PRODUCTION OF BIO-FERTILIZER FROM LANDFILL LEACHATE THROUGH VERMICOMPOSTING WITH RICE HUSK ADDITION AS A BULKING AGENT

MOHAMMED ZAINUL ARIFF B ZAHARUDDIN

BACHELOR OF CHEMICAL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

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MOHAMMED ZAINUL ARIFF BIN ZAHARUDDIN

Thesis submitted in partial fulfilment of the requirements
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Dedicated to my parents, and my family.

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ABSTRACT

Landfill leachate is a very complex high-strength wastewater which contains suspended and dissolved materials removed from the decomposing waste in the landfill body. It consists of soluble organic and inorganic constituents. It is highly toxic and has detrimental effects on the environment. Landfill leachate is generally characterized by extremely high concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal-nitrogen, and heavy metals (e.g. Cd, Cu, and Zn). However, it is also a source of nutrients, which consists of high organic matters (e.g. nitrogen, phosphorus, potassium and trace elements) that make leachate has a potential to be developed as a bio-fertilizer. The vermicomposting process by using rice husk as the additive found to be an effective way to reduce the toxicity of the leachate and stabilize the nutrients level for the leachate to be applied safely on soil. Therefore, a study was conducted to identify the amount of nitrogen-N, phosphorus-P, and potassium-K composition in the leachate. N, P, and K content in the leachate can be utilized through vermicomposting process to produce high and better quality of bio-fertilizer. Parameters that would be monitor along the composting process are the temperature, compost mass ratios, pH and moisture content to produce high quality of final product that could serve as a soil amendment in the shortest time. The matured end-product also will be undergoes a phytotoxicity assays on the growth of eggplants to test whether it can be used as a bio-fertilizer. Finding from this work is crucial for landfill leachate management as to minimize its pollution risk to the environment. An economic estimation showed that the production cost of leachate as fertilizer is low and that an interesting profit margin could be obtained through the commercialization of composted leachate as a bio-fertilizer.

ABSTRAK

Cecair ‘leachate’ adalah sisa air berkonsentrasi tinggi yang kompleks serta mengandungi bahan-bahan terampai dan larut yang terhasil daripada proses penguraian sisa pepejal. Cecair ini terdiri daripada bahan-bahan toksik sama ada organik atau bukan organik dan mempunyai kesan buruk kepada alam sekitar. Cecair ‘leachate’ umumnya dikenali oleh keperluan oksigen biokimia (BOD) dan keperluan oksigen kimia (COD) yang tinggi, serta mengandungi ammonia-nitrogen, dan logam berat seperti kadmium, tembaga dan zink. Walau bagaimanapun, ia juga merupakan sumber nutrien, yang terdiri daripada bahan-bahan organik (contohnya nitrogen, fosforus, kalium dan unsur surih) yang membuatkannya berpotensi untuk dijadikan sebagai baja organik. Proses vermi-pengkomposan dengan menggunakan sekam padi sebagai bahan tambahan didapati sebagai cara yang berkesan untuk mengurangkan kadar toksik cecair ‘leachate’ selain mampu menstabilkan tahap kandungan nutrien yang membolehkannya selamat digunakan ke atas tanah. Oleh itu, satu kajian telah dijalankan untuk menentukan kuantiti serta komposisi nitrogen (N), fosforus (P), dan potassium (K). Kandungan N, P, dan K yang terkandung di dalam ‘leachate’ boleh diekstrak dan dimaksimakan melalui proses vermi-pengkomposan untuk menghasilkan kompos yang berkualiti tinggi yang mampu digunakan sebagai baja organik untuk tumbuhan. Parameter yang akan dikawal sepanjang proses pengkomposan adalah suhu, nisbah kompos, pH dan kandungan lembapan untuk menghasilkan produk kompos yang yang berkualiti tinggi dalam jangka masa singkat, yang mampu menyumbang kepada penyuburan tanah. Kompos akhir yang telah matang akan digunakan untuk pertumbuhan pokok terung untuk memastikan kompos yang dihasilkan benar-benar selamat untuk digunakan sebagai baja organic. Dapatan kajian ini adalah penting untuk pengurusan tapak pelupusan sampah untuk mengurangkan risiko pencemaran cecair ‘leachate’ kepada alam sekitar. Anggaran ekonomi menunjukkan bahawa kos pengeluaran cecair ‘leachate’ sebagai baja adalah rendah dan margin keuntungan yang tinggi mampu diperoleh melalui pengkomersialan leachate yang telah menjalani proses pengkomposan sebagai baja organik.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
BOD	Biochemical Oxygen Demand
C	Carbon
COD	Chemical Oxygen Demand
CO_2	Carbon Dioxide
K	Potassium
MSW	Municipal Solid Waste
N	Nitrogen
NaOH	Sodium Hydroxide
NHx-N	Ammoniacal Nitrogen
NOx-N	Nitrogen Nitrate
$NOx\text{-}NL^{-1}$	Nitrogen-Leached Nitrate
NO_3	Nitrate
P	Phosphorus
RBC	Rotating Biological Contactor
TOC	Total Organic Carbon
TSS	Total Suspended Solids
WSC	Water-Soluble Carbon
NH_3-N	Ammonia Nitrogen
TOC	Total Organic Carbon

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Leachate is the liquid that drains or pass through a landfill that is usually contains both dissolved and suspended materials. Leachate generations nowadays has become a major problem for municipal solid waste (MSW) landfills and also affected surface and ground water (Raghab et al., 2013). The natural characteristic of leachate that contains nitrogen, phosphorus, potassium and trace elements has been a potential and a viable way to generate new economic sources. The term 'vermicomposting' is basically refers to the use of earthworms for composting organic matter in developing organic fertilizer. Vermicomposting process can help in eliminating pathogens, parasites and weed seeds content in the leachate as well as improving soil structure (Chowdhury et al., 2014). Other than that, it can help in reducing substrate odors while increasing the content of available form of macronutrients. Production of high quality vermicompost requires optimal conditions for the survival and development of earthworms. Several parameters such as pH, C/N ratio, temperature and moisture content need to be considered in preparing an optimum condition of the vermicompost. Humidity is an important factor for the activity of earthworms. It is recommended that the moisture content of the compost should be in a range of 50-70%, while the optimum temperature for earthworms range from 12 to 28^{o}C (Bożym & Engineering, 2016). Since the leachate contains high amount of nitrogen, so rice husk, which is a good bulking agent will be used as the additive in the composting process as it rich in organic carbon that is needed to stabilize the carbon to nitrogen (C/N) ratio of the compost. The good compost required a C/N ratio between 25:1 to 30:1 to be used as a soil amendment (USDA-NRCS, 2011). The composted leachate is the source of organic matter with a unique ability to improve the chemical, physical and biological characteristics of soils (Romero et al., 2013). Nowadays, the demand on bio-fertilizer has increasing rapidly. Global bio-fertilizers market size was estimated at USD 535.8 million in 2014 (Agrochemical and

Fertilizers, 2016). Growing awareness about product benefits is expected to augment demand over the forecast period. Figure 1.1 shows the increasing market revenue of bio-fertilizer over 10 years forecast period.

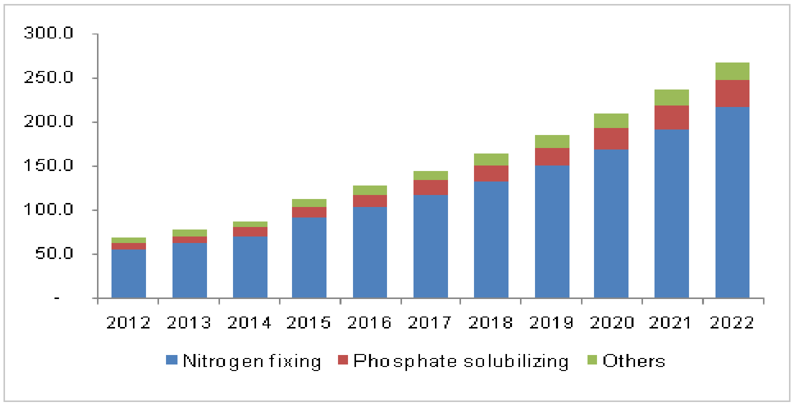


Figure 1.1: U.S. bio-fertilizers market revenue by product (USD Million), 2012-2022 (Market & Analysis, 2017)

Thus, a study will be conducted to identify the amount of Nitrogen-N, Phosphorus-P, and Potassium-K, (NPK) composition in the composted materials (leachate + soil + rice husk) throughout the composting process. These NPK are numerous building biological that plants need for a healthy growth. Thus, the NPK content could be utilized to produce high and better quality of bio-fertilizer by composting the materials in the right ratio and keeping them in the optimum condition. This research focus on controlling the NPK and its processing parameters that affecting the value of NPK particularly. The basic parameters of the leachate like biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH and total suspended solid (TSS) will be tested first. Next, it will be composted with soil and rice husk in three different mass ratios. The samples will undergo the NPK analysis by using HACH Spectrophotometer throughout the vermicomposting process which takes four weeks to finish. The outcome of this research is to produce value added end-product (i.e: the bio-fertilizer), which has significance effect on the growth and yield of the plants.

1.2 Motivation

Excessive reliance on chemical fertilizers has led to the exhaustion of soil of its nutrients reserves. Thus, bio-fertilizer serves as an alternative way to deal with this issue as to maintain a long term soil fertility and sustainability. Heavy use of chemical fertilizers has also led to the environmental pollution and contamination of soil, has polluted water basin and making the crop more prone to diseases. Other than that, massive waste generation is attracting much global attention in recent time due to increasing population, changing consumption patterns, urbanization and industrialization. Landfilling is the most common method in dealing with municipal solid wastes worldwide, and leachate produced from landfills as a result of water percolating through or emerging from the buried waste is a major environmental concern. Harmful leachate generated from landfill in high amount, which is 3 million litre per day in Malaysia (Alaribe & Agamuthu, 2010), nowadays are released into underground water stream and has contaminated the soil.

In 2008, about 620 million tons of rice straw and 125 million tons of rice husks, referred to as residues were produced in Asia, and this quantity is increasing every year. These residues have no commercial values in most places and have been disposed of in various ways. Burning of rice husk residues is a popular disposable practice and has caused severe air pollution in some regions (Pode, 2016). Alternatively, the residue has been incorporated into the soil, but in turn it has led to methane emissions from rice fields and thus contributing to climate change. Thus, there is an urgent need to find ways and means to alleviate these problems.

1.3 Problem Statement

Leachate in the landfill have a good potential to be used as an organic fertilizer as it contain carbon, nitrogen, phosphorus, potassium and trace elements that can be used as nutrients by plants (Romero et al., 2013). Finding a way to properly dispose leachate in the landfill without contaminating the water and soil are major concern of waste management. There are numerous studies before investigated the potential of sewage sludge to be develop as a bio-fertilizer through vermicomposting process as an alternative way to deal with environmental issues. However, there is still no research working on the development of landfill leachate as a fertilizer and soil amendment. Since landfill leachate has quite similar properties as sewage sludge, which contain high concentration of nitrogen (regarded as an alternative nitrogen source for plants) and rich in nutrients and organic matters, this study focus on composting the leachate to produce final valuable product that serve as a good soil amendment and have significance contribution to agricultural industry.

Many different methods are currently in use to treat landfill leachate such as rotating biological contactor (RBC) process, activated carbon adsorption systems, and activated sludge treatment. Most of the methods are comparatively much expensive when compared to composting method. Thus, composting process is considered as the most efficient leachate treatment in term of operational cost, since the final product of the vermicomposting process are marketable.

1.4 Objectives

The followings are the objectives of this research:

1) To produce bio-fertilizer from landfill leachate through vermicomposting process by using rice husk as the additive for the composted mixture.

2) To determine the best ratio of leachate to rice husk in preparing the vermicompost to produce a bio-fertilizer.

3) To test whether the matured vermicompost could be used as a bio-fertilizer by running phytotoxicity assay on the growth of eggplants.

1.5 Scopes of Study

The following are the scopes of this research:

1) NPK analysis on the compost every week from the start until the end of the composting period.

2) Measure the pH and moisture content of the vermicompost every week as to promote an optimal condition to ensure successful vermicomposting and development of the earthworms.

3) Measure the total organic carbon (TOC) and determine the change in C/N ratio along the vermicomposting process.

4) Prepare the compost based on three different ratios of leachate to rice husk which are:
   I. 1:1 (Sciubba et al., 2013)
   II. 2:1 (Cruz et al., 2010)
   III. 3:2 (Pandebesie & Rayuanti, 2013)

5) Examine the growth of eggplants by using the matured compost (based on the average number of leaves and the plant height).

