PRODUCTION OF BIOFERTILIZER FROM VERMICOMPOSTING PROCESS OF MUNICIPAL SLUDGE

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ABSTARCT

The potential of the epigeic tiger worms (*Eisenia fetida*) in this study is aimed at safe reuse and recycling of municipal sewage sludge (MSS) in vermicomposting process and the major nutrient status, its simple vermicompost were assessed across different periods in relation to its respective initiative substrates. The present study aims to find out the possibility of utilization of sewage sludge for vermiculture. 1000 g of tiger worms were cultured in plastic container (0.55 wide x 0.30 high x 0.25 long) metre containing 25000 g sewage sludge. The optimum daily feeding rate of sludge is equal to the weight of worm biomass in the bin. This bin was used to calculate the sludge volume reduction by vermicomposting process and it was determined that there is a nearly 90% of volume reduction. Their physical parameters – temperature and moisture is maintained also the pH is decreased (alkali to acidic) during the vermicomposting process, were recorded. The nutrients –total nitrogen (TN), Total phosphorus(TP), and Total potassium(TK) in the vermicast as the process progressed from 0 to 1, 7, 14 and 21 days were also obtained. It was found that the vermicast are rich in nutrients of Nitrogen, Phosphorus and Potassium. The present study also inferred that the application of sewage sludge can be reused and retreated as a good quality biofertilizer in agricultural fields after vermicomposting would not have any adverse effect to the environmental. Results indicate that vermicomposting might be useful for managing the energy and nutrient rich sewage sludge on a low-input basis. Products of this process can be used for sustainable land restoration practices. The feasibility of tiger worms may also reduces the possibility of soil contamination. The advantages of this concept are high performance, easy collection of compost and long run without cleaning. Worms were also produced as a very useful by-product.

ABSTRAK

Potensi epigeic cacing harimau *(Eisenia fetida)* dalam kajian ini adalah bermatlamat kepada guna semula yang selamat dan kitar semula kumbahan enapcemar perbandaran (MSS) dalam proses pembajaan vermi dan status nutrien utama, merupakan baja vermi mudah telah ditaksir merentasi tempoh-tempoh yang berbeza berkaitan dengan inisiatif substart masing-masing. Kajian bertujuan dalam mengetahui kemungkinan penggunaan kumbahan enapcemar untuk budaya vermi boleh di laksana. 1000 g cacing harimau hidup dalam bekas plastik berukuran (0.55 lebar x 0.30 tinggi x 0.25 panjang) meter yang mengandungi 25000 g kumbahan enapcemar. Kadar pemakanan cacing terhadap kumbahan enapcemar pada harian optimum sama dengan berat cacing dalam tong. Tong ini digunakan bagi mengira pengurangan isipadu enapcemar oleh proses pembajaan organik dan ia telah menentukan bahawa hampir 90% pengurangan isipadu. Parameter-parameter fizikal iaitu suhu dan lembapan di kekalkan dan nilai pH menurun (alkali kepada asid) semasa proses pembajaan vermi dan telah direkodkan. Nutrien itu ialah nilai jumlah nitrogen (TN), jumlah fosforus (TP), dan jumlah kalium (TK) dalam baja vermi berjalan dalam jangka masa dari 0 hingga 1, 7, 14 dan 21 hari juga di perolehi. Di dapati bahawa baja vermi kaya dalam nutrien Nitrogen, Phosphorus dan Potassium. Kajian menunjukkan dan kesimpulan di buat bahawa penggunaan kumbahan enapcemar itu boleh digunakan semula dan berundur kepada satu baja organic berkualiti dalam sektor pertanian selepas pembajaan vermi yang tidak mempunyai sebarang kesan buruk untuk alam sekitar. Keputusan menunjukkan yang pembajaan vermi boleh di jadikan untuk menguruskan penggunaan tenaga dan kaya dengan zat makanan enapcemar kumbahan pada satu input asas yang rendah. Produk yang di proses ini boleh digunakan untuk amalan pemulihan tanah mampan. Kemungkinan cacing-cacing harimau juga dapat mengurangkan pemalaan tanah. Kelebihan bagi konsep ini adalah prestasi yang tinggi, koleksi pengumpulan kompos yang mudah dan jangka masa yang panjang tanpa pembersihan. Cacing-cacing juga dapat menghasilkan satu hasil sampingan yang sangat berguna.

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LIST OF SYMBOLS

TN - Total nitrogen
TP - Total phosphorus
TK - Total potassium
NPK - Nitrogen phosphorus potassium
MSS - Municipal Sewage Sludge
pH - Alkalinity and acidity
et al - With friends
mg/L - Milligram per liter
m - meter
kg - kilogram
g - gram
CO_2 - Carbon Dioxide
NH_4 - ammonia
NH_3 - ammoniacal
NO_3 - Nitrate
Ca - Calcium
Mg - Magnesium
Na - Sodium
% - Percentage

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CHAPTER 1

INTRODUCTION

1.1 General

Processing and disposal of the residual sludge of the wastewater plants is a serious environmental problem over recent years because of stricter environmental regulation that controls the disposal of raw and untreated sludge. The awareness of environmental problems has forced governments, local authorities and utilities for management to search for new alternative process or solutions for future waste management strategies. Effective solid and liquid separation persists to be a major problem in various operation units in waste- water treatment. Among them, sludge dewatering has been pointed out as one of the most expensive and least understood processes.

Biosolids are the nutrient rich by-product of wastewater treatment, generated by channeling human waste through treatment plants and collection systems. Although the terms biosolids and sewage sludge are often used interchangeably, biosolids are the end product after treating sewage sludge with anaerobic digestion in combination with heat. The use of biosolids as soil amendments (soil conditioners or fertilizers) or for land reclamation has increased to reduce the volume of biosolids that must be landfilled, incinerated, or disposed of at surface sites. In the last several years, numerous scientific, political and social factors have contributed to a growing public concern over the safety of biosolids which has resulted in strict local ordinances banning.The management of biosolids is layered and complex.

Although there exist many alternatives for sludge treatment and disposal such as landfill, incineration, physical-chemical process, physicochemical process, adsorption, membrane process in recent years, interest has grown in the methods/processes based on resource recovery approach known as recycling and utilization of useful materials from sludge.

The concept of organic matter recovery is becoming more popular to be applied for various purposes. Composting as a resource recovery is becoming a more acceptable alternative for the sludge treatment due to potential use for land application as bio fertilizer and soil conditioner . Liquid state bioconversion (LSB) of domestic wastewater treatment plant sludge is being proposed to solve these problems.The organic portion of the solid waste however could be utilized in a very profitable way by composting or by using vermicomposting. *Vermes* is Latin word for worms and Vermicomposting is essentially composting with worms. So in such case vermicomposting aids in the disposal by improving the physical quantities of waste (Ghatnekar et al., 1998).

