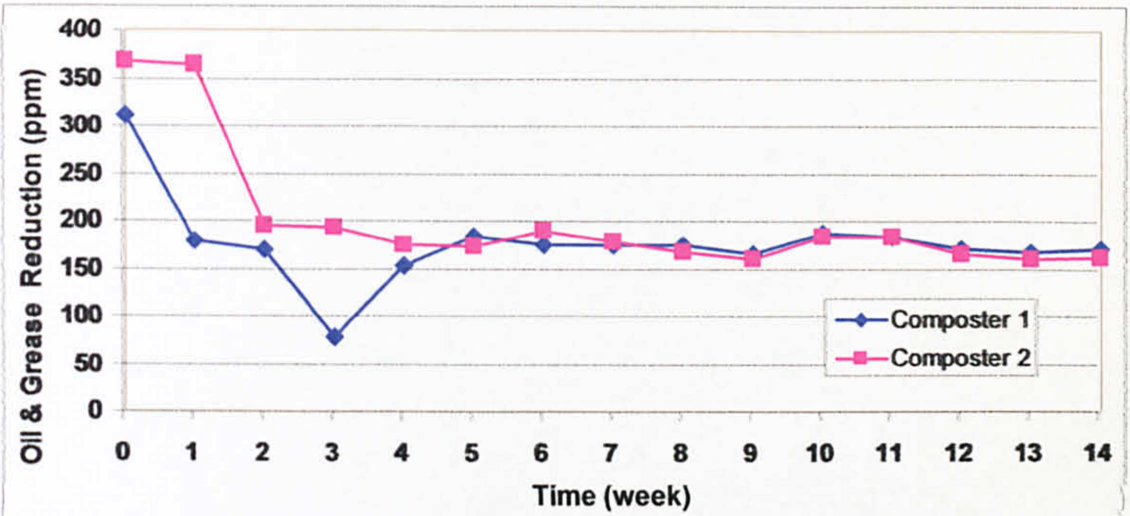

Figure 4.4: Oil and grease level in composters at different weeks of composting

CHAPTER 5
ECONOMIC BENEFITS

The cost spent in constructing the full scale of composter cannot be easily determined because it depends on the volume and the quantities of materials need to be compost. In comparison with land farming which has traditionally been the biological treatment method chosen to dispose of most oil sludge, aerobic composting is more environmentally friendly and to be less damaging local property values than land disposal, it may be easier to site a composting facility than a new landfill.

Indirect cost of land farming gives a lot of advantages to choose aerobic composting over land farming. Land farming takes approximately a longer time to degrade the oil sludge contaminated soil compare to aerobic composting. Thus, the longer time require, the higher cost are needed to manage it. Land farming also had a problems to control contaminant migration from the incorporation zone. Volatilization of organics and wind-blown dust represent air pathways for migration of waste constituents. Infiltration of rainfall can leach waste constituents into groundwater, a major environmental concern. So, an adequate construction and maintenance of control structure (eg., berms, runoff channels) were needed [26]. Compare to aerobic composting which is more in control situation

CHAPTER 6
CONCLUSION AND RECOMMENDATION

The 14-week study has shown that there is much potential in using composting as a method for treating oil sludge contaminated soil. Although reduction of oil and grease in contaminated soil has been achieved during aerobic composting in both systems, shredded paper shows better performance than dry yard waste. However, both of bulking agents does not show very significant different in oil and grease reduction compare to each other.

For further study, they need to conduct the same study in bigger scale compost pile which allows temperature profile to be developed and further the duration of experiment to investigate the final reduction of oil and grease. Also can done a variation of bulking materials and soil volume to find the optimum percentage combination to be mixed with ORS.