CHAPTER 2

LITERATURE REVIEW

2.1 Potential of Leachate as a Bio-fertilizer

Waste generation and subsequent accumulation generated by rapid increase in human populations is one of the major problems confronting future generations. This is caused by improper waste disposal that will lead to bigger problems in term of environmental pollution as well as disease occurrence, not only to human beings but also to animals. Landfilling is the most common method in dealing with municipal solid waste worldwide, and leachate produced from landfills as a result of water percolating through or emerging from the buried waste is a major environmental concern. Landfill leachate consists of soluble organic and inorganic constituents. It is highly toxic and has detrimental effects on the environment.

Leachate in the landfill have a good potential to be used as an organic fertilizer as it contain carbon, nitrogen, phosphorus, potassium and trace elements that can be used as nutrients by plants (Cruz et al., 2010). Cheng et al., (2011) has tested the leachate irrigation on several plants and the result has shown that none of the plants exhibited retarded growth after 90 days. Each plants experienced positive increment in tree height, standing leaf number and basal diameter. Figure 2.1 shows the biomass of seedlings of 19 tree species harvested after irrigation with water and leachate. Most of the plants have greater seedlings biomass after irrigated with leachate.

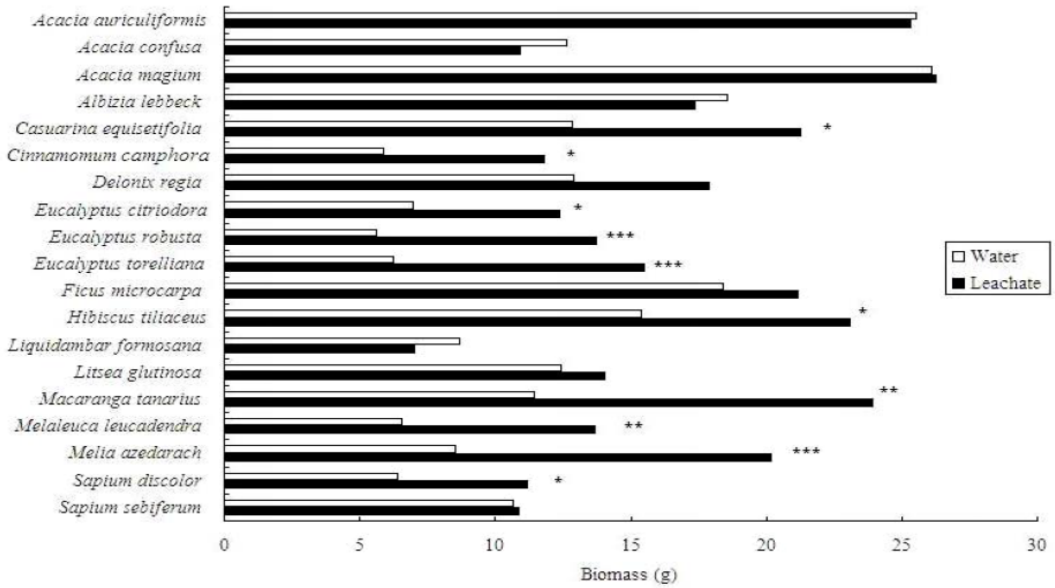


Figure 2.1: Biomass of seedlings of 19 tree species harvested after 90-day irrigation with water and diluted leachate (Cheng et al., 2011)

The high concentration of ammoniacal-nitrogen (NHx-N) in the leachate could be regarded as an alternative nitrogen source for plant. Nitrogen is usually the limiting element in unfertilized ecosystems. The amount of available nitrogen in soil is small, while the quantity removed annually by plants is comparatively large. It should not be surprising that leachate irrigation remarkably increases soil NHx-N content up to 4 times. Landfill leachate which contained less than 1 mg nitrogen leached-nitrate ($NOx\text{-}NL^{-1}$) could increase soil nitrogen nitrate (NOx-N) by 25 times after 40 weeks. Research was done by Cheng & Chu, (2011) for nitrogen effect on the plant by leachate, fertilizer and water irrigation. The plants with leachate irrigation received continuous supply of nitrogen in a readily available NHx-N form, all of which had tissue nitrogen contents higher than their respective control (with water). There was a luxury consumption, during which nitrogen was taken up in excess of the plant's physiological demand. The data is shown in Table 2.1 below for tissue nitrogen content, before and after 12 weeks of receiving application of diluted leachate and fertilizer.

Table 2.1: Tissue nitrogen content, before and after 12 weeks by leachate and fertilizer irrigation (Cheng & Chu, 2011)

Species	Treatment	Tissue N content (% w/w)	
		Aboveground	Underground
Hibiscus tiliaceus	Initial	1.19 ± 0.52	0.85 ± 0.37
	Water	1.20 ± 0.34 b	0.90 ± 0.26 b
	Fertilizer	2.20 ± 0.71 b	1.63 ± 0.50 b*
	Leachate	5.00 ± 0.50 a*	3.45 ± 0.36 a*
Litsea glutinosa	Initial	2.11 ± 0.09	1.62 ± 0.05
	Water	2.10 ± 0.20 c	1.55 ± 0.18 c
	Fertilizer	3.17 ± 0.32 b*	2.14 ± 0.22 b*
	Leachate	4.90 ± 0.58 a*	3.51 ± 0.38 a*
Paspalum notatum	Initial	1.87 ± 0.13	1.33 ± 0.05
	Water	1.93 ± 0.36 b	1.44 ± 0.19 b
	Fertilizer	1.76 ± 0.03 b	1.31 ± 0.12 b
	Leachate	3.90 ± 0.48 a*	2.75 ± 0.29 a*
Vetiveria zizanioides	Initial	1.16 ± 0.36	0.91 ± 0.31
	Water	0.79 ± 0.06 b	0.63 ± 0.12 b
	Fertilizer	1.68 ± 0.32 a	1.25 ± 0.31 ab
	Leachate	1.90 ± 0.62 a	1.34 ± 0.44 a

Leachate irrigation could provide a steady source of nitrogen in a readily available form to meet the annual nutrient requirement which could not be achieved by a single dose of fertilizer, since the available nitrogen from the fertilizer declines quickly by leaching. Normally, repeated applications of fertilizers at lower rates are required to offset the leaching loss.

Landfill leachate also contains high total organic carbon (TOC) and could increase soil fertility up to 4 times. The use of leachate as bio-fertilizer would minimize the consumption of chemical fertilizers which need higher production cost and energy. Since leachate is a waste product, no direct production cost is associated. Research done by Romero et al. (2013) has proved that a raw leachate always presents a higher germination power when compared with commercial fertilizers. Table 2.2 below presents the relationship between the germination index comparison between raw leachate and commercial fertilizers.

Table 2.2: Germination indexes (%) for a raw leachate, digested leachate and commercial fertilizers (Romero et al., 2013)

Dilution	**Raw leachate**		**Commercial Fertilizers**	
	Grass	**Barley**	**Grass**	**Barley**
1/10	128.3	107.1	0	0
1/100	120.8	127.7	42	50.7
1/1000	121.2	150.2	72.1	75.9

The leachate in landfill contains organic matter, nitrogen and phosphorus available for plant growth that indicate a high germination index. However, it may also contain pathogenic microorganisms and weeds that will have negative effect when it applied directly to soil. To be used for agricultural purposes, these pathogens should be destroyed, which can be achieved with the thermophilic phase of composting (Cooperband, 2002).

2.2 Vermicomposting

Vermicomposting is a degradation process involving interactions between earthworms and microorganisms which is economical, viable and sustainable option for waste management. It can be operated in contained space to produce a high quality product (bio-fertilizer) and is easy to handle. Until now, earthworms have been successfully attributed in the vermicomposting of urban, industrial and agricultural waste as to produce added value bio-fertilizer that is useful for soil fertility and is harmless to the environment. Research into the potential use of earthworms to decompose and manage sewage sludge began in the late 1970s and it has been termed vermicomposting or vermistabilization (Khwairakpam & Bhargava, 2009). It can be considered as a low-cost waste treatment and management system.

Vermicomposting is practiced for the mass production of earthworms with the multiple objectives of waste management, soil fertility and detoxification and vermicompost production for sustainable agriculture. The practice was started in the middle of 20th century and the first serious experiments were established in Holland in 1970, and subsequently in England and Canada. Later vermicomposting practice was followed in USA, Italy, Philippines, Thailand, China, Korea, Japan, Brazil, France and Australia (Environmentalist, 2017). The American Earthworm Technology Company started a 'vermicomposting farm' in 1978-1979 with 500 ton / month of vermicompost production. Japan also have imported 3000 metric ton of earthworms from the USA during the period between 1985 to 1987 for cellulose waste degradation. The Aoka Sangyo Co. Ltd has 1000 ton / month plants processing waste from paper pulp and the food industry. This produced about 400 ton of vermicompost and 10 ton of live earthworms per month. In Italy, vermiculture is used to biodegrade municipal and paper mill sludges. Aerobic and anaerobic sludge are mixed and aerated for more than 15 days in a 5000 m^3 of sludge with 5 kg addition of earthworms. In about 8 months, the sludge is converted into vermicompost (Sharma, 2003).

Earthworms have a potential both to increase the rate of aerobic decomposition and composting of organic matter as well as to stabilize the organic residues in the sludge (Sinha et al., 2009). They feed readily upon components of the wastes, rapidly transforming them into vermicompost, reduce the pathogens to safe levels and ingest heavy metals. Earthworms have a great ability to increase the aerobic degradation rate as well as the composting process of organic matter. Besides, it also can stabilize the organic residues contained in the landfill leachate. The harmful pathogens in the leachate can be successfully removed by the antibacterial coelomic fluid released by the earthworms. The essential nutrients like nitrogen, phosphorus and potassium in the leachate can also be mineralized by the action of earthworms. The earthworms act as an aerator, grinder, chemical decomposer and biological stimulator (Environmentalist, 2017). The components of the leachate are softened by the grume produced in the mouth of the earthworms and transferred to the earthworms' oesophagus. Then, the soften components are neutralized by the calcium released by the inner walls of oesophagus and passed to the gizzard and the intestine for further action. The components are then grinded into small particles in muscular gizzard before passed on to the intestine for enzymatic digestion. The particles are then decomposed by proteases, lipases, amylases, cellulases and chitinases secreted in the earthworms' intestine. Finally, the humification process converted the organic particles into complex amorphous colloids before being discharged from the earthworm as excreta or vermicast (Sinha et al., 2009).

Earthworms stimulate and enhance the microbe populations that act as an organic matter decomposer through improving aeration. They also host thousands of decomposer microbes in their gut and discharge them along with nutrients nitrogen and phosphorus in their excreta (Singleton et al., 2003). These nutrients will further used by the microbes for multiplication and enhance action through the vermicomposting process. Earthworms in general are highly resistant to many pesticides and have been reported to concentrate those pesticides and certain type of heavy metals in their tissues. These properties of earthworms can be utilized for effluent treatment and heavy metals and pesticides removal from industrial and agricultural waste. Earthworms are important secondary decomposers after natural existed microbes, and vermicomposting in nature can be stated as ongoing process if the natural populations of the earthworm are undisturbed. Vermicomposting promoted the growth of beneficial nitrogen-fixing and decomposer microbes and fungus in the degraded waste.

Earthworms participation enhance natural biodegradation and decomposition of wastes from 70 to 80 percent (with optimum temperature and moisture content) which significantly reducing the composting time by several weeks. The process is nearly odor free because of excreted coelomic acid from the body of earthworm promote the aerobic condition in the vermicompost mixture. Study by Maribel, (2005) also showed that a higher germination index (the value most used to evaluate the maturity level) of vermicomposting end-product compared to normal composting. This indicate that vermicomposting promote a shorter period toward the end stable phase. On the other hand, the vermicomposting process also modified the physical and physicochemical properties of the substrate. It has significantly increased the size of particle by 73 to 90% as well as the bulk density, as a consequence of the substrate transferred through the gut of the earthworm.

Vermicomposting carried out in a properly prepared station. The side walls of the station must strictly attach, as well as the bottom. The station of vermicompost should consist of a layer drainage, pipes which collecting worm tea as to avoid an overflow of liquid at the bottom part of the vermicompost station. Figure 2.2 shows the scheme of the vermicomposting of sludge station.