The use of earthworm in sludge management has been termed as ‘vermistabilization’. Vermistablization represents a technology that is environmentally sound andrelatively new technology that can be classified as an innovative and alternative technology .A bibliographic survey has shown that in most of the sewage sludge related vermicomposting studies, activated sludge (a product of biological wastewater treatment) has been used as raw substrate but there is a paucity of data on the possibility of vermicomposting of primary sewage sludge which is available in huge quantities. Earthworms have been used for waste stabilization for many years, especially in Southeast Asia and some third world countries mainly, Canada, United States, Australia and France. Earthworms are one of the major soil macroinvertebrates and are known for their contributions to soil formation and turnover with their widespread global distribution. Later in the passage of time, different experimental studies are carried out in studying the role of earthworm in maintaining the soil fertility and in the degradation of the organic matter present in the soil

1.2 Problem Statement

The proposed project that we are looking at is the treatment and disposal of sludge produced during waste treatment is one of the most critical environment issues of today. At the time investigation was conducted, a sustainable approach to handle this will be to convert it to a useful recyclable product at site by an eco-friendly and economical product, Biofertilizer through vermicomposting process. In its basic form, this is a low- cost technology system that primarily uses earthworms in the processing and sustainable option for sewage sludge management. Biofertilizer which is such beneficial microorganisms on application to seed, roots or soil mobilize the availability of nutrients by their biological activity in particular, and help build up the micro-flora and in turn the soil health in general. Bio fertilizer do not contain any chemicals which are detrimental to the living soil displaying their ill-effects in polluting water basins

1.3 Objectives

The objectives of the study are:

1. To determine the characteristic of municipal sewage sludge.
2. To determine the potentially of tiger worms *(Eisenia fetida)* in converting the sewage sludge into vemicast.
3. To determine the properties of vermi composted municipal sewage sludge

1.4 Scopes

1. This study includes the tiger worms *(Eisenia fetida)* at favorable condition in the vermicomposting .
2. This study was carried out in several of period observation in production of vermi composted by Municipal sludge and earthworms which is 21 days composting .
3. The municipal solid waste was composted and the sewage sludge used in this study was collected from a sewage treatment plant in Indera Mahkota,Kuantan .

1.5 Significant of Study

The study will serve the good application of reducing the domestic sewage sludge which are includes an instant need of safe technology to manage such noxious industrial waste; the technologies must be ecologically sound, economically viable and socially acceptable into practice by giving the opportunity for each individual especially student to conduct their own worm bin activity. Yelm Earthworm (worm bin) and Castings Farm can help schools, institutions and commercial businesses develop large-scale vermicomposting operations using state-of-the-art continuous-flow vermicomposting systems. Preliminary research in laboratory showed that vermicomposting involves great reduction in populations of pathogenic microorganisms, thus not differing from composting from this point of view. As an aerobic process, composting leads to a nitrogen mineralization and the use of earthworms in vermicomposting increases and accelerates this nitrogen mineralization rate. Vermicomposting may also bring about a greater decrease of bioavailable heavy metals than in the composting process. From the vermicomposting, a strong, nutrient rich liquid feed, which dilute with water prior to use as an excellent plant food for house plants, garden flowers, shrubs, vegetables or as a lawn feed. A rich organic compost known to keen gardeners as "Black Gold" (bio fertilizer) and there is evidence that the final product may contain hormone like compounds which accelerate plant growth by replacing the chemical fertilizer also help to solve problems such as chemical runoff from soil that can harm the ecology system. Thus, individually and cumulatively agro-industrial waste products seem to have the potential to afford eco-friendly, cost-effective and socially acceptable and sustainable bio-resources for increasing the human health and environmental safety.

1.6 References

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Vermicomposting is the conversion of biodegradable garbage into a high quality chemical free bio-fertilizer with the aid of Earthworms. Whereas, the composting is the other way round where the organic part of the refuse is consumed by a series of successive bacteria according to the heat of the system.Earthworms have from time immemorial played a key role in soil biology by serving as versatile natural bioreactors to harness and destroy soil pathogens, thus converting organic wastes into valuable bio-fertilizers, enzymes, growth hormones and proteinaceous worm biomass. The worms do it by feeding voraciously on all biodegradable refuse such as leaves, paper (non-aromatic), kitchen waste, vegetable refuse. It then burrows deep into the soil, positioning its castings towards the surface of the soil thereby enriching the soil with a pre-digested, easy to assimilate bio-fertilizer that is now rich with NPK. So when looking for a fertilizer for a farm or garden it would do well if people would consider the revolutionary vermicompost as an option. Certain types of earthworms ingest, digest, and excrete vermicompost with excellent nutrient content (Bhiday, 1995). Ingestion ensures the sorting out of only organic matter while the digestion accelerates the maturing process. Excretion ensures the grading of the vermicompost as opposed to any inorganic matter, which may be existing in the waste and not concerned with the biological activity in the earthworm gut. During the composting process, microorganisms decompose organic compounds, which consist of carbohydrates, sugar, proteins, fats, cellulose and lignin. Carbohydrates are more easily decomposed whereas lignin is more resistance to decomposition. Many factors affect the composting process. Aerobic microorganisms need oxygen, water and nutrients for their metabolism and cell synthesis. As a result of microbial activity heat is liberated and, if contained within the composting mass, the temperature rises. Temperature increases through the mesophilic phase into a thermophilic phase and then back in to the mesophilic phase. During the course of these transitions, the microbial population changes, thereby affecting the rate of organic matter decomposition.

2.2 Definition

2.2.1 Vermicomposting

The method of employing earthworms in reducing the organic matter present in the waste is called as the vermicomposting. Vermicomposting, also known as worm composting, is simply the way redworms transform decaying organic matter into worm castings (Zorba, 1998). Vermicomposting is the process involved in the degradation of organic waste into useful components by using earthworms. It is all-together a natural system in which the earthworms play their major roles in degrading the organic portion of the waste. The use of earthworm in sludge management is called as vermicomposting or vermistablization. (Edward et al., 1988).

2.2.2 Composting

Composting is the biological decomposition of organic matter under controlled aerobic condition (Epstein, 1977). Composting in a way is one such method by which we can practically and economically use those waste streams dominated by organic refuse. As stated by Roger (1993) that there is no universally accepted definition of composting.According to him, it is the biological decomposition and stabilisation of organic substrates, under conditions that allow development of thermophilic temperatures as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land. Or simply it can be defines as the biological reduction of the organic waste to humus (Jerry, 1979). In brief we can consider composting as a way of stabilising the waste.

2.3 Types of vermicomposting systems

2.3.1 Windrows

This system takes into account the availability of large land and other appropriate technology for operating the whole system. These systems are extensively being used for used both in the open and under cover.

2.3.2 Wedge system

This is a modified type of windrow system where one can easily harvest the vermicompost without disturbing the earthworms. In this system organic materials are applied in layers against a finished windrow at a 450 angle.

2.3.3 Bed and bin system

Here in this systems bins are used to breed and harvest the vermicompost and also in some case beds are made on the ground for the same purpose. This method is labor intensive but is much easier to handle and is widely.