REFERENCES

1. M. S. Fountoulakis; S. Terzakis; E. Georgaki; S. Drakopoulou; I. Sabathianakis; M. Kouzoulakis; T. Manios. (2008) *Oil Refiery Sludge and Green Waste Simulated Windrow Composting*. Biodegration (2009) 20:177-189. doi:10.1007/s10532-008-9211-5
2. Chua Choon Ling & Mohamed Hasnain Isa. (2006) *Bioremediation of Oil Sludge Contaminated Soil by Co-composting with Sewage Sludge*. Journal of scientific & Industries Research. Vol. 65, April 2006, pp. 364-369
3. Jose´ A. Marı´n, Jose´ L. Moreno*, Teresa Herna´ ndez & Carlos Garcı´a. (2006) *Bioremediation by composting of heavy oil refinery sludge in semiarid conditions.* Biodegradation (2006) 17: 251–261 _ Springer 2006. DOI 10.1007/s10532-005-5020-2
4. Kristin Van Gestel, Joris Mergaert, Jean Swings, Jozef Coosemans, Jaak Ryckeboer, (2003) ***Bioremediation of diesel oil-contaminated soil by composting with biowast.*** **Environmental Pollution 125 (2003) 361–368. doi:10.1016/S0269-7491(03)00109-X**
5. Xiuxia Zhang, Jicheng Wang, Yundo Zhang, Qiyou Liu, Chunxiang Geng and Jun Lu (2007) *Influential Factors in Fermentation of Refinery Oily Sludge.*
6. Land farming: http://www.pdo.co.om/hseforcontractors/online_library/downloads/20060902083035.ppt **(May 2010)**
7. **Lewis M. Naylor, Geoffrey A. Kuten & Daniel J. Hagen. (1989)** ***Shredded*** *Magazines and Glossy Paper as A Bulking Agent.*
8. Composting: Yard and Municipal Solid Waste. TECHNOMIC Publishing Co. Int (1995)
9. George Tchobanoglous, Hilary Theisen and Samuel Vigil (1993) *Integrated Solid Waste Management,* Engineering Principles and Management Issues. McGRAW-HILL INTERNATIONAL EDITIONS

10. Holger Kirchmann & Wasiyhun Ewnetu (1998) *Biodegradation of petroleum-based oil wastes through composting.* Biodegradation 9: 151–156.
11. Nicholas P. Chemisinoff, Ph.D. (2003) Handbook of Solid Waste Management and Waste Minimization Technologies
12. Frank R. Spellmen. (1996) *Wastewater Biosolids to Compost.*
13. Roger Tim Haug. (1980) *COMPOST ENGINEERING Principles and Practice.*
14. http://aces.nmsu.edu/pubs/_h/H-110.pdf **(May 2010)**
15. http://www.shoshonebannocktribes.com/documents/YardWasteComposting.pdf **(May 2010)**
16. http://compost.css.cornell.edu/yardwastecomposting2.pdf **(October 2009)**
17. **Zhi-Zhou Chang and Richard W. Weaver (1998)** ***Organic Bulking Agents for*** *Enhancing Oil Bioremediation in Soil.* Bioremediation Journal /(3): 173-180 (1998)
18. http://www.ecochem.com/t_compost_faq2.html **(20 February 2010)**
19. **Andrew M. Fogarty & Olli H. Tuovinen* (1991)** ***Microbiological Degradation*** *of Pesticides in Yard Waste Composting.* Microbiological Reviews (June 1991), p. 225-233 Vol. 55, No. 2
20. http://www.compost-info-guide.com/measure_moisture.htm **(20 February 2010)**
21. **HACH (1999).** ***Wastewater and Biosolids Analysis Manual.*** **Digestion and** Selected Methods for Determining Metals, and Other Related Parameters
22. University of Arkansas Division of Agriculture. *Composting.* (http://www.arhomeandgarden.org/composting/cnratio.htm, **October 2009)**
23. **Nor Asmat Bt Adnan (July 2009)** ***Bioremediation Treatment of Oily Sludge*** *Using Composting Method.* Final Year Report, Universiti Teknologi Petronas.
24. Manual of Total Nitrogen Determination according to Kjeldahl with the BUCHI Kjeldahl Line
25. Manual of Oil and Grease
26. Michael D. LaGrega, Philip L. Buckingham, Jeffrey C. Evans and Environmental Resources Management (2001) *Hazardous Waste Management,* Water Resources and Environmental Engineering. McGRAW-HILL INTERNATIONAL SECOND EDITION

Appendix 1:

Table A1-1: Project Gantt Chart for Final Year Project I

ID	TASK NAME	JULY		AUGUST				SEPTEMBER				OCTOBER				NOVEMBER			
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	**PLANNING**																		
2	Outline the project objectives																		
3	Determine the scope of work																		
4	Set the project boundary																		
5	Research																		
6	**Design Requirement**																		
7	Design the composter																		
8	Fabrication																		
9	**COLLECTIONS**																		
10	Sample																		
11	Bulking agents																		
12	Seeding materials																		

Table A1-2: Project Gantt Chart for Final Year Project II

ID	TASK NAME	JANUARY		FEBRUARY				MARCH				APRIL				MAY			
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	**PROCESSING**																		
2	Shredding bulking agent																		
3	Mixing																		
4	Composting																		
5	**EXPERIMENTAL**																		
6	pH																		
7	Moisture content																		
8	Temperature																		
9	Nitrate																		
10	Oil and grease																		
11	**DATE COLLECTION**																		
12	**RESULT ANALYSIS**																		
13	Submission of Progress Report																		
14	Poster Exhibition																		
15	Submission of Dissertation																		
16	Oral Presentation																		

Appendix 2: Oily Sludge Waste Sample Analysis (based on-dry weight basis)

No.	Parameter	Reference Method	Accreditation to ISO/IEC 17025	Unit	Result
1	Total solid @ 105°C	APHA 2540 E	Yes	%	23.6
2	Moisture content @ 105°C	By calculation	Yes	%	76.4
3	Volatile solids @ 550°C	APHA 2540 E	Yes	%	17.0
4	Fixed solids @ 550°C	By calculation	Yes	%	83.0
5	Ash content @ 900°C	Oven drying QWI-CH/17-8	Yes	%	33.7
6	Loss of ignition @ 900°C	By calculation	Yes	%	66.3
7	Total metals on dry-weight basis @ 550°C	USEPA 3050B, 6010B	Yes	mg/kg	
7.1	Arsenic	USEPA 3050B	Yes	mg/kg	<1
7.2	Barium	USEPA 3050B	Yes	mg/kg	931
7.3	Boron	USEPA 3050B	Yes	mg/kg	<10
7.4	Cadmium	USEPA 3050B	Yes	mg/kg	0.58
7.5	Chromium (total)	USEPA 3050B	Yes	mg/kg	20.1
7.6	Copper	USEPA 3050B	Yes	mg/kg	46.6
7.7	Lead	USEPA 3050B	Yes	mg/kg	13
7.8	Mercury	USEPA 7471A	Yes	mg/kg	0.13
7.9	Nickel	USEPA 3050B	Yes	mg/kg	15.3
7.10	Selenium	USEPA 3050B	Yes	mg/kg	<5
7.11	Silver	USEPA 3050B	Yes	mg/kg	<0.5
7.12	Tin	USEPA 3050B	Yes	mg/kg	<5
7.13	Zinc	USEPA 3050B	Yes	mg/kg	579

Appendix 3: Blending Calculation

Oil refinery sludge	Yard waste	Paper
moisture content = 83.84%	moisture content = 60%	moisture content = 7%
nitrogen = 0.16%	nitrogen = 0.842%	nitrogen = 0.3%
C:N = 138.3 : 1	C:N = 0.97 : 1	C:N = 144.7 : 1

1) Percentage composition for yard waste and ORS.

a) for 500g of yard waste:	water	: 500g (0.60) = 300g
	dry matter	: 500g - 300g = 200g
	N	: 200g x 0.00842 = 1.684g
	C	: 0.97 x 1.684g = 1.633g
b) for 500g of ORS:	water	: 500g (0.8384) = 419.2g
	dry matter	: 500g - 419.2g = 80.8g
	N	: 80.8g x 0.0016 = 0.1293g
	C	: 138.3 x 0.1293g = 17.882g

1) Amount of ORS to be added to 500g of yard waste to achieve a C:N ratio of 25.

$$\frac{C}{N} = 25 = \frac{\text{C in 500g of yard waste} + x(\text{C in 500g of ORS})}{\text{N in 500g of yard waste} + x(\text{N in 500g of ORS})}$$

x = weight of ORS required

$$25 = \frac{1.633\text{ g} + x\,(17.882\text{ g})}{1.684\text{ g} + x\,(0.1293\text{ g})}$$

$$x = 2.7623\text{ g ORS / 500 g yard waste}$$

1) Percentage composition for paper and ORS.