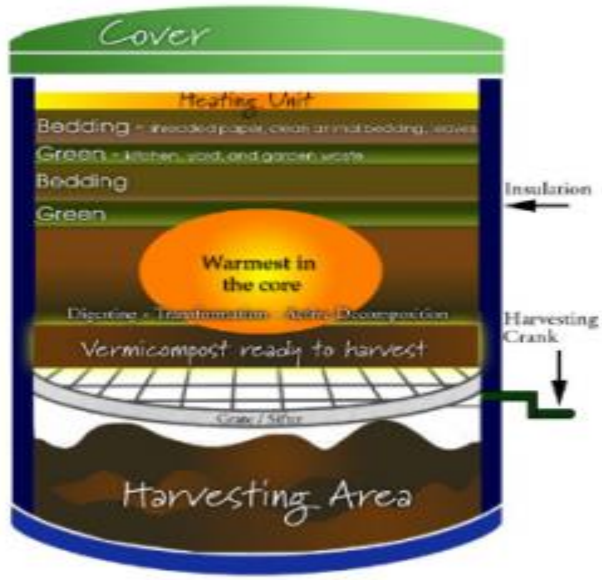


Figure 2.2: Sewage sludge station diagram

Vermicompost production takes place in several stages. Basically, there is no need to flip through the compost mass, which is a routine when dealing with a normal composting process in pile. The most important treatment is a constant water spray and regular feeding for the earthworms. The moisture content is the important controlling parameter throughout the vermicomposting process since a large hydration or dehydration may cause decay and death of the earthworm population. Therefore, it is important to include a well-functioning drainage below the vermicompost. It is also recommended that the station is installed with cover as to minimize evaporation or loss of ammonia nitrogen, NH_3-N throughout the vermicomposting process.

Reddy & Ohkura, (2004) have reported that a higher growth of various plants characteristics in vermicompost compared to normal composting treatment of sewage sludge. This can be related to presence of greater amount of micro nutrients as well as the microbial metabolites, the plant-growth promoting hormone-like substances. The earthworms have also influence the development of the plants and promoted stem elongation, root initiation, and root biomass. However, the quality of vermicompost and its significant effect on plant growth may depend upon a variety of factors, which may needs a further investigation.

2.2.1 Biology of earthworms

Earthworms are long, narrow, cylindrical, segmented animals without bones. They have a muscular gizzard which consistently grinds the food (fresh and decaying plant debris, living or dead larvae and microorganisms (bacteria as well as protozoa). The gut of the earthworm is inhibited by millions of decomposer microbes. They are basically a bisexual animals and cross fertilization occurs as a rule. Copulation may last for about an hour, before the worms then separated. Later, the clitellum of each worm eject cocoon where sperms enter to fertilize the eggs. Up to three cocoon per week are produced normally and there are about 10 – 12 tiny new earthworms emerge from each cocoon. Then, the earthworm will continue to grow throughout their life and the number of segment continuously reproduce from a what so called 'growing zone' located near the anus. Generally, a single earthworm contains 70 to 80 percent high quality lysine rich protein on a dry weight basis. The life span of the earthworm may vary between three to seven years depending upon the type of earthworm species and the ecological condition (Environmentalist, 2017).

2.2.2 Factors affecting optimal earthworm activity

Production of vermicompost requires optimal conditions for the survival and development of earthworms. The effectiveness of earthworms in the stabilization of landfill leachate or sewage sludge is greatly affected by several factors including leachate and sludge age, initial nutrient content, aerobic conditions, moisture content, compost temperature, and the C/N ratio (Pattnaik & Reddy, 2010). It is recommended that an adequate moisture content for successful vermicomposting process is between 70 to 80 percent (Bożym & Engineering, 2016) and the ideal temperature for optimum earthworm activity is between 15 and 25^{o}C (Sinha et al., 2009). The moisture content should be monitored regularly due to a specific diet of the earthworms, which draw nourishment in the form of semi-liquid. The temperature of the vermicompost also need to be maintain within the optimum range since the temperature which is below 15^{o}C and above 25^{o}C may reduce the reproduction rate of the earthworms.

Generally, earthworms can survive in a pH range of 4.5 – 9, but they function best at neutral pH 7.0. The pH can be adjusted by adding alkaline products throughout the process such as chalk, limestone or acidic such as peat, leaves or conifers. Earthworms are very sensitive to touch, light and dryness. Water logging in the soil can cause them to come to the surface. Carbon to nitrogen (C/N) ratio can be an indicator to determine the stability of the vermicompost. An appropriate C/N ratio of 25 can be considered good for vermicomposting and reduction of volatile solids. Landfill leachate may have low C/N ratio since it contain higher nitrogen. This can be improved throughout the vermicomposting process by the addition of carbon-rich materials (bulking agents) such as rich husk and wheat straw.

2.2.3 Advantages of vermicomposting

The quality of a final vermicompost is significantly stable, rich in key minerals and beneficial soil microbes when compared to the normal composting method since composting method promote a high temperature in a thermophilic phase (up to 55 ^{o}C) in which many beneficial microbes are killed during that phase. Besides, earthworms also maintain the fully aerated (aerobic) system by their burrowing actions. The aerobic processes are much faster than anaerobic processes (Powerknot, 2016). The aerobic condition will then led to a nearly odor-free composting process.

The earthworms release coelomic fluids that have antibacterial properties and destroy all the available pathogens. They also consume upon protouzoa, bacteria and fungi as food along the vermicomposting process. Singleton et al., (2003) has found that there are some bacteria and fungi (Penicillium spp. And Aspergillus spp.) in the intestine of the earthworms which produce antibiotics that can kill the pathogens. Gupta & Garg, (2008) also stated that pathogens parasitic eggs and E.coli were reduced to safe levels in vermicomposted sludge. Other than that, it is reported that 90% of faecal coliforms and 100% of helminths were successfully removed from the sludge after vermicomposting process (Rodríguez-canché et al., 2010). These indicate that the action of earthworms could greatly reduce the high pathogens content in the landfill leachate through the vermicomposting period.

Vermicomposting is also able to reduce heavy metals content and toxic chemicals of the leachate and sewage sludge. The high concentration of heavy metals can be bio-accumulated by the tissues of the earthworms without affecting their physiology. Heavy metals that can be successfully reduced include cadmium, mercury, lead, copper, manganese, iron and zinc. Maribel, (2005) confirmed that the stabilized sewage sludge contain a metal levels within the standard set by the USEPA after 60 days of vermicomposting. Laos et al., (2002) also proved a significant removal of lead and cadmium from vermicomposted sewage sludge. The heavy metals are accumulated by the chloragogen cell in the earthworms in which they are immobilized in the small spheroidal chloragosomes and debris vesicles contained in the cell.

The nitrogen and phosphorus in the landfill leachate can be mineralized by the earthworms so that it will be bio-available to plants as nutrients. The final product is homogenous, rich in N, P, and K, micronutrients beneficial soil microbes and the level of contaminants are significantly reduced (Affiliation et al., 2017). It is proved that vermicomposted sludge showed two times more available magnesium, 15 times more available nitrogen and seven times more available potassium compared to the surrounding soil (Sharma, 2003b). The resulting product appears to retain more nutrients for longer period of time since vermicompost made from the sludge and leachate contains enzymes like amylase, lipase, cellulose and chitinase, which continue to break down organic matter in the soil to release nutrients and make them bio-available to plant roots for longer period.

2.3 Rice Husks as a Vermicomposting Additive

Bulking agent is a carbon-based material that adds structure (bulk) to a compost pile. Examples of bulking agents are wood chips, sawdust, rice husk, dry leaves and animal bedding. They are mainly used to maintain the moisture and C/N ratio of the compost. These bulking agents are used in the composting process due to the need of compost, such as nutritive values, moisture, pH and air supply to compost material. Study by Chang & Chen, (2010) has shown the bulking agents like rice husk successfully increased the degradation and hence, resulted a very good quality compost of food waste. They have been mixed with waste materials to adjust the moisture content, N content, C/N ratio, and void spaces between particles in the past (Leconte, Mazzarino, Satti, Iglesias, & Laos, 2009), since most waste materials like sewage sludge contain too high moisture and too low C/N ratios for efficient composting. Another study by (Suthar, 2009) has shown that the use of bulking agent in the vermicomposting of sewage sludge resulted the high quality of vermistabilization and better nutritive values. Bulking agents do so much for composting, that it is difficult not to fully appreciate its value. Different bulking agents not only modify physical properties of the composting feedstock, but also change the biodegradation kinetics and composting performance (Adhikari et al., 2009).

In this research, the bulking agent that is going to be use as the additive for the composting process is the rice husk. The rice husk is the outermost layer of the paddy grain that has been separated from the rice grains during the milling process. Around 20% of paddy weight is husk and rice production in Asia produces about 770 million tonnes of husk annually (Francis, 2016) It is largely considered a waste product that was often burned or dumped on landfills.

Figure 2.3: Rice husk

Rice husk was evaluated as a possible additive to vermicomposting, to ascertain its contribution to the biological efficiency and nutrient content. The dominant physical property of rice husk that has water high absorption capacity of the composting mixture is one factor that affected composting rate. It also increased free air space of the composting pile, which aerobic process would accelerate composting rate with higher temperature reached. It is a good material to be mixed with raw compost material with high water content.

High amount of carbon in the rice husk act as a source of energy for the microbes and the earthworms to perform degradation activity of the organic matter during vermicomposting process. Other than that, the high carbon content in the rice husk are used to control and maintain the C/N ratio toward the end of the vermicomposting period, since leachate is rich with nitrogen sources (nitrate nitrogen, NO_3-N and ammonia nitrogen, NH_3-N). Rice husks are characterized by a waxed surface and high silica contents which reduce water-holding capacity and could limit microbial attack. Thus, it can be expected that, when mixed with the same nutrient-rich leachate, rice husk will enhance the composting efficiency and final compost quality in terms of length of the process, degree of stabilization, final quantity and quality of organic matter and available nutrients. Since rice husk are subjected to have low nutrients contents, this research will focus more on the extraction of nutrients (NPK) from the leachate only.

Rice husks are added to the vermicomposted mixture to provide the structural support to create inter-particle voids (Zhou et al., 2014). It could add vital air space to the compost pile that will allow aerobic microbes to breathe as they undergo decomposing activity. As the free air space of the composting matrix increase, composting rate would also accelerate and higher temperature reached due to more air flow through the composting matrix (Chang & Chen, 2010).

The pH value is one of the important factors that influence composting quality since it could manipulates the rate of biodegradation. Composting is a process consists of serial microbial activities and microbes are only survived at specific pH value. The use of rice husks allows us to control the pH value of composting. The pH value should be between the range of 6 to 8 for the optimum biodegradation condition (Banegas et al., 2007). Composted leachate with soil tend to have too high of a moisture content and limited structure for air space. Rice husks used are able to give the microbes room to breathe as it has air space in it because of its light in weight and its low bulk density. As the rice husks contain high percentage of carbon, it provides enough carbon to balance out the high nitrogen content of a landfill leachate (Doublet et al., 2011). The ratio of carbon to nitrogen in composted materials is an important consideration in optimizing the composting process and the composting process occurs more efficiently, when the carbon to nitrogen (C/N) ratio is between 20 to 30 while the moisture content between 50% and 65% (Cooperband, 2002).

4 Bio-fertilizer and its Significant to Agriculture

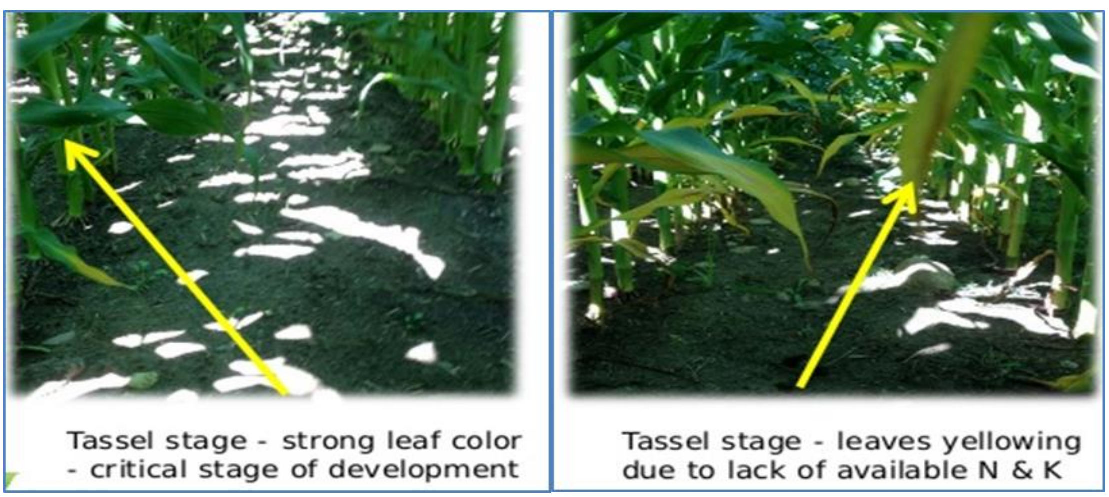
Massive use of chemical fertilizers has led to the pollution and contamination of the soil, has polluted water basins and destroyed micro-organisms in the soil. It is estimated that by 2020, to achieve the targeted production of 321 million tonnes of food grain, the requirement of nutrients has been 28.8 million tonnes while, their availability has been only 21.6 million tonnes being a deficit of about 7.2 million tonnes (Mahdi et al., 2010). Therefore, many researches have been conducted to fulfil the requirement of nutrient by plant. Bio-fertilizers serve as the best modern tool and gift of agricultural science as a replacement to the chemical fertilizers.