2.3.4 Reactor system

Reactor systems have raised beds with mesh bottoms. Finished vermicompost is harvested by scraping a thin layer from just above the grate, and then it falls into a chamber below. These systems can be relatively simple and manually operated or fully automated with temperature and moisture controls. Factors that may be considered for selecting the appropriate vermicomposting technology for a project include: Amount of feedstock to be processed; Funding available;Site and space restrictions; Climate and weather; State and local regulatory restrictions; Facilities and equipment on hand; and Availability of low-cost labors etc.

2.4 Breeding of earthworms

Worms will be breeded by setting up a vermibed in a suitable container or a site under a shade, in an area on upland or an elevated level to prevent water stagnation in the pit.

2.4.1 Bedding preparation

For the preparation of the bedding we can have various choice regarding the availability of the bedding materials. Here in the below figure show the basic requirements for a Vermibed. In the setting up of an ideal vermibed one should have the following layers, basal layer comprising of broken bricks or pebbles to a small extent followed by coarse sand to a thickness of 6 – 7.5 cm, this layer is to ensure proper drainage. This is topped by a layer of loamy soil up to a height of not less than 15 cm after it is moistened. Now we can inoculate worms here in this layer. Over this small lump of cattle dung are scattered over the soil and this is covered by layer of hay up to a height of 10 cm. Broad leaves finally cover the unit and a net can be used to prevent the intrusion of any unwanted worms or other predators. (Ismail, 1997).

2.4.2 An ideal environment for earthworms

The following are the environmental conditions, which are vital and may affect the breeding, cocoon production and hatching of young earthworms. They are lots of literature describing the various limiting parameters towards a successful breeding.

2.4.2.1 Temperature

In Vermicomposting, temperatures are kept generally kept below 350C(Riggle et al., 1994). Most worm species used in vermicomposting require moderate temperatures from (10-35)0C. While tolerances and preferences vary from species to species, temperature requirements are generally pretty similar. The majority of vermicomposting worms can tolerate temperatures ranging from 50 °F to 85°F but decrease activity as temperatures move toward the extremes. Most species prefer temperatures within roughly ten degrees of 70 °F.

2.4.2.2 Moisture

Earthworm requires plenty of moisture for growth and survival, they need generally moisture at the range from (60 –75) %. The soil should not be too wet else it may create an anaerobic condition which may drive the earthworms from the bed (Ronald et al., 1977). It is very important to moisten the dry bedding material before putting them in the bin, so that the over all moisture level is well balanced.

2.4.2.3 pH

Although studies have suggested that worms perform best in neutral pH (Ronald et al., 1977). It has been recorded by Edward et al., (1976) that different species of earthworms have their own pH sensitivity and generally most of them can survive at the pH range between (4.5 – 9).

2.4.2.4 Feed

The first step in starting a vermicomposting unit is to arrange for regular input of feed materials for the earthworms. These can be in the form of a nitrogen rich material like goat manure cattle dung and pig manure. When the material with high carbon content is used with C/N ratio exceeding 40: 1, it is advisable to add nitrogen supplements to ensure effective decomposition. All organic matter should be added only as a limited layer as an excess of the former may generate heat (Ismail, 1997). From the waste eaten up by the worms 5 – 10 % are being assimilated in their body and the rest are being excreted in the form of a nutrient rich cast.

2.4.2.5 Stimulants

They are no known stimulants which will force the earthworms to breed but fairly fresh manure or other nitrogen rich green organic matter seems to be the best stimulant to rapid breeding (Ronald et al., 1977).

2.5 Biology of earthworm

The earthworm is a tube shaped, segmented, invertebrate. Lacking bones or cartilage, its body holds its shape because it’s full of a thick mucous-like liquid called coelomic fluid. If one were to view a cross section of the worm body it would resemble a target, with the center representing the internal organs and the outer circle representing the skin or dermal layer. The cavity between the internal organs and dermal layer is filled with the coelomic fluid. The pressure of this fluid against the dermal layer gives the worm its shape (Slocum, 2001).

2.5.1 Classification of earthworm

According to their feeding habits, earthworms are classified into detritivores and goephages . Detritivores feed near the soil surface. They feed mainly on the plant litter or dead roots and other plant debris in the soil. These worms comprise the epigeic and the anecic forms. Geophagous worms, feeding deeper beneath the surface ingest large quantities of organically rich soil. These are generally called as humus feeders and comprise of endogeic earthworms.Epigeic are surface dwellers serving as efficient agents in fragmentation of organic matters on the soil surface. Whereas the anecics feed on the organic matter mixed with soil. Endogeic earthworms live deep within the soil and derive their nutrition from the organically rich soil they ingest. The distribution of earthworm in the soil is influenced by several factors of which are soil texture and aeration, temperature, moisture, pH, inorganic salts and the organic matter (Govindan, 1998)

2.5.2 Types of earthworms

In general we have six common types of earthworms (Ronald et al., 1977).

1. The native night crawler, or Lumbricus terrestris.
2. The common field worm, or Helodrilus caliginosus
3. The green worm, or Helodrilus chloroticus.
4. The manure worm, or Eisenia foetida.
5. The slim earthworm, or Diplocardia verrucusa
6. The red worm, or Lumbricus rubellus.

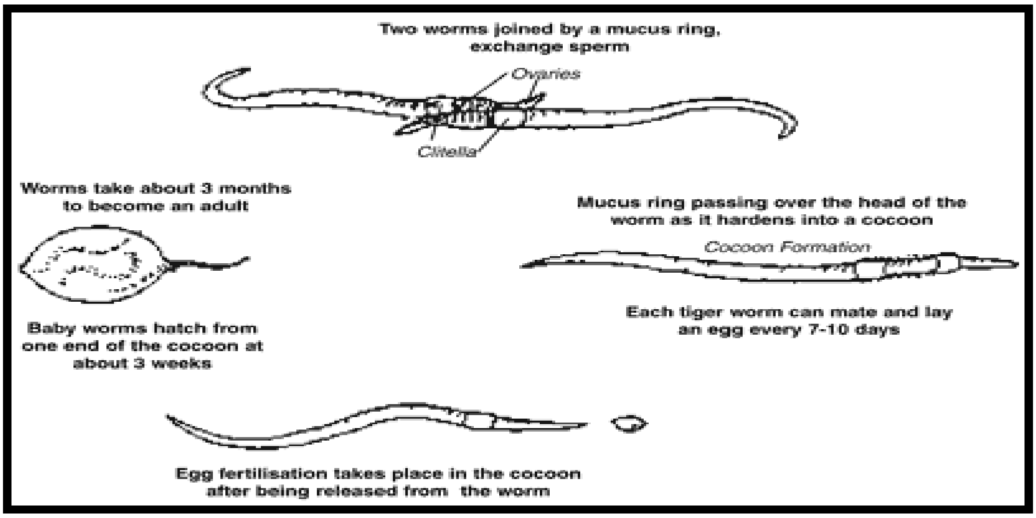
2.5.3 Reproduction

Earthworms are hermaphrodite, which is each individual has its own male and female reproductive organs. In sexually matured earthworms the body wall of the forward segment is thickened by gland cells, forming a conspicuous girdle known as clitellum (Ronald et al., 1977). During reproduction they exchange sperm at a point just above the clitellum, the swollen band encircling the worms body. After sperm of worms move apart and secrete a thick mucous around the clitellum, which forms a jelly-like band. Once the band slips off the worm’s body, the ends close, forming a cocoon with sperm and eggs inside where fertilization takes place.