a) for 500g of paper:	water	: 500g (0.07) = 35g
	dry matter	: 500g - 35g = 465g
	N	: 465g x 0.003 = 1.395g
	C	: 144.7 x 1.395g = 201.8565g
b) for 500g of ORS:	water	: 500g (0.8384) = 419.2g
	dry matter	: 500g - 419.2g = 80.8g
	N	: 80.8g x 0.0016 = 0.1293g
	C	: 138.3 x 0.1293g = 17.882g

1) Amount of ORS to be added to 500g of paper to achieve a C:N ratio of 25.

$$25 = \frac{201.8565\text{ g} + x\,(17.882\text{ g})}{1.395\text{ g} + x\,(0.1293\text{ g})}$$

x = weight of ORS required

$$x = -11.3984\text{ g ORS / 500 g paper}$$

Appendix 4: Results

Table A4-1: Result of composter 1

WEEK	PH	TKN	TOC	C:N	moisture	O&G	TEMP.
0	7.02	7.939	60.567	7.63 : 1	66.24	310.7	15
1	7.17				53.2	179	31
2	6.75				59.65	169.1	34
3	6.64				54.05	77.4	31
4	6.55				56.36	152	33
5	7.02				50.89	183.2	32
6	7.34				54.11	174.6	32
7	7.3				52.56	174.3	32
8	7.28	55.106	52.625	0.95 : 1	51	173.9	27
9	7.36	49.97	48.27	0.97 : 1	58.82	166.1	27
10	6.57	40.629	57.45	1.4 : 1	60	188	33
11	7.09	3.269	38.978	11.92 : 1	62.21	184.3	33
12	7	96.67	65.006	0.67 : 1	58.24	171.8	27
13	6.7	26.62	67.466	2.53 :1	56.64	166.5	27
14	7.16	30.36	69.503	2.298 :1	54.31	170.9	28

Table A4-2: Result of composter 2

WEEK	PH	TKN	TOC	C:N	moisture	O&G	TEMP.
0	7.03	54.639	64.56	1.18 : 1	66.84	366.7	15
1	7.32				55.9	364	34
2	5.71				59.14	194.5	35
3	7.2				54.82	191.9	34
4	7.34				58.92	174.3	34
5	7.41				55.66	171.9	32
6	7.44				55.87	189.8	33
7	7.32				55.67	178.85	32
8	7.26	83.126	74.208	0.89 : 1	55.46	167.9	27
9	7.44	49.97	47.706	0.95 :1	55.66	160.1	27
10	6.59	31.28	40.511	1.3 : 1	57.58	183.6	33
11	7.11	3.736	26.987	8.34 : 1	59.06	183.3	33
12	6.85	26.619	66.348	2.49 :1	57.21	165	27
13	6.84	77.989	54.689	1.43 : 1	55.17	159.4	27
14	7.46	30.355	45.824	1.5 :1	54.55	161.7	28

Appendix 5: Pictures of Composter

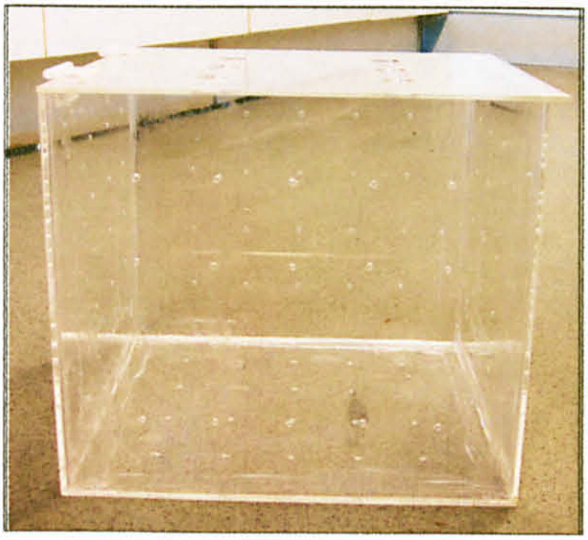

Figure A5-1: Composter without wrapping

Figure A5-2: Composter with wrapping

Figure A5-3: Composter 1

Figure A5-4: Composter 2

Figure A5-5: Location of composters