Bio-fertilizers define as the product containing carrier based (solid or liquid) living micro-organisms which are agriculturally useful in terms of nitrogen-N fixation, phosphorus-P solubilisation and potassium-K nutrient mobilization, to increase the productivity of the soil and crop (Chatterjee et al., 2006). Furthermore, bio-fertilizers are the formulation of living microorganisms, which are able to fix atmospheric nitrogen in the available form for plants either by living freely in the soil or being associated symbiotically with plants (Dumitrescu et al., 2008). Bio-fertilizer have significant influence on the growth and yield of the plants (Chandrasekar et al., 2005). The primary components in the bio-fertilizer are the NPK which it consist of 3.5% - 4% nitrogen, 2% - 2.5% phosphorus and 1.5% potassium.

Bio-fertilizers, which are mainly come from agricultural waste residues such as manure, food waste and sewage sludge are well known subjected to suitable local bio-fertilizer. These organic wastes contain high level of nutrients, especially nitrogen as well as high amount of organic matters that are needed by plant. The usage of landfill leachate as a developed bio-fertilizer can be an effective alternative to the chemical fertilizer. It is believe to improve soil texture, pH, maintaining long term soil fertility and sustainability and produce plant growth promoting substances.

Bio-fertilizer have significant influence in the on the growth and yield of the plants (Chandrasekar et al., 2005). Apart of that, chemical fertilizers pose a health hazard and microbial population problem in soil besides beings quite expensive and making the cost of production high. In such a situation, the bio-fertilizers play a major role (Hanapi et al., 2013). Several authors such as Dumitrescu et al., 2008); and Cruz et al., (2000) concentrate on the quality and the influenced on the growth and yield of plants by the application of bio-fertilizer farming system.

Bio-fertilizer, which mainly come from agricultural waste residues such as cow manure, vegetable waste or municipal solid waste compost like sewage sludge and landfill leachate are often identified as suitable local bio-fertilizer. These organic wastes contain high levels of nutrients such as N, P and K and high amounts of organic matter (Suthar, 2009). According to the studies, the usage of sewage sludge as bio-organic fertilizer can be an effective alternative to chemical fertilizers. Besides that, bio-fertilizers are minimizing the ecological disturbance, cost effective and eco-friendly. They improve soil texture, pH, maintaining long term soil fertility and sustainability and produce plant growth promoting substances such as amino acids and vitamins. Figure 2.4 shows the effect of both bio-fertilizer and chemical fertilizer on plants.



a) b)

Figure 2.4: a) Effect of bio-fertilizer and b) Effect of chemical fertilizer

The landfill leachate that have been well vermicomposted could be used as an organic soil amendment or bio-fertilizer for plants uptake. Compost products earmarked for agricultural crop production, horticultural plant production, gardening or land use reclamation should be applied correctly and in the proper amount. Although composted landfill leachate not a top choice for soil application, it could serve as excellent compost useful to improve soil health and plant growth (Alaribe & Agamuthu, 2010).

2.5 N, P, and K's Influence on Soil and Yield

Bio-fertilizers show their nutrients content with three bold numbers on the package. These numbers represent three different compounds: Nitrogen (N), Phosphorus (P), and Potassium (K), which can also described with the letters N, P, and K. The three numbers labelled correspond to the percentage of these materials compounding the fertilizer. Basically, there are numerous building blocks of life that plants need for a healthy growth. Soil often lack of these elements either naturally, or as a result of over cultivation, and needs to have these building blocks put back into it.

Nitrogen (N) is the essential recognized as major nutrient. The amount of N provided can control the balance between vegetative and reproductive growth. Adequate availability of N in the soil at the right time is important to support optimal crop growth and production. N helps plant grow quickly, while also increasing the production of seed and fruit, and bettering the quality of leaf and forage crops. It is also a component of chlorophyll, the substance that gives plant their green colour, and also aids in photosynthesis (Evans, 1989). N is a part of every living cell. The two forms of N which plants take up are in the ammonia ($NH4$) and nitrate ($NO3$) ion froms. Most agronomic crops take up the most of their nitrogen in the nitrate ion form. Lack of nitrogen and chlorophyll means that plants cannot utilize sunlight as an energy source to carry on essential functions such as nutrient uptake. Research by (Shimako et al., 2016), has proved that foliar or leaf applications of nitrogen is one form of application that can be supplement a plants nitrogen requirements during the growing cycle.

Phosphorus (P) is important for a healthy root and is used more heavily during blooming and seed set. It is released in soil through decomposing of organic matter. It plays an important role in energy transfer in living cells and also for the formation of carbohydrates and fatty acids. It, also a key player in the photosynthesis process, plays a vital role in a variety of the things needed by plants. P supports the formation of oils, sugars, and starches. The transformation of solar energy into chemical energy is also aided by P, as well as is development of the plant, and the ability to withstand stress (Islam et al., 2011). Additionally, P encourages the growth of roots, and promotes blooming. Phosphate is a very important plant nutrient (macro-nutrient) needed for the plant to complete its normal production cycle. The highest level of P in young plants is found in tissue at the growing stage. As plants mature, most of the P moves into the flower and then to the seed or fruit.

Potassium (K), is the element required for successful crop production and is important for general health of plants. It plays an important role in the formation of chlorophyll and other plant compounds. It is also known to help with disease resistance and is essential to the room for water uptake and nutrient transport within plants. Therefore, K is essential nutrient plants demand, assists in photosynthesis, fruit quality, the building of protein, and the reduction of disease. An important function of K is its influence in efficient water use (Bergmann, 2016). It helps in the process of opening and closing of plant leaf pores, called the stomata. K is found in the cell walls which surround stomata. Adequate amounts of K can increase stress conditions on plants during drought conditions. K is also responsible for producing quality crops.

There is no general standard on the optimum NPK fertilizer ratio. The most important nutrient element being is the nitrogen. Excessive application of nitrogen only has a depressing effect on both phosphorus and potash uptake. It is generally suggested that balance nutrition should be ensured to the crop by applying phosphate and potassium also, irrespective of the level of nitrogen. Fertilizers with ratio of 1:1:1 is considered all-purpose and is also labelled as general-purpose fertilizers.

Farmers in Vietnam and Cambodia obtained 25% higher yields with deep placement of NPK fertilizer (bio-fertilizer) over the broadcasting of chemical fertilizer (Theng et al., 2014). In Bangladesh, yield of rice was increased by 15-25 %, while expenditure on commercial fertilizer was decreased by 24-32 % when NPK fertilizers were used as the source of plant nutrients. Deep placement of bio-fertilizers which contain high N, P, and K also offered environmental and economic benefits. In tidal ecosystem, nutrient management strategies would be different from other ecosystem. Because, applied NPK fertilizers are washed-out from rice field during tidal flood. So, deep placement of all fertilizers would be effective rather than broadcasting. Moreover, sufficient amount of nutrients was added to the soil during tidal sedimentation. Costal soils are blessed with tidal deposition containing organic matter and plant nutrients consisting of N, P, K and other materials (Islam et al., 2010).

Study by (Adejumo, 2010) discovered that appropriate management of N, P, and K fertilizers leading to a reduction in infection of inflorescence blight and increase in yield is an additional tool for minimizing the use of pesticides on cashew. It is clear that N, P, and K are not necessarily the most important elements you need for your plants to grow well. In fact, elements such as carbon, hydrogen, oxygen, sulfur, magnesium, copper, cobalt, sodium, boron, molybdenum, and zinc are just as important to plant development as N, P, and K. The bad news was that this has led to a vast amount excess nutrients building up in our streams, lakes, and rivers, because chemical fertilizers are often over-applied. Surprisingly, much of this overuse of chemical fertilizers is actually from homeowners, and not from farmers, who typically carefully measure and apply the least amount of fertilizer necessary to get the job done in order to grow their crops in the most cost effective way possible.

Based on the literature review, vermicomposting process is believed to be an efficient low-cost method to treat the landfill leachate as well as to extract and stabilize the available nutrients contained in the leachate. The use of rice husk as a bulking agent can be considered as a catalyst for the vermicomposting process since it can reduce the composting period and also enhance the microbial degradation process since it provide sufficient amount of organic carbon which then be used as a source of energy for the microorganisms and earthworms activities. Abundant supplied of organic carbon also important as to promote a balance carbon to nitrogen ratio since the concentration of nitrogen will tend to increase gradually toward the end of the vermicomposting process as the result of nitrification while the carbon content will decrease over time due to mineralization and decomposition of organic matter by the earthworms and the loss of carbon compound as carbon dioxide, CO_2.

CHAPTER 3

MATERIALS AND METHODS

3.1 Overall Workflow

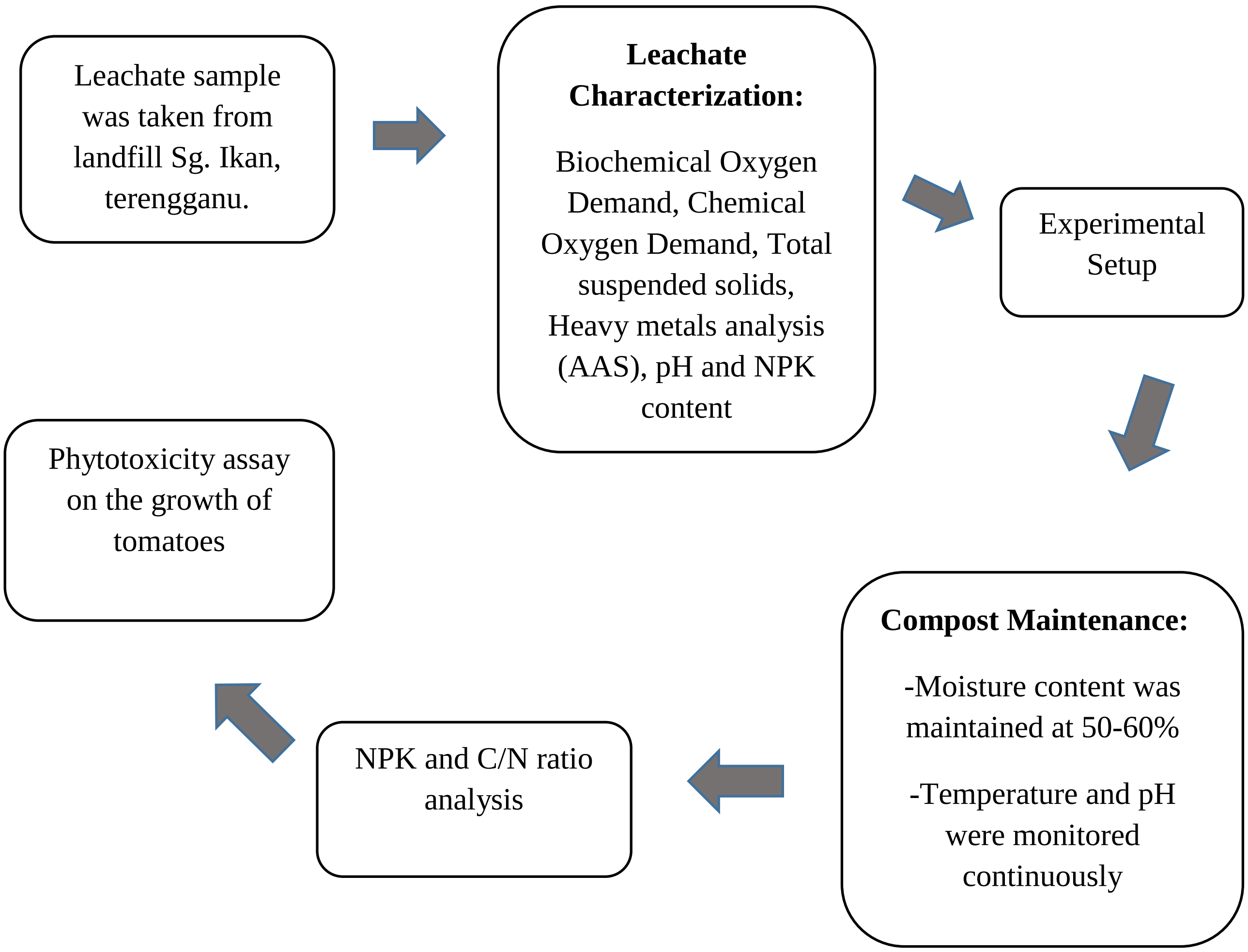


Figure 3.1: Overall research workflow

3.2 Materials

Materials that will be used to produce the compost are soils, rice husk, landfill leachate and water. For NPK analysis, materials that will be used are NitraVer 5 Nitrate Reagent Powder Pillow for N test; Acid Hydrolyzable Test Vial, 1.00 N sodium hydroxide (NaOH) and PhosVer3 Powder Pillow for P test; and Potassium 1 Reagent Pillow, Potassium 2 Reagent Pillow and Potassium 3 Reagent Pillow for K test.