2.5.4 Life cycle

In their natural habitat, earthworms follow a well-defined yearly cycle. This cycle is considered to starting at the autumn season (Ronald et al., 1977). Life cycle of an earthworm is divided into four major phases.

Figure 2. 1 Schematic diagram representing the life cycle of an earthworm (http://www.tdc.govt.nz/pics/1927-worm-life-cycle.gif)



2.5.4.1 Cocoon phase

Many cocoons were produced when the temperature rises up and the greatest number occurred between May and July. Thereafter, the numbers of cocoons produced decreased quite rapidly with falling temperature. Lofty et al., (1976) reported that fewest cocoons were produced during winter and there was a temperature threshold of about 3°C, below which no cocoons were produced.

2.5.4.2 Juvenile phase

On hatching the worms measure to an average up to 0.8 – 1.5 mm in length and weigh around 7 mg. Their length gradually increases to about 4 cm and may latter weigh up to 150 mg .

2.5.4.3 Non- clitellates

Young earthworms whose clitellum are yet to develop are grouped into this nonclitellates here the young worms are very active at this stage and will weigh up to from 150 mg to 450 mg .

2.5.4.4 Clitellates

Clitellates are the mature and adult worms. Clitellates have the potentials for reproduction, the worms at this stage will appear bit darker in their colour due to the pigmentation of the epithelial cells . Here in this stage of life the body wall of the forward cell is thickened by gland cells, forming a conspicuous girdle known as Clitellum (Ronald et al., 1977).

2.6 Role of earthworm in organic matter recycling

The rate of decomposition depends on the type of the litter. If physical conditions are suitable then the number of earthworm’s increase until the food becomes a limiting factor. Even when the organic matter such as dung is present in sufficient or are freely available still then the worms ingest large quantity of mineral soils . The increased interest in diverting organic wastes from landfill has raised concerns about the need to ensure that the end products are safe to use and meet minimum quality standards. One such concern is that strategies are adopted that minimizes the risk of spreading pests, plant diseases (pathogens) and weeds in recycling organic wastes.

2.6.1 Recycling of organic waste

2.6.1.1 Fragmentation and breakdown

The rate of organic matter breakdown depends mainly on the type of litter. Very soft plant and animal residues may be decomposed by the microflora but much organic matter, particularly the tougher plant leaves, stems and root material does not break down without first being disintegrated by the soil animals, mainly earthworm. Earthworms have an important role in this initial process of the cycling of organic matter. Soils with only few earthworms have a well-developed layer of undecomposed organic matter lying on the soil surface. Many sorts of leaves are not acceptable to the earthworms when they first fall on the ground, but require a period of weathering before they become palatable. It is believed that this weathering leaches the water-soluble polyphenols from the leaves (Edward, 1976). These tiny creatures are responsible for translocating the accumulated organic debris from the soil surface the subsurface layers and during this process much of the organic materials is ingested, macerated and excreted. Earthworms also contribute several kinds of nutrients in the form of nitrogenous waste (Lakshmi, 2000).

2.6.1.2 Nitrogen mineralization

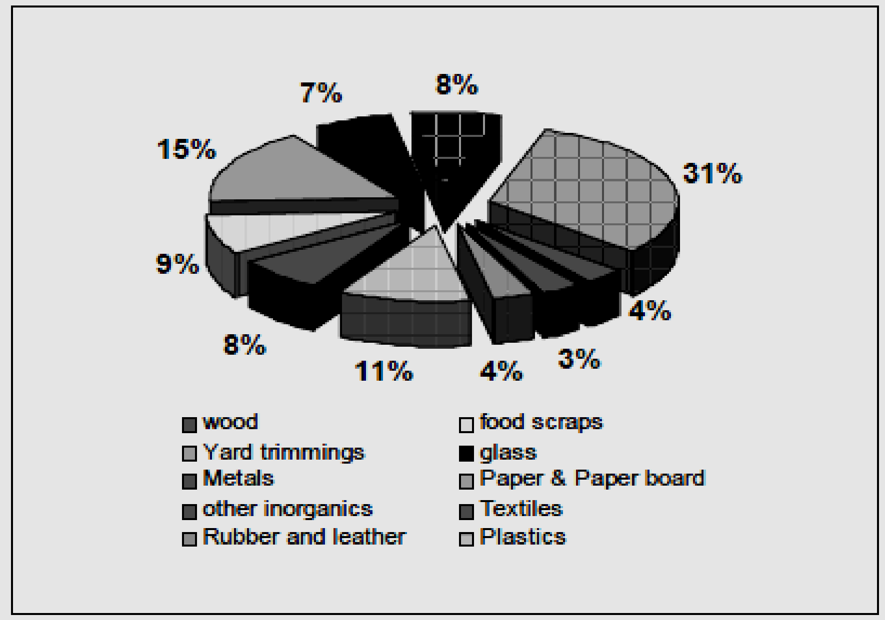
Earth worms greatly increases the soil fertility, and at least part of this must be due to the increased amounts of mineralized nitrogen that they make available for the plant growth. There have been reports of increase in the amount of nitrogen in which the earthworms are reared (Edward et al., 1976). This may be due to the decay of the bodies of dead earthworms. Since the body of the earthworm are rich in proteins. Govindan (1998) reported that earthworm body contains 65% protein, 14% fats, 14% carbohydrates and 3% ash. Similarly Ronald (1977) reported that 72% of the dry weight of an earthworm is protein and that the death of an earthworm will releases up to 0.01 gram of nitrate in the soil. Earthworms consume large amount of plant organic matter that contains considerable quantities of nitrogen, and much of this is returned to the soil in their excretions.

2.6.1.3 Effects on the C/N ratio

Plants root in general cannot assimilate the mineral nitrogen unless the ratio is in the order of 20:1 or lower. (Edward et al., 1976). Therefore the ratio of carbon to nitrogen is important for the proper growth of any plant. Earthworms help to lower the carbon to nitrogen ratio of fresh organic matter by consuming the matter, breaking it down and using the carbon for energy during respiration (Ronald, 1977). To assess the role of earthworm in lowering the C/N ratio, the consumption of the carbon must be measured, and this can be done approximately, by measuring the respiration. So they is always the disadvantages to this method, since the laboratory test will not always reflect the actual situation. Daniel et al., (1999) have done an experiment in vermicomposting of selected leaf litter and cowdung mixtures (1:1) and shown a substantial variation in the Electrical conductivity, NPK, organic carbon and C/N ratio than worm unworked compost. The C/N ratio also showed here a remarkable reduction in the worm worked vermicompost than the worm unworked compost. Such type of reduction has been brought about by the respiratory activity and microflora present in the system (Daniel, 1999). With the dawn of the consumerist culture, the composition of the waste will change drastically and pose an even bigger problem. The solid waste so generated can be of two types biodegradable or organic and non-biodegradable or the inorganic. The organic waste includes the mainly kitchen waste, straw, hay, paper and animal excreta. The inorganic portion of the waste is generally dominated by the ash, stone, cinders, plastics, rubber and ferrous and non-ferrous metals. The residential and the commercial portion make up to about 50 to 70 percent of the total MSW generated in a community.