3.3 Methods

1) Leachate collection and analyzation

The leachate was taken from leachate pond in Sg. Ikan Landfill, Terengganu. Leachate sample has been analyzed first, for N, P and K content, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS) level as well as presence of heavy metals analysis, Atomic Absorption Spectroscopy (AAS).

2) Experimental Setup

I. The materials (leachate + soils + rice husk as an additive) were mixed at three different ratios of leachate to rice husks which are 1:1 (Sciubba, Cavani, Marzadori, & Ciavatta, 2013), 2:1 (Cruz et al., 2010) and 3:2 (Pandebesie & Rayuanti, 2013) in a total of six containers, since each ratios was duplicated. The total mass of each ratio was set to 1 kg and the volume of leachate added had been fixed at 150 ml.

II. The rice husks was grinded to reduce its size and to optimize air porosity when apply to the compost.

III. The mixed materials were moistened to enhance the decomposition process.

IV. The shredded materials were piled in the container, cover with plastic to increase the temperature, maintain moisture and minimize escape of gases to the atmosphere (Badar & Qureshi, 2014). The cover was opened slightly to let oxygen entering the container, allowing aerobic decomposition process to take place. Turning process of the compost has been done weekly.

V. 40 healthy earthworms of the same species were placed in each compost after the moisture content have reached the stable range which is about 70 to 80% (Bożym & Engineering, 2016), which provide an initial favorable environmental condition for the earthworms.

VI. The NPK content of the mixture were analyzed weekly until the end of the composting period.

VII. The moisture content and pH of the piled were monitored weekly.

VIII. After a month, the compost was expected to be matured. Matured compost is the one that does not generating heat, had no smell of decomposing material and looked like soil (Cruz et al., 2010).

IX. The phytotoxicity test was conducted on the matured compost to test whether it can be used as bio-fertilizer and is safe for environment.

3) Moisture Content

Apparatus and materials needed: weighing boat, spatula, samples of compost. The steps involve in determining the moisture content are as below:

I. The empty weighing boat was weighted.

II. 10 g of vermicompost sample (wet weight) was added to the weighing boat.

III. The sample (10 g of samples + weighing boat) was dried up for 24 hours in the oven at temperature of 110^{o}C.

IV. The sample was then reweighted.

V. The weight of the empty weighing boat was subtracted by the reweighted sample to determine the dry weight. The moisture content was calculated by the following equation:

$$\text{Moisture content} = \left(\frac{wet\ weight - dry\ weight}{wet\ weight}\right)\ x\ 100$$

4) NPK Analysis

The content of N, P and K in each vermicompost was extracted throughout the vermicomposting process. The samples were analyzed using HACH spectrophotometer. The methods and chemicals used during the analysis were listed in Table 3.1.

Table 3.1: Methods and Chemicals for N, P and K analysis

Method	Chemical	Component analyzed
Cadmium Reduction Method	NitraVer 5 Nitrate Reagent Powder Pillow	N
PhosVer 3 with Acid Hydrolysis Method	Total and Acid Hydrolyzable Test Vial, 1.0 N Sodium Hydroxide, PhosVer 3 Powder Pillow,	P
Tetraphenylborate Method	Potassium 1 Reagent Powder Pillow, Potassium 2 Reagent Powder Pillow, Potassium 3 Reagent Powder Pillow	K
Salicylate Method	Ammonia Cyanurate Reagent Powder Pillow, Ammonia Salicylate Reagent Powder Pillow	NH_3-N

5) Calculation of C/N Ratio

The percentage of carbon contained in each composted mixture was taken weekly. 10 g of sample from each compost was initially dried at 105 °C for 24 hours in the oven. Then, it was incinerated in the laboratory furnace at 500 – 600 °C for about 2 hours, leaving only the ash. The calculation for percentage of carbon is represented as below:

$$\%\text{ volatile solids} = 100 - \%\text{ash}$$

$$\%\text{carbon} = \frac{\%volatile\ solids}{1.8}$$

Figure 3.2: Calculation for carbon percentage (Cooperband, 2002)

The value of nitrogen-N obtained from HACH Spectrophotometer method is in mg/L. In order to calculate the C/N ratio, both C and N must be in the same units thus, unit mg/L of N would be converted to percentage as below:

1 mg/L = 0.001 %

Figure 3.3: Unit conversion from mg/L to % (Milligrams & Percent, 2016)

6) Phytotoxicity Test

The final vermicomposted materials consist of matured soil, leachate and rice husk after 30 days period were collected and used as a bio-fertilizer for growing eggplants. Two parameters that have been considered are average number of leaves and plant height.

CHAPTER 4

RESULT AND DISCUSSION

Several parameters such as NPK, ammonia nitrate (NH_3-N) concentration, total organic carbon, C/N ratio and pH level were measured and analyzed during the vermicomposting process. Three different mass ratios of leachate to rice husk, 1:1 (V1), 2:1 (V2) and 3:2 (V3) were used in this study.

4.1 Nitrogen

Total nitrogen consists of inorganic form of nitrogen, which are ammonium (NH_3-N) and nitrate (NO3-N). Highest concentration of N in V3 at the final week of vermicomposting might attributed by the enhanced decomposition of the organic matter and higher nutritive quality as a result of adequate addition of rice husk. Based on Figure 3, it can be observed that the content of N in all three ratios increased gradually toward the end of the composting process. It was probably due to mineralization of the organic matter containing proteins and transformation of NH_3-N into NO_3-N. The increasing pattern of N was helped by the activities of the earthworms.

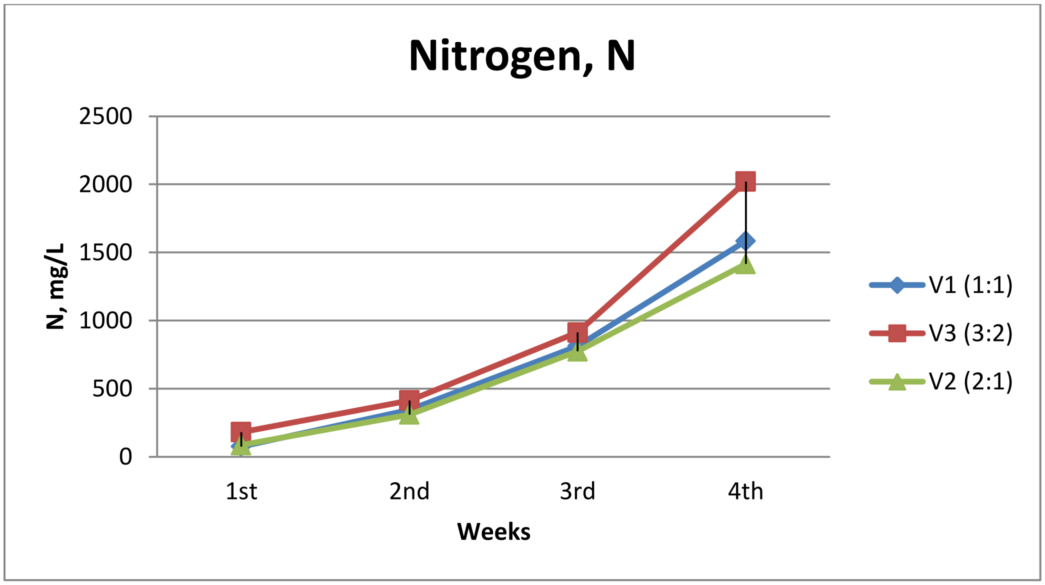


Figure 4.1: N changes throughout 4 weeks vermicomposting

Digestion process in the gut of earthworms releases a nitrogenous excretory products and enzymes that can boost up the N level of the compost. The highest final N content in V3, which is up to 2020 mg/L shows that it has achieved the best condition for the nitrifying microbial activity to occur and thus, lead to a solubilization of high N concentration. Nitrogen level was significantly low at the initial phase of composting due to heat produced in mesophilic phase and excessive NH3-N concentration that reduced the nitrifying bacterial activity. As the level of NH3-N decreased over time, the nitrification activity was enhanced and as a result, the NH3-N concentration increased. The rapid rate of nitrification provides nitrate-nitrogen for plant uptake which is internally reduced to amino acids that can be easily utilized by cells (Fang et al., 1999). There is a drastic rise of N at week 4 for V3, followed by V1 and V2. This indicated the end of thermophilic phase and beginning of maturity phase since rapid nitrification activity start to take place.

4.2 Phosphorus

Figure 4 shows the increasing pattern of P from initial to the end of vermicomposting process. The extractable concentration was the highest in V1 (468.5 mg/L), followed by V3 (364 mg/L) and V2 (259.5 mg/L), indicated that the compost was at the optimum condition for the microorganisms present in the worm cast to mineralize the insolubilizing P.

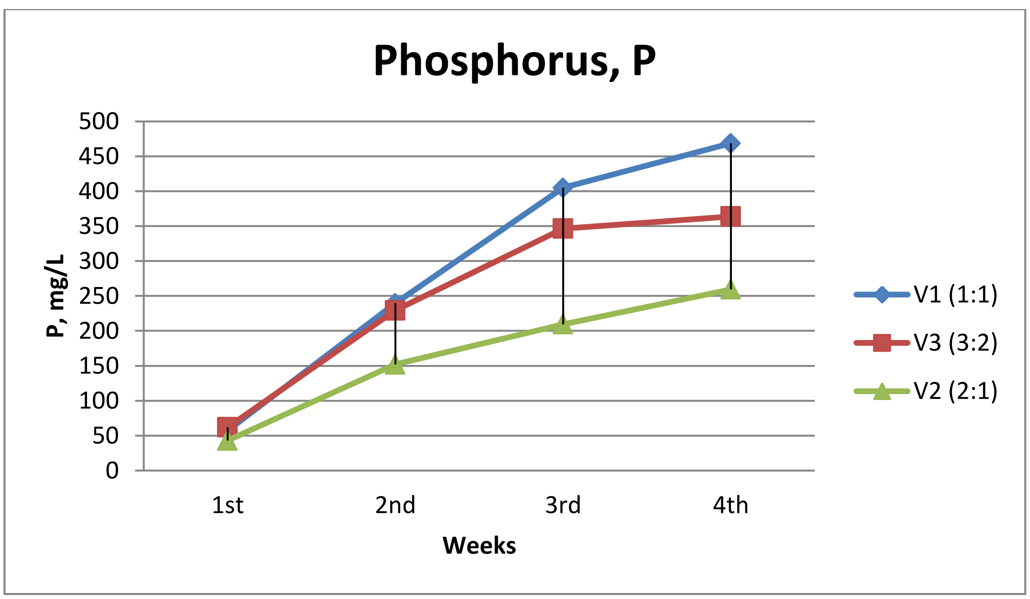


Figure 4.2: P level throughout the vermicomposting process

It can be stated that the high amount of rice husk added to the vermicompost has contributed to a maximum extraction of available P at the final composting phase. The highest increase of P was from week 1 to week 2. This reflected the maximum activities of earthworms occurred within the mesophilic phase. The earthworms converted the insoluble P into a soluble forms with the help of P-solubilizing microorganisms through phosphate present in the gut of the worms (Reddy & Ohkura, 2004). The general rise in P level during the vermicomposting process is probably due to mobilization and mineralization of P as a product of bacterial phosphatase activity of earthworms (Lim et al., 2012).

4.3 Potassium

The final K content increased (168.8 – 230%) for all the three composts as shown in Figure 5. A similar increase of K was reported by Khwairakpam & Bhargava, (2009). The increase in K value was related to the physical decomposition of organic matter of waste due to biological grinding during passage through the earthworms' gut, along with enzymatic activity, which in turn caused the K to increase.

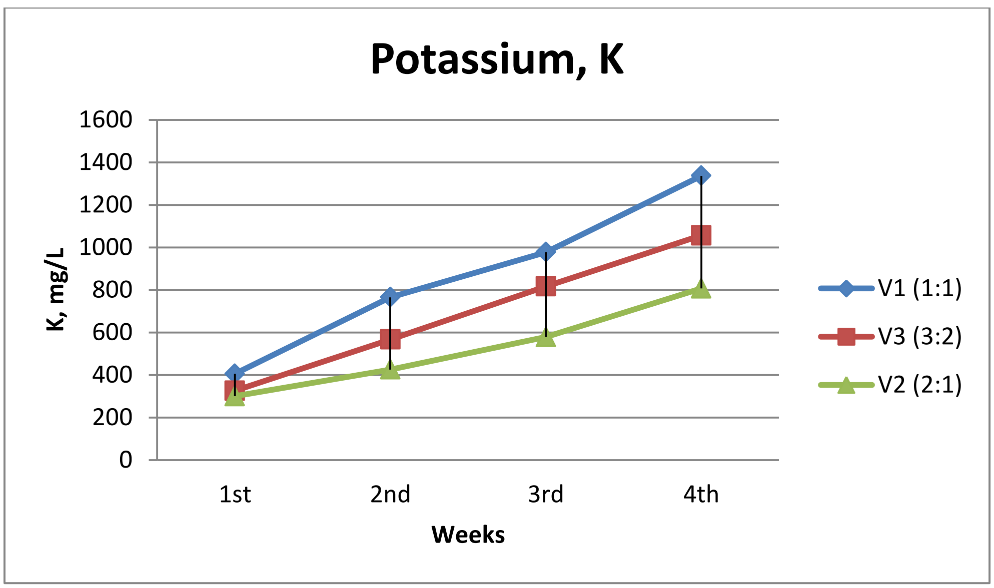


Figure 4.3: K level throughout the vermicomposting process

The insoluble K was transformed into the soluble form by the microorganisms exist in the earthworms through the production of microbial enzymes (Bożym & Engineering, 2016).

Potassium exists as a part of micronutrients that can be boosted by the presence of earthworm activity on organic matter. From the graph, it can be observed that the final level of K in the composts V1 was the highest (1336.5 mg/L). This is probably due to high K content in the rice husk as reported by Milla et al., (2017). Rice husk as a main source of potassium played a significant role in extracting the level of K in the compost. The increased in K in the initial raw materials via the addition of rice husk has resulted in higher K concentration in the end product, as obtained by compost V1. Production of acid during organic material degradation by microorganisms is a main contribution to a solubilization of K during vermicomposting (Lim et al., 2012). The high amount of microflora in the earthworms gut played an important role in the enhancement of available K in vermicompost. Thus, K contained in the rice husk was solubilized, leads to a higher amount of extractable K in the vermicompost.

4.4 Decrease in NH3-N concentration

The decreased in NH3-N concentration is shown in Figure 6 for all the three composts. NH3-N volatilization throughout the composting process was the main factor that resulted in the drop of NH3-N level. Based on the Figure 6, the content of NH3-N is the highest in compost V3 (87.5 mg/L) followed by V1 (76.0 mg/L) and V2 (33.5 mg/L). The natural characteristic of rice husk that act as an adsorbent have the capacity to absorb NH3-N, reducing the rate of volatilization. The loss of NH3-N along the composting process was mainly caused by nitrification during pile turning, which could possibly lead to emission of some nitrogen oxide, NO_2.

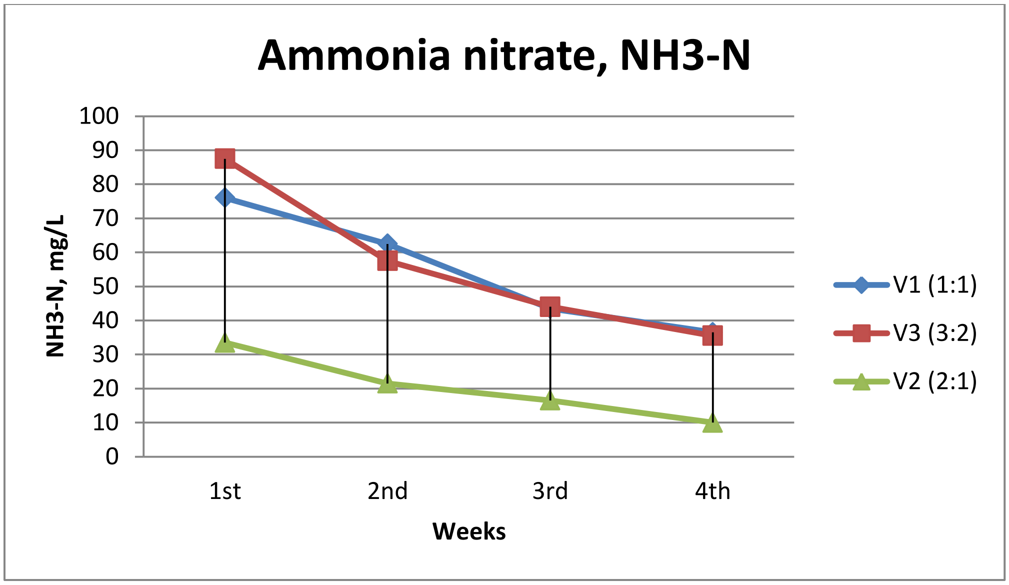


Figure 4.4: NH_3-N level throughout the vermicomposting process

The enhancement of nitrification later and the continuous volatilization of ammonia reduced the NH3-N level. The enhanced humification may be one of the factors that caused the content of NH3-N declined rapidly until the final vermicomposting process. This is in consistency with the study by Hao & Benke, (2008). A sharp drop of NH3-N level between week 1 and 2 indicated a rapid emission of NH3-N occurred in the initial phase of vermicomposting. The increased microbial activity followed by the aeration during turning, have caused the temperature to increase and stimulating further release of NH3-N. Ammonia level keep decreasing toward the end of the composting process may due to microbial stability and maturity of the material and most ammonia was successfully converted to organic nitrogen.

4.5 Total organic carbon consumption

The initial percentage of TOC is the highest in V1 as shown in Figure 7, which indicated a value up to 73%, followed by V3 (61%) and V2 (53%). This is mainly related to the highest proportion of rice husk added in V1, followed by V3 and V2. As the rice husk made up of major carbon component, it is the main factor that led to a high percentage of TOC in the initial compost. The graph in Figure 7 shows a decreasing pattern of TOC percentage over time for all the composts. This finding is in consistence with those of earlier authors (Shrimal & Khwairakpam, 2010). A decreased in carbon is a reflection of enhanced decomposition. The organic carbon was lost as carbon dioxide, CO_2 through microbial respiration within the compost and mineralization of organic matter. Microorganisms need the carbon as a source of energy to decompose organic matter. It can be observed in the graph that the percentage of TOC was decreased drastically at the initial phase of composting. This can be related to the combined action of microorganisms and the earthworms, which a large fraction of the TOC was lost as CO_2.

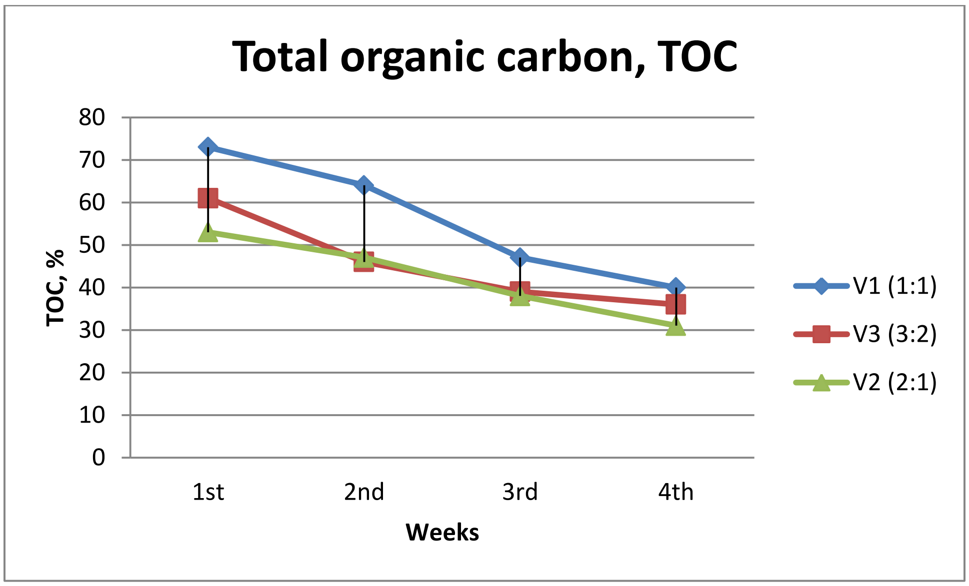


Figure 4.5: TOC level throughout the vermicomposting process

The total percentage of TOC loss during composting as shown in Figure 7 for V1, V2 and V3 are 45.21%, 39.8% and 40.65% respectively. A large percentage of TOC loss in V1 indicate that a rapid microbial degradation was occurred since high amount of C used as a source of energy for a successful degradation process. The earthworms experienced rapid organic carbon mineralization rate in vermibeds. Thus, there is a need of sufficient sources of organic carbon, which come from the rice husk as a bulking agent. The final TOC content of V1 is the highest, which promoted the most stable C to N ratio of the end product.

4.6 C/N ratio as an indicator of vermicomposting maturity

Based on Figure 8, it can be observed that the C to N ratio of all the three composts decreased gradually over composting time. Basically, the C to N ratio of the composts reflects the organic waste mineralization and stabilization.

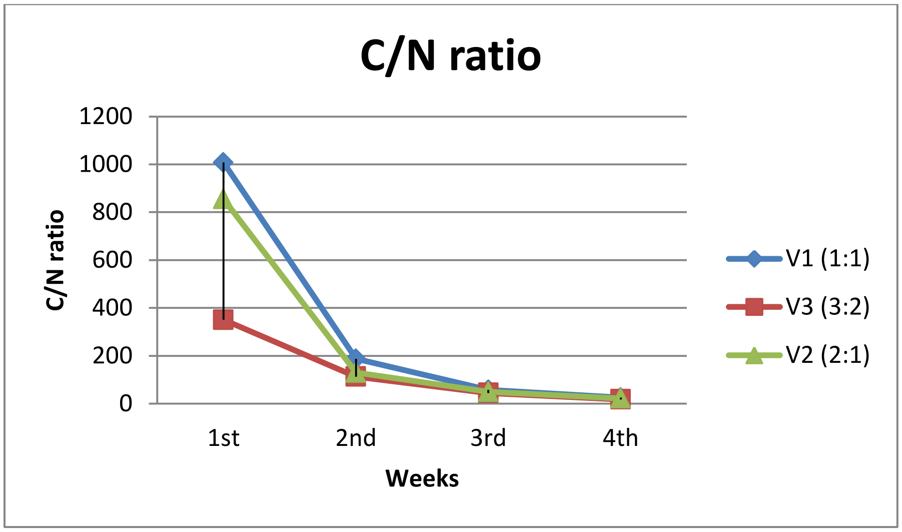


Figure 4.6: C/N ratio level throughout the vermicomposting process

Compost with higher C/N ratio indicates slow degradation process, whereby the lower C/N ratio led to a higher efficiency level of mineralization (Doublet et al., 2011). The C/N ratio declined the most at the initial week (1^{st} week) of vermicomposting process, which is by 81.4% (V1), 67.9% (V3) and 84.9% (V2). From the result, it shows that the presence of rice husk in the pile helped in maintaining a stable C/N ratio along the composting process. Rice husk addition optimized the moisture content of the pile and so the soil structure. This in turn reduced the volatilization of nitrogen in the form of ammonia and led to a good increasing pattern of N toward the end of composting process. The significant decrease of the C/N ratio over time is mainly caused by the increasing content of N and the losses of TOC throughout the vermicomposting process. The content of N was keep increasing toward the end of process because of the simultaneous addition of nitrogen by worms in the form of mucus and nitrogenous excretory material (Journal & Sciences, 2014). By week 4, the C/N ratio of V1 and V2 and V3 showed a value of 25:1, 22:1 and 18:1 respectively which appointed between the optimum ranges of matured compost. The C/N ratio between such range make nutrients easily available to the plants since mineral N could not be assimilated by plants with C/N ratio higher than 30:1 (Sciubba et al., 2013). The decrease of TOC to N ratio with composting time has been widely reported as an indicator of stability and maturity of the compost. Changes in C/N ratio indicates the degree of maturity and an increase in humification.

4.7 pH level

In this study, the pH during the vermicomposting process range from 6.5 to 7.3 for all the three composts. The pH values of all the final composts showed neutral conditions after four weeks of vermicomposting (Figure 9). Presented earthworms exerted physiological control, like secreting intestinal calcium and excreting NH_3-N for maintaining neutral pH (Lim et al., 2012). The rise of pH in the final vermicompost for all the ratios can be related to a degradation of short-chained fatty acids and intensive mineralization of N by the microbial activity. The pH value is one of the factors that may influence the microbial activities and diversity in the compost. The increasing pattern of pH (Figure 9) indicated the acceleration in microbial degradation.