2.7 Composition of municipal solid waste

Figure 2.2 Composition of municipal discards (Robert, 1996)



With the dawn of the consumerist culture, the composition of the waste will change drastically and pose an even bigger problem. The solid waste so generated can be of two types biodegradable or organic and non- biodegradable or the inorganic. The organic waste includes the mainly kitchen waste, straw, hay, paper and animal excreta. The inorganic portion of the waste is generally dominated by the ash, stone, cinders, plastics, rubber and ferrous and non-ferrous metals. The residential and the commercial portion make up to about 50 to 70 percent of the total MSW generated in a community. The actual percentage distribution will depend on the extent of the construction and demolition activities

- Extent of the municipal service provided
- Types of water and wastewater treatment facilities that are used.

The wide variation in the special waste category is due to the fact that in many communities yard waste are collected separately. Typical values for paper in the residential MSW range for about 20 to 40 percent. For the remaining components of the waste can vary to about 40 to 100 percent. It is being noted that percentage of food waste is high because most vegetables are not pre-trimmed.

2.7.1 Transformation of waste

Transformations of waste can occur through the intervention of people or by natural phenomena.

2.7.1.1 Physical Transformation

These include component separation, mechanical volume reduction, and mechanical size reduction. Component separation is used to describe the separation processes (manual and/or mechanical) in commingled waste. It can include such things as magnetic separation. The usual materials recovered include separation of recyclable, the removal of hazardous wastes, and the recovery of energy products. Volume reduction refers to the processes whereby waste volumes are reduced, usually by force or pressure.

2.7.1.2 Chemical Transformation

This usually involves a change of phase, eg solid to liquid, solid to gas etc. The main processes are combustion, pyrolysis, and gasification. Combustion is the chemical reactionwith oxygen of organic materials accompanied by the emission of light and heat.

2.7.1.3 Biological Transformation

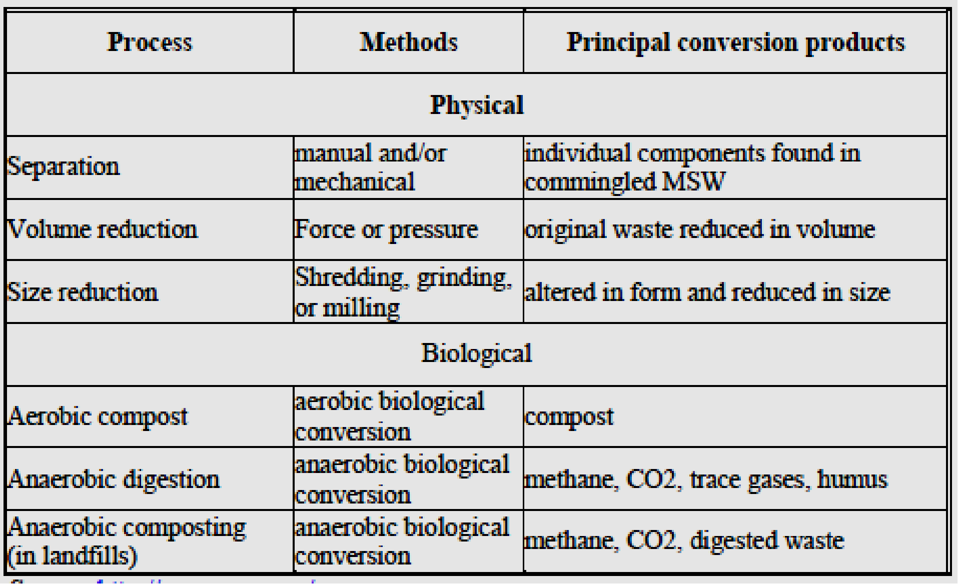
The biological transformation of the organic fraction bother reduces the volume and weight of material but also produces compost. When carried out anaerobically methane is produced - a typical component of landfill gas.

2.7.1.4 Importance of Waste Transformation

Typically waste transformations are used:

1. to improve the efficiency of solid waste management systems
2. to recover reusable and recyclable materials
3. to recover conversion products and energy

Table 2. 1 Transformation Processes in Solid Waste Management
(http://www.epa.gov/epaoswer)



Process	Methods	Principal conversion products
Physical		
Separation	manual and/or mechanical	individual components found in commingled MSW
Volume reduction	Force or pressure	original waste reduced in volume
Size reduction	Shredding, grinding, or milling	altered in form and reduced in size
Biological		
Aerobic compost	aerobic biological conversion	compost
Anaerobic digestion	anaerobic biological conversion	methane, CO2, trace gases, humus
Anaerobic composting (in landfills)	anaerobic biological conversion	methane, CO2, digested waste

2.7.2 Environmental problem in disposal of the municipal solid waste

Most of the municipal refuse is still discarded in the sanitary landfills. One of the problems it will create in it is the generation of the methane gas due to the anaerobic decomposition of the organic materials compacted inside. It further can cause explosion

Sewage sludge: Being the product of wastewater treatment plant is usually of liquid mixture composed of solid and dissolve organic and inorganic material. This solid part being biologically unstable consisting of organic and inorganic materials is usually referred to as the sewage sludge.

Heavy metal: Heavy metal in the sewage sludge is of great concern to the public health. Heavy metals are those metals that have density, > 5 - 6 gm/ cm3. The heavy metal content n the sewage sludge depends greatly on the type of industry. In general municipal sludge is high in Al, Fe, Zn, Cu and Cr content.

2.7.6 Importance of recycling

A significant challenge confronting engineers and scientist in the developing countries is the search for appropriate solutions to the treatment and disposal of the domestic waste. The treatment and recycling of organic waste can be most effectively accomplished by biological process employing the activities of microorganisms and higher life forms (Polprasert, 1996). The main objective behind this recycling is to treat the waste and to reclaim the valuable substance present in the waste for possible reuse. Here, in vermicomposting we are collecting the waste as input raw material for our reactors. Latter these wastes are converted into useful compost by the action of the earthworms within a given period of time.

2.7.7 General fate of organic waste

When the domestic waste and other household waste enter the municipal waste steam without any pretreatment or source segregation, it either ends up in a landfill or in an open dumping site. This, then become a major sanitation issue and also a big problem in the landfill leachate management.