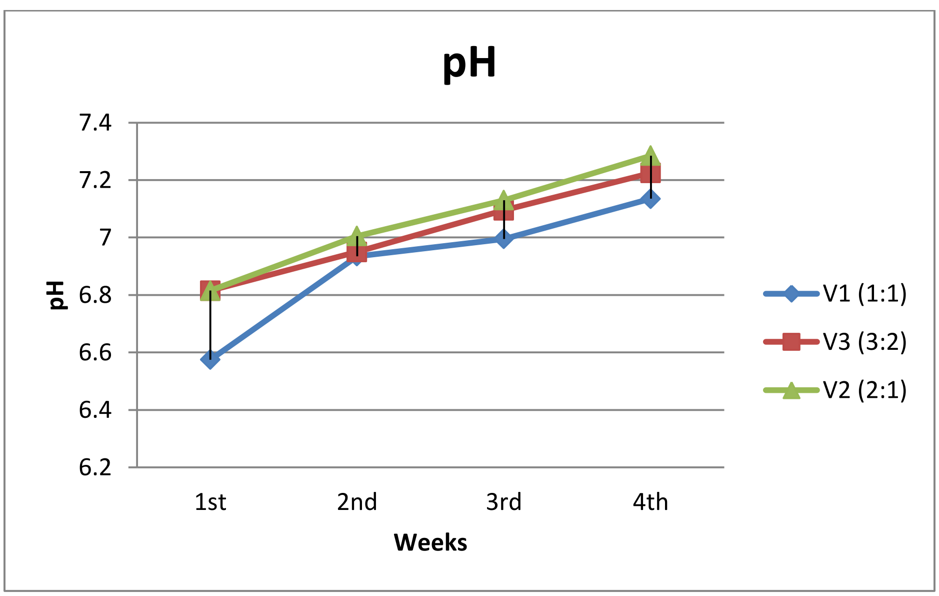


Figure 4.7: pH level throughout the vermicomposting process

A further increased in pH is caused by a decomposition of organic matter containing nitrogen, led to a formation of ammonia. It can be observed from Figure 9 that compost V2 contained highest pH value compared to V1 and V3 at the final (fourth) week of vermicomposting. This can be caused by the least amount of rice husk added (ratio of 2:1), since rice husk consist of carbohydrates and aliphatic structures with long carbon chains which is difficult to be biodegraded to acid compounds. The near-neutral pH of vermicompost may be attributed by the secretion of ammonia ions, NH_4^+ that reduced the pool of H^+ ions and the activity of calciferous glands in earthworms containing carbonic anhydrase that catalyzed the fixation of CO_2, which in turn preventing the fall in pH (Pattnaik & Reddy, 2010). The increase in pH throughout the process was mainly because of the decomposition of fatty acids and ammonification of organic N. Progressive utilization of organic acids and increase in mineral constituent of waste are also the factors that lead to the increment of pH value toward the final composting process.

4.8 Phytotoxicity test on plant (Eggplants).

The matured vermicomposts of all the three ratios (V1, V2 and V3) have been applied to brinjal plants to test whether the vermicomposted leachate is safe for its application as a soil amendment. Two main parameters have been monitored to determine the growth of the plant which is the number of leaves and the height of the plants. Table 4.1 shows the growth of brinjal plants based the number of leaves for 30 days duration.

Table 4.1: Stem height and average no. of leaves of eggplants.

Weeks	***1st***	***2nd***	***3rd***	***4th***	***1st***	***2nd***	***3rd***	***4th***
Vermibin	*Height of eggplants (in cm)*				*Average no. of leaves*			
V1 (1:1)	2.0	5.4	8.3	10.1	3	4	7	10
V2 (2:2)	1.8	4.9	7.4	13.5	2	4	6	12
V3 (3:2)	1.9	4.7	6.5	9.5	2	3	5	9
Control	2.0	5.80	7.20	8.25	2	2	3	5

Number of leaves of a plant is an important parameter to examine the overall growth of a plant. The plant with higher number of leaves exhibit a higher growth rate, and thus contain sufficient amount of good nutrients needed. Based on Table 4.1, it can be observed that number of leaves of each eggplant increased upon time, which indicated that each plants undergone a good growth. From the result, it shows that all the three matured vermicomposts could be serve as a bio-fertilizer since there is no sign of toxicity effect to the germinated plants. The vermicomposting method has proved to be good medium to reduce the contamination of the landfill leachate as well as to increase the rate of mineralization of nutrients (NPK) in the leachate. The effect of earthworms on the chemical composition and physical properties of the vermicomposted leachate have led to a nutrients-stable end product and can be safely applied to soil. Figure 4.8 shown the increment on number of leave of the tested plant (Brinjal), plant that have been supplied by vermicompost V3 shown the highest increment compared to vermicompost V1 and V2.

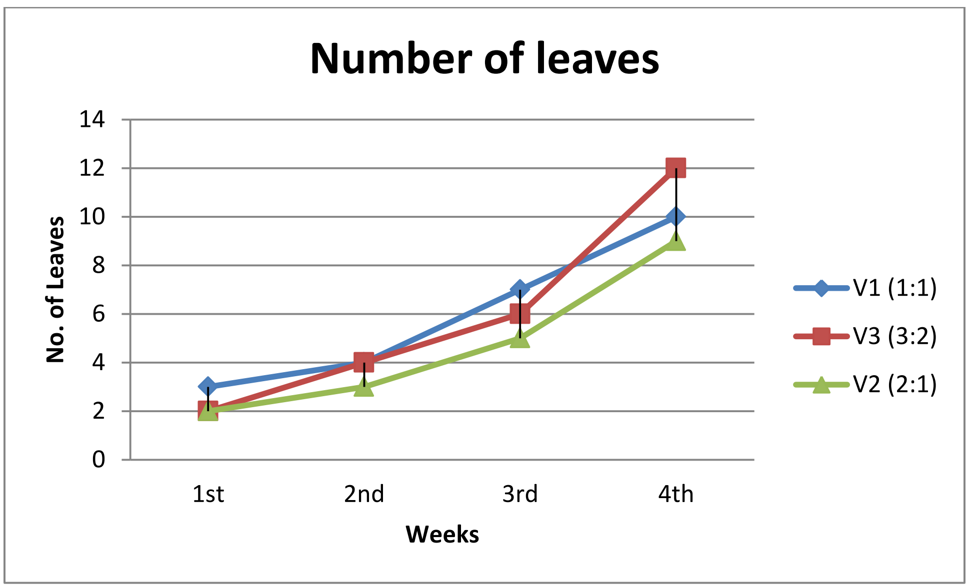


Figure 4.8: Increment on no. of leaves of tested plant (Brinjals)

Table 4.1 and Figure 4.9 show a plant height increment of the tested plants for all the three compost. The height of the plants has been taken weekly. Plant height is a common parameter used to examine growth of the plants. From the results (Table 4.1), the plant that have been applied by vermicompost V3 shows the highest growth rate, followed by V1 and V2 all the tested plants still exhibit a positive growth rate.

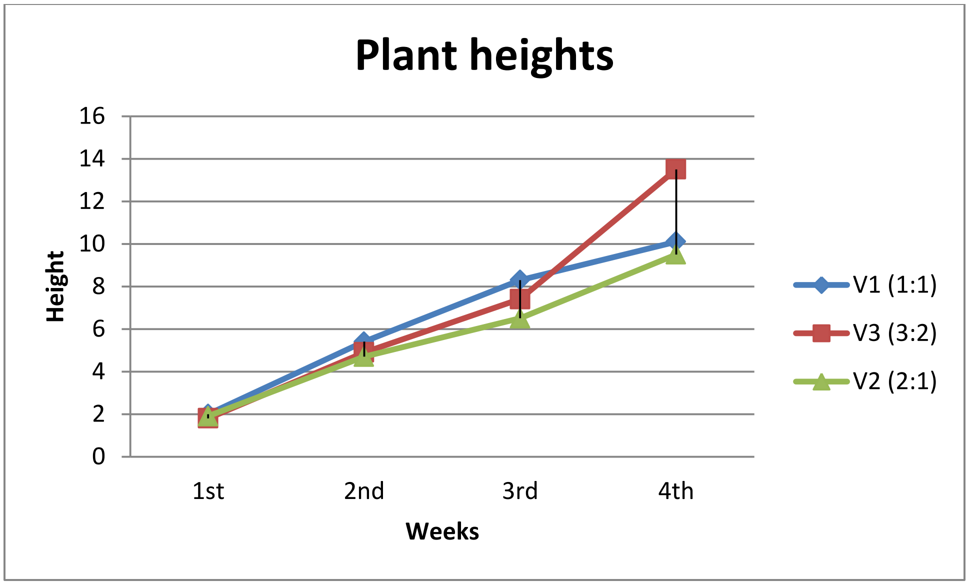


Figure 4.9: Plant height increment over time

The increase in plant height based on the result in Figure 4.9, indicate that the tested plant undergone a healthy growth and the toxicity level of the leachate has been successfully reduced through the vermicomposting approach with the help of the rice husk as a bulking agent.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results demonstrated vermicomposting as an alternative technology for the management of landfill leachate. The ability of earthworm to degrade organic material into a more available form for plant uptake in a vermicomposting process has led to the high plant extractable nutrients which are beneficial to the agro ecosystems. All composts reached a maturity stage in the end vermicomposting period of 30 days. The addition of rice husk reduced the loss of nitrogen in the form of ammonia led to the high final nitrogen content. The present results show higher C/N ratio for the vermicompost with higher rice husk composition but all of them are within the stable range. Variation of leachate to rice husk ratio have a significant effect on the extraction of NPK content throughout the vermicomposting process but there is not much different for all the three ratios applied, since all the composts still experienced a good overall NPK extraction. The study also shows that vermicompost of V1 (ratio of 1:1) contained the highest average concentration of NPK as well as optimum C to N ratio at end of the vermicomposting process and is proved to be the best ratio among the two other ratios. Based on the result of phytotoxicity essay, it has been observed that the final product can be applied safely on soil and plants since there is no sign of detrimental effects shown to the tested plants. Vermicomposting is now can be considered as one of the method that can be practiced to treat landfill leachate.

5.2 Recommendations

There are several recommendations for future studies based on this research.

1. In this work, result only was analyzed of N, P and K contents. It was suggested for future to extract and analyze more nutrients content like calcium and magnesium.

2. In this work, there is no analysis on the rate of reproduction of the earthworms. It was suggested for future study to relate the significant effect of the rice husk used to the earthworms' reproduction rate.