2.8 Earthworm in sewage stabilization and processing

2.8.1 Potential for sewage sludge processing

Earthworms are these days intensively used in the degradation of sewage sludge. Research done by Neuhauser et al.,(1980) has shown that aerobic sewage sludge can supply the nutrients necessary for the growth and reproduction of the earthworm.

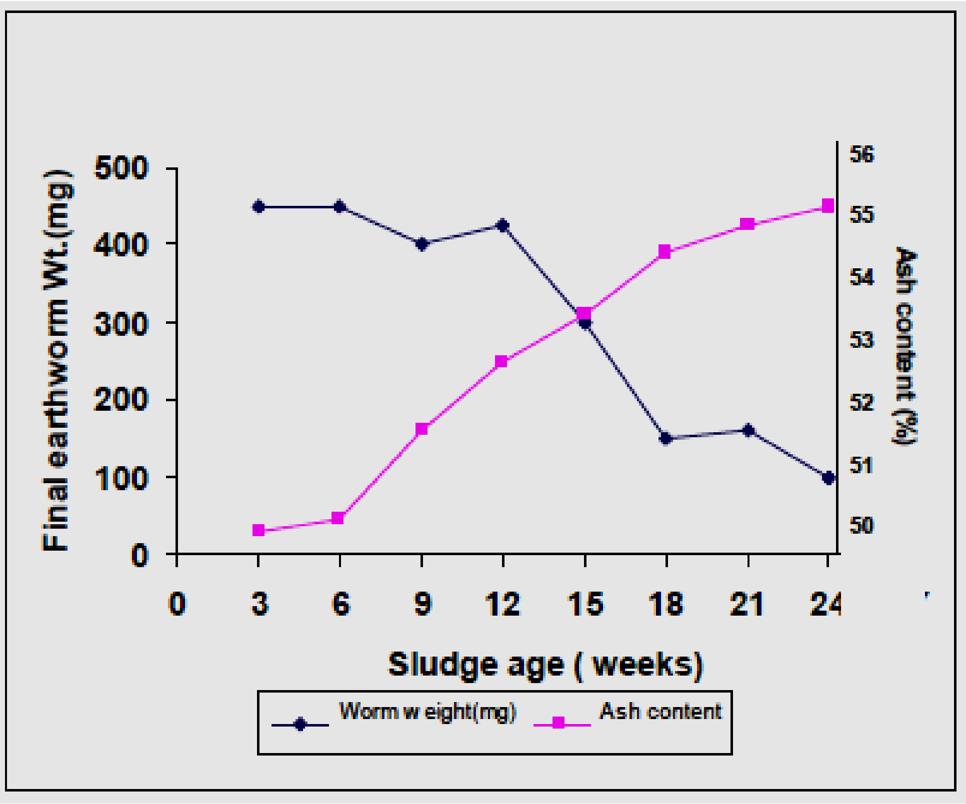
2.8.1.1 Degree of stabilization

If earthworms are useful in stabilizing sludge they must increase the stabilization rate. This can be shown if the presence of earthworm in the sludge causes an increase in the rate of volatile solids reduction. Maximum reduction of the volatile solids is a goal of any sludge stabilization system. Esenia foetida can increase the rate of volatile solid sludge destruction, when present in aerobic sludge. This increase in the sludge solids destruction rate reduces the probability of putrefaction occurring in the sludge due to anaerobic conditions. The more rapid degradation of organic matter was probably due to increased aeration and other factors brought about by the earthworms (Neuhauser et al., 1988). Bhiday (1997) reported that the aerobic and the anaerobic stages of the sludge help to convert the organic matter into the right type for rapid consumption and digestion by the earthworms. The role of earthworm in vermistablization is linked to the aerobic condition of the sludge and the moisture content. In sludge’s that are aerobic, the worms have a strong and positive effect. Earthworms can not exist in anaerobic sludges and will not have a positive effect until aerobic condition occurs.

2.8.1.2 Sludge age

It is also very important to relate the rate of earthworm growth to the age of the sludge, i.e., the time after the sludge was removed from the aerobic reactor and dewatered. (Neuhauser et al., 1988) reported that as the sludge ages, its nutritive value to the earthworm decreases rapidly after about twelve weeks removal from the digester, whereas the ash content of the sludge increases with the time, an indication of sludge stabilization.

Figure 2. 3 Effect of aging aerobically digested sludge on the growth of *E. fetida* (Neuhauser, 1988).



2.8.1.3 Moisture content of the sludge

Both excessive and insufficient moisture can adversely impact earthworm growth. A series of experiments were conducted to determine the moisture content of the media that will exist in vermistablization units. In an experiment conducted by Neuhauser (1988), an aerobically digested sludge was dewatered to a moisture content of 75% and exposed to a temperature of 250C. Here in this media four earthworms of one species (E. foetida) were placed and their growth was recorded accordingly for four weeks. Latter they found out that optimum worm growth occurred when the total solid content of the media is from 9-16 %. Very high and very low moisture concentration will also inhibit the earthworms (Raymond et al., 1988)

2.8.1.4 Choice of earthworm

There are many earthworm species that have the potential to be used in sludge stabilization systems. Since earthworm growth and reproductive rates are the way of indicating the potential for use in sludge management systems, therefore the proper choice of earthworm is an important factor that might effect the rate of sludge stabilization. Neuhauser et al., (1976) have used five species of earthworm to determine the optimum temperature for growth and reproduction in dewatered (10-12 % solids) aerobically digested sludge for twenty weeks. He estimated the over all reproductive capability of each species by using the total number of cocoons produced over the study period and fund out that amongst the other four species, (D. veneta, E. eugenia, P. excavatus and P.hawayana.) E. foetida appears to be the appropriate species to use in vermistablization studies. Local worms can also be used effectively in the combined process of litter and soil management. Since the introduction of foreign species may create a complex chain of interaction amongst the soil organisms which may lead to the competition among the species for the food.

2.8.2 Vermicomposting of liquid municipal sludge

Earthworms are also used effectively in the stabilization of the municipal sludge's, the worms maintain aerobic conditions in the mixture, ingesting the solid content and also converting a portion of the organic matter into its biomass and to respiration products, and discard the remaining partially stabilized matter as casting. As per reported by Neuhauser et al., (1988) the degree to which the organic matter is degraded is a function of, the portion of the waste that is biodegradable, maintenance of aerobic condition and avoidance of toxic conditions. The role of earthworm in stabilization of municipal sewage sludge is greatly linked to the aerobic condition of the sludge, ash content or the sludge age, the moisture content and the loading rate.

Failure occurred in those reactors where the liquid no longer flow through the accumulated sludge solids, resulting in ponding of the media and latter development of anaerobic condition. (Loehr et al., 1998). Other possibilities to make these waste more palatable to the worms is to aerate the sludge in rotor drums to encourage the aerobic microbes before feeding them to earthworms (Seenappa et al., 1995).

2.8.3 Refused feed

2.8.3.1 Types of refused feed

2.8.3.1.1 Animal manures

Table 2.2 Different types of Manure

No.	Types of Manure
1.	Cattle solids: They are the easiest animal wastes in which the earthworms will grow. Theyusually contain no materials that are unfavorable to the earthworms. Cow slurry is a suitable substrate for vermicomposting, both when mixed with solid materials and when applied to the surface of bedding materials containing earthworms. Hand et al., (1998) reported that the mixture of slurry with paper tissue waste produced greater earthworm growth and cocoon production per unit of slurry consumed.
2.	Horse manure: Horse manure is very suitable for the growth of earthworms. It also doesn’t need any pretreatment and thus can be applied directly as a feed. Ronald et al., (1978) reported that horse manure contains 0.7 % of nitrogen, 4.38 %of protein and 60 % of organic matter and trace amounts of phosphoric acid and potassium oxide. Another reason for recommending the horse manure is that it doesn’t require addition of other material for moisture retention, aging, porosity and above all it doesn’t require to check for the acidity of the bedding.
3.	Pig solids Waste from the piggeries is probably regarded as the most productive refuse for growing the earthworms. This waste if it comes in slurry, the solids must be separated either by sedimentation or other mechanical means. Edward et al., (1988) reported the presence of some inorganic salts and some ammonia, which have to be washed out can be composted for about two weeks or longer prior to inoculation with earthworms.
4.	Poultry waste These manures are higher in protein content, nitrogen and in terms of phosphoric acid than any other animal manure (Ronald et al., 1978). The fresh waste generated from the poultry farms contains significant amount of inorganic salts. (Edward et al., 1988).

2.9 Composting

With the advancement of human civilisation and its never-ending tertiary consumers, our planet is deliberately heading towards a fateful direction. With the dawn of a theoretic new century, we are knowingly and unknowingly contributing thousands of tons of solid waste per day. Which if not regulated or channeled properly might bury us within it, in the long run just to get composted.

During the composting process, microorganisms decompose organic compounds, which consist of carbohydrates, sugar, proteins, fats, cellulose and lignin. Carbohydrates are more easily decomposed whereas lignin is more resistance to decomposition. Many factors affect the composting process. Aerobic microorganisms need oxygen, water and nutrients for their metabolism and cell synthesis. As a result of microbial activity heat is liberated and, if contained within the composting mass, the temperature rises. Temperature increases through the mesophilic phase into a thermophilic phase and then back in to the mesophilic phase. During the course of these transitions, the microbial population changes, thereby affecting the rate of organic matter decomposition. and may be accomplished within a building, out-of-doors or under a simple roof.

2.9.1 Production from vermicomposting

2.9.1 .1 Biofertilizer

Bio-fertilizers based on renewable energy source are cost effective supplement to chemical fertilizers, eco-friendly and can help to economise on the high investment needed for chemical fertilizer use as far as nitrogen and phosphorus are concerned. (www.glsbiotech.com/products/biofertilizer)

2.9.1.2 Biofertilizer galaxy

- Phospho:

It releases insoluble phosphorus in soil and fix this phosphorus in clay minerals which is of great significance in agriculture.

- Rhizo:

Rhizo Bacterial plays a very important role in agriculture by inducing nitrogen fixings nodules on the root of legumes such as peas,beans clove and alfalfa.

- Azotobactor:

Atmosphere contains 78% nitrogen which is a very important nutrient for plant growth. Azotobactor fixes the atmospheric nitrogen in the soil and make it available to the plants. It protects the roots from other pathogens present in the soil

- Trichoderma:

It is a non- pathogenic and eco-friendly product. The product is antagonistic hyper parasitic against different pathogens in the field and economically well established biocontrol agent.

- Composter:

(Decomposing Culture): Composter breaks down any organic matter such as dead plants farm yard waste, cattle waste etc. thereby increasing the soil productivity.

- Tricho-Card:

Trichogramma is an efficient destroyer of eggs of many leaf and flower eaters, stems, fruit, shoot borers etc. It can be used in a variety of crops as well as in horticultural and ornamental plants,such as sugarcane,cotton,brinjal,tomato,corn,jawar,vegetables,citrus,paddy apple etc.

- Vermi Compost:

It is 100% pure eco-friendly organic fertilizer. This organic fertilizer has nitrogen phosphorus, potassium,organic carbon,sulphur,hormones,vitamins,enzymes and antibiotics which helps to improve the quality and quantity of yield. It is observed that due to continuous misuse of chemical fertiliser soil losses its fertility and gets salty day by day. To overcome such problems natural farming is the only remedy and Vermi compost is the best solution.

- Biocompost:

It is eco-friendly organic fertilizer which is prepared from the sugar industry waste material which is decomposed and enriched of with various plants and human friendly bacteria and fungi. Biocompost consists of nitrogen, phosphate solubilizing bacteria and various useful fungi like decomposing fungi, trichoderma viridea which protects the plants from various soil borne disease and also help to increase soil fertility which results to a good quality product to the farmers.

2.9.1.3 Types of Biofertilizer

Table 2.3 Different types of Biofertilizer
(URL:http://www.oldgrowth.org/compost/forum_vermi2/index.cgi)

No.	Types of Biofertilizer	Usages
1.	For Nitrogen	• Rhizobium for legume crops. • Azotobacter/Azospirilium for non legume crops. • Acetobacter for sugarcane only. • Blue-green algae (BGA) and Azolla for low land paddy
2.	For phosphorus	• Phosphatika for all crops to be applied with Rhizobium. • Azotobacter, Azospirilium and Acetobacter.
3.	For enriched compost	• Cellulolytic fungal culture

2.9.1.4 Properties of Biofertilizer

Table 2. 4 Properties of Biofertilizer
(URL:http://www.oldgrowth.org/compost/forum_vermi2/index.cgi)

Properties	
Total Nitrogen (%)	0.672
Total Nitrogen (P.P.M)	397
Total Phosphorus (%)	1.20
Available Phosphorus (P.P.M)	80
Available Potassium (P.P.M)	5250
Iron (P.P.M)	21.80
Manganese (P.P.M)	16.63
Carbon % Nitrogen percentage	6.16:1
Moisture (%as per Qty)	12-17%