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APPENDIX

Appendix A-1: Nitrogen Test Method

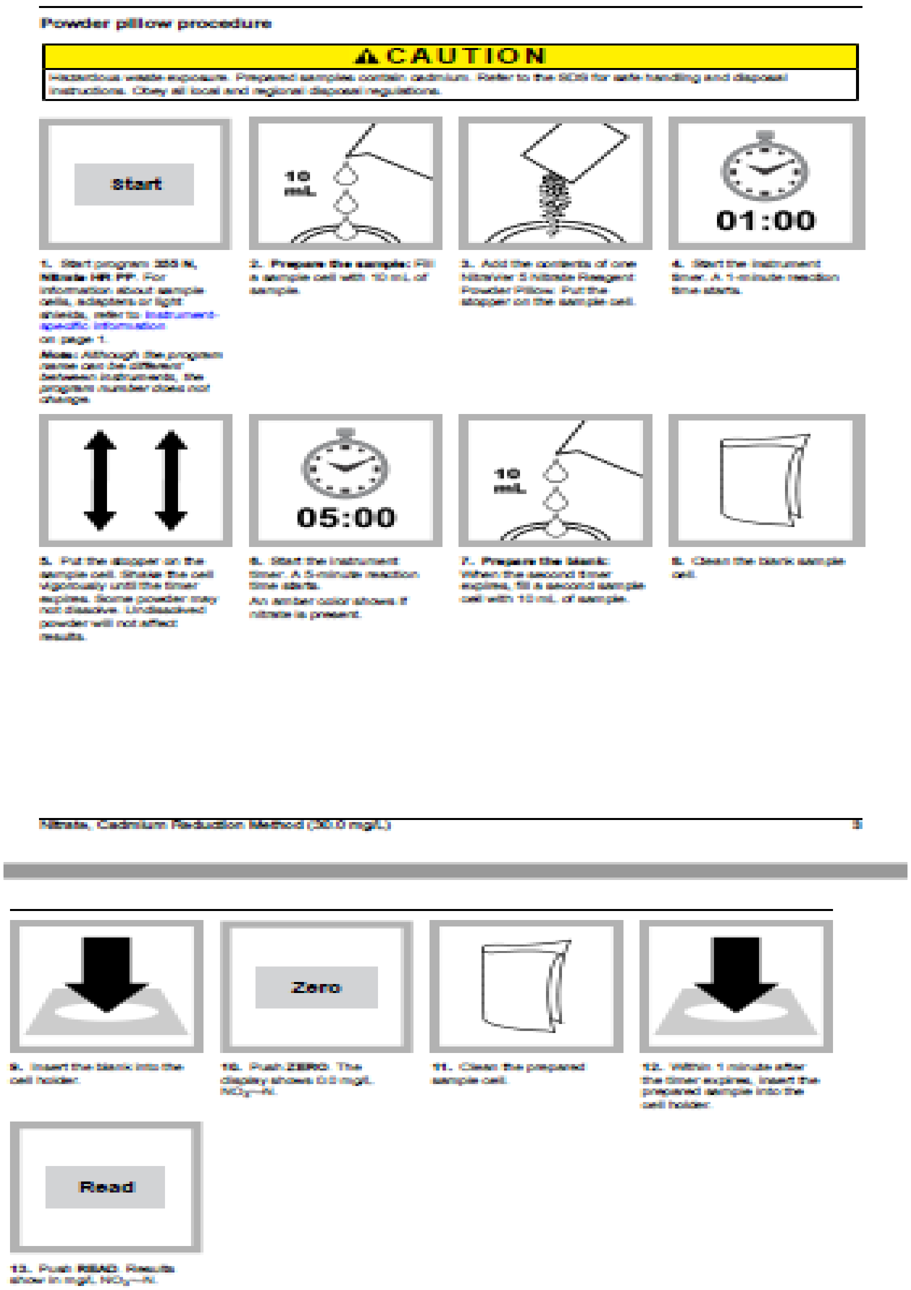

Figure A-1: Cadmium reduction method procedure

Appendix A-2: Phosphorus Test Method

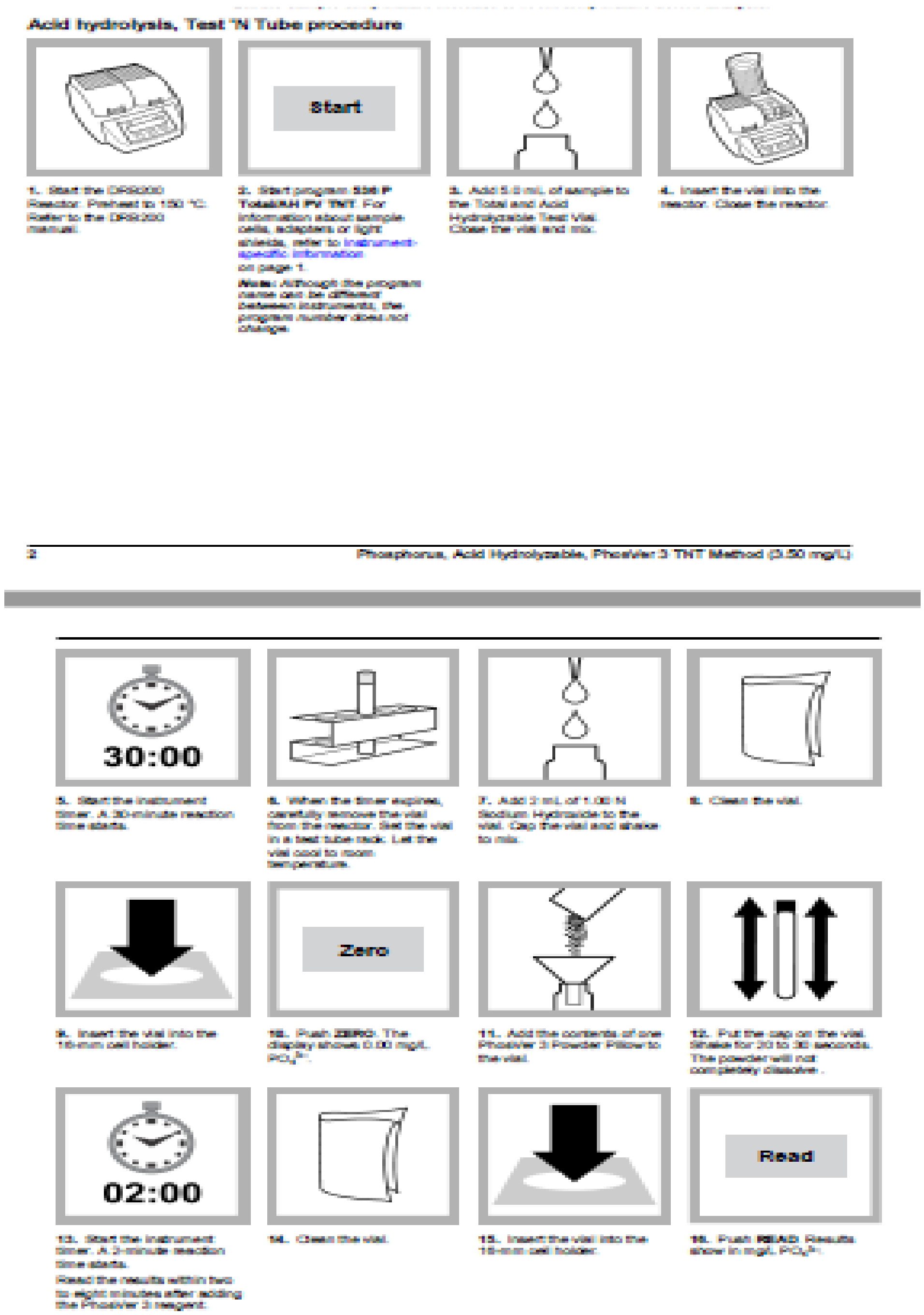

Figure A-2: PhosVer 3 with Acid Hydrolysis Method

Appendix A-3: Potassium Test Method

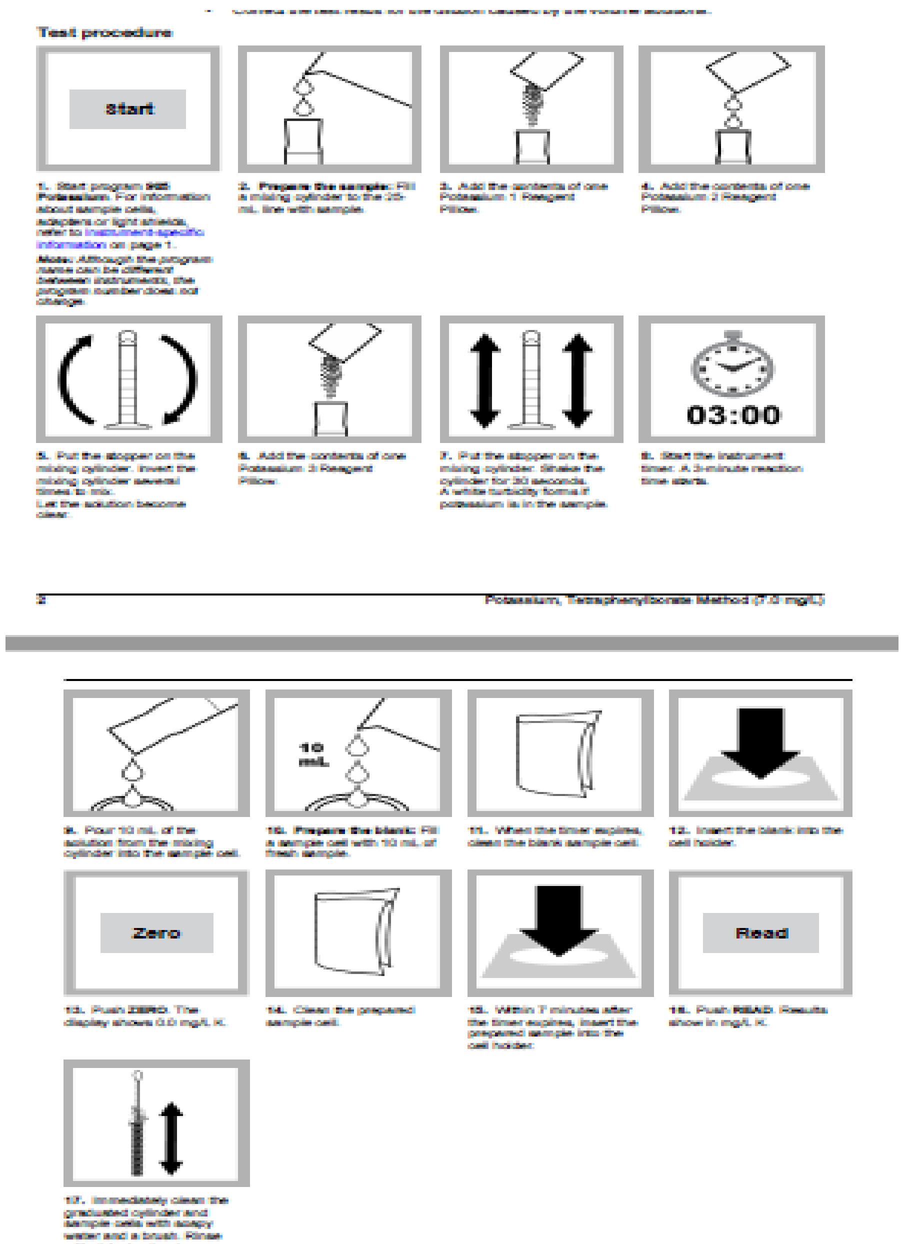

Figure A-3: Tetraphenylborate method procedure

Appendix A-4: Analysis of Sample

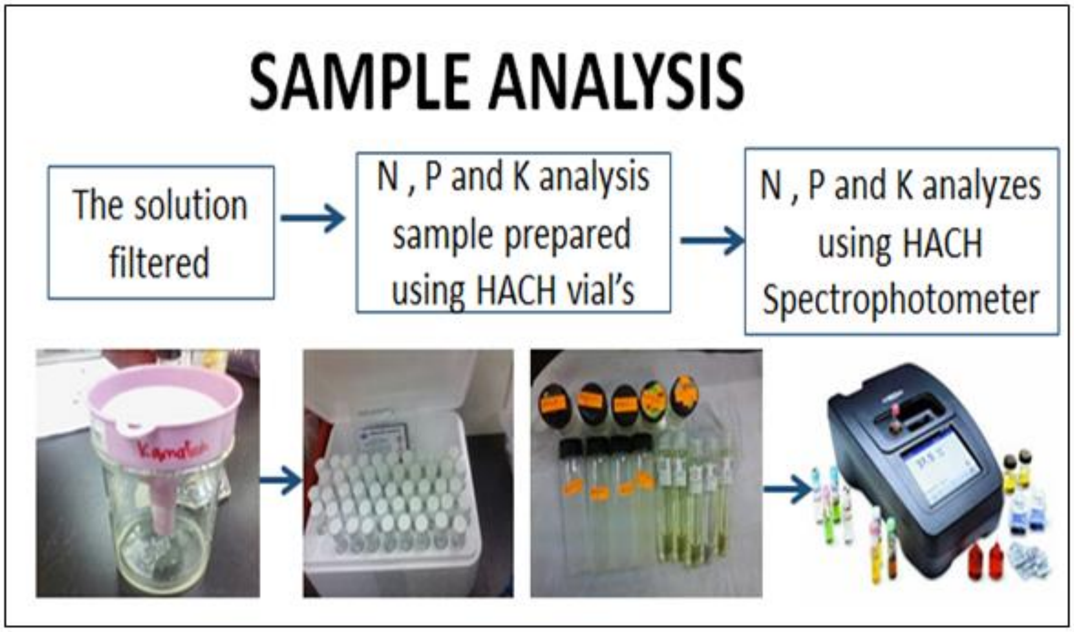

Figure A-4: Sample analysis

Appendix A-5: Initial landfill leachate characterization

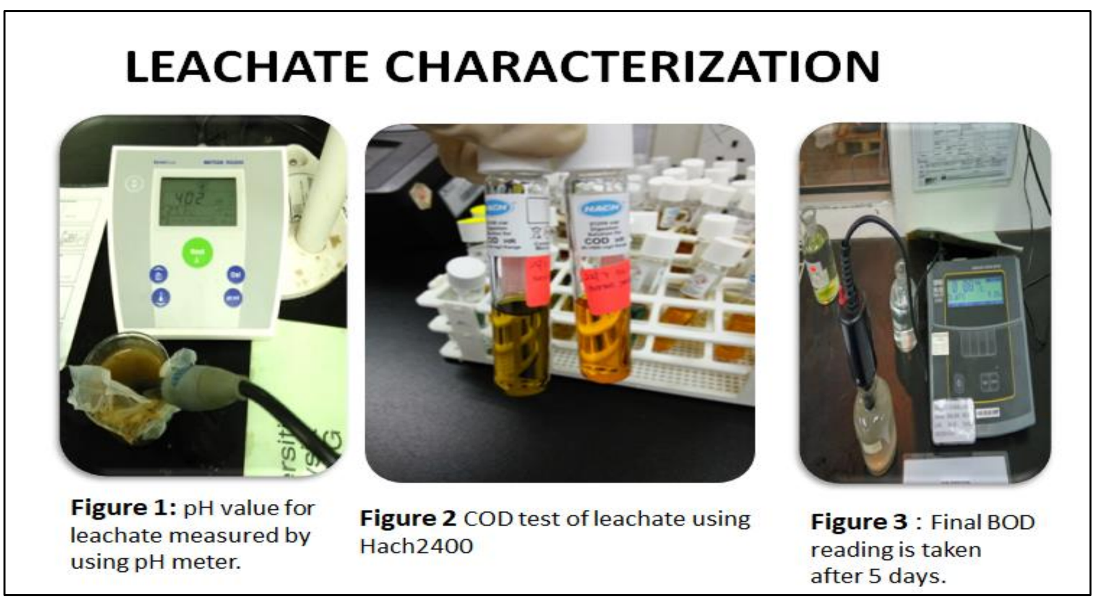

Figure A-5: Landfill leachate analysis