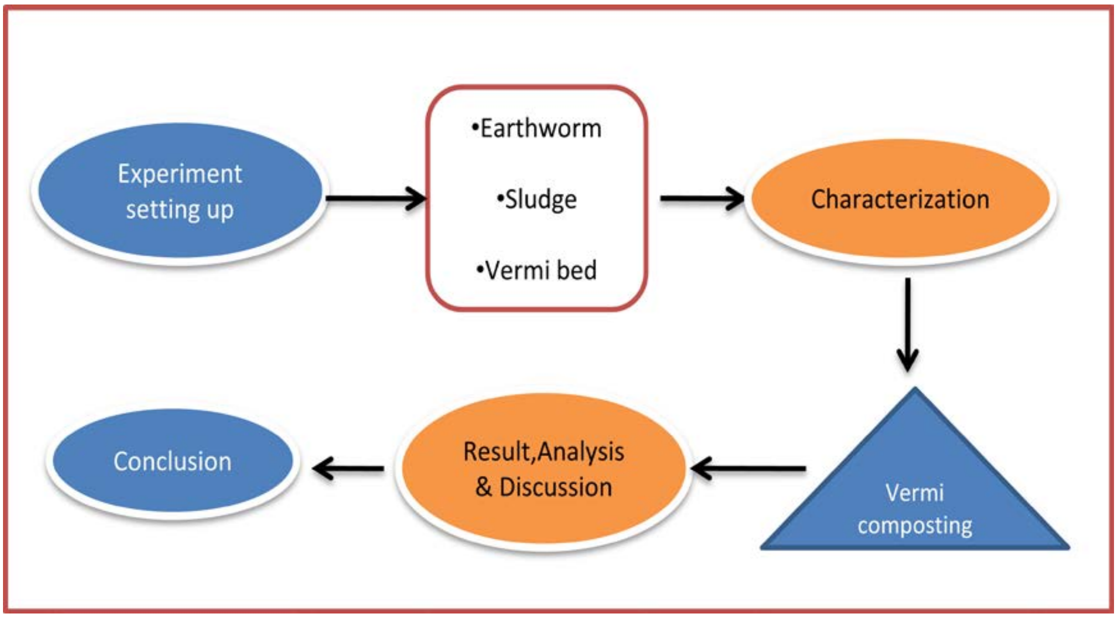
CHAPTER 3

METHODOLOGY

3.1 Overview of the general methodology and experimental set up

The main objective behind this experimental study is to characterize the municipal sewage sludge and the vermi casting from vermicomposting process by tiger worms *(Eisenia fetida)*in 21 days. The overall flow of experiment setting up is show in Figure 3.1 .

Figure 3.1 Overall experiment setting up



3.2 Collection of sewage sludge

For this study the Municipal Sewage Sludge (treatment sludge) was collected from Sewage Sludge Treatment Plant in Indera Makhota,Kuantan. The sludge as received was introduced in the vermicomposting unit without any source separation. About 25000 g of treated sludge are being collected for vermicomposting process. The cumulative average moisture content of the MSS as collected from the site is 60% - 70 % (wet basis).

These sludge were studied for a maximum of three several weeks only since our main emphasis is in the vermicomposting and the characterization of the sludge includes the testing of parameter pH, Total Nitrogen(TN), Total Phosphorus(TP) Total Potassium (TK) and the final weight of vermin cast. The sludge that we receive, although doesn't contain any hazardous materials but since it was handled manually during its composting period therefore gloves and other precautionary measures were also practiced. The initial temperature of the sludge in the heap is measured and is recorded as about (27-29)°C and then it remains constant for couple of days.

3.3 Vermicomposting Study

3.3.1 Vermicomposting of sludge

The earthworm species used is *Esenia Fetida* (tigerworm), which is epigeic and is a potential waste composting worm. About 1 kg of *Esenia Fetida* will be used in this vermicomposting of sludge. The tiger worms was bought from the earthworm farm at Kuantan, Pahang.(Figure 3.2)

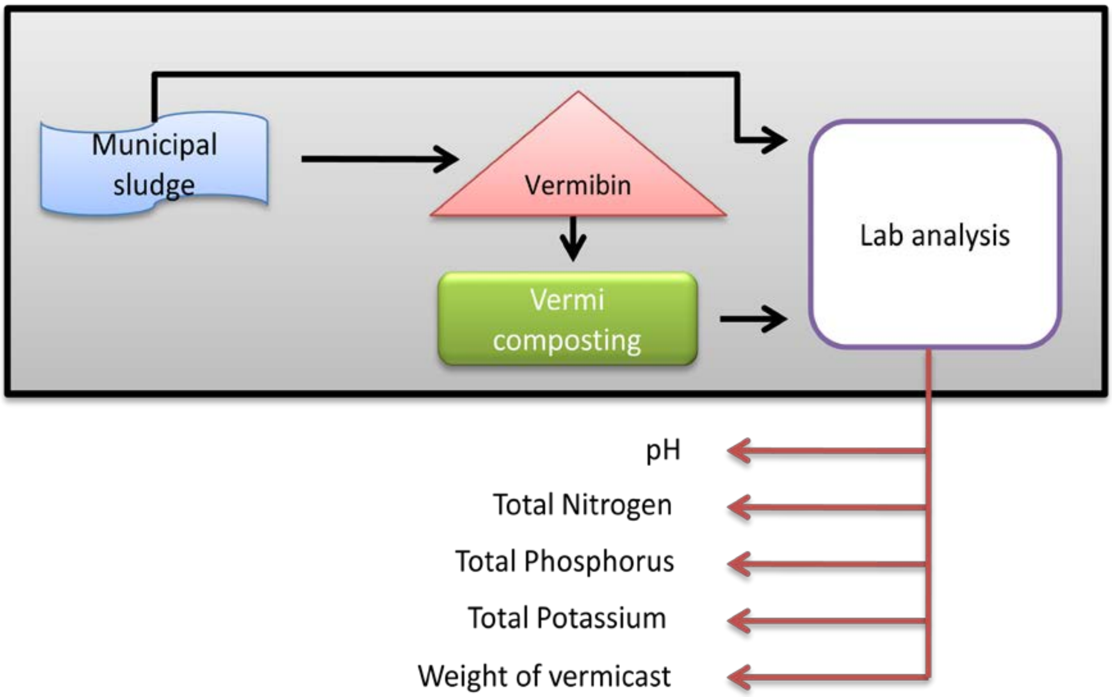
Figure 3.2 Tiger worms *(Esenia fetida)*

3.3.2 Process involved within

3.3.2.1 Vermicomposting Process

As the figure below describes clearly the methods that was adopted to compare and to study the potential of vermicomposting. Every 1st, 7th ,14th and 21st day in the 21 days of vermicomposting period, the vermicast will be analyzed also the initial sludge collecting. The initial and the final sample from each system was analyzed in the laboratory and are being compared in the previous study.

Figure 3.3 Vermicomposting study



3.4 Characterization

Characterization of the sewage sludge was done before a brief period of vermicomposting, and the result so obtained was compared amongst each other. This characterization includes of testing parameter of the pH, Total Nitrogen (TN), Total Phosphorus (TP) and Total Potassium (TK) show in Figure 3.3. The waste that which are passed through the vermibin are seen more easier to handle, if compared to the ones that are being composted aerobically. As it is clear from the above figure that the lab analysis was also done after the characterization to check the chemical parameters listed in the table 3.1 and the parameter is determined by using the suitable experiment apparatus show as Figure 3.4.

Table 3. 1 Experimental parameters and analytical methods

Parameter	Principal	Unit	Reference
pH	pH meter	…….	Standard method (1980)
Total Nitrogen (TN)	DR2500 (hach)	mg/L	Method 10071
Total Phosphorus (TP)	DR2500 (hach)	mg/L	Method 8049
Total Potassium (TK)	DR2500 (hach)	mg/L	Method 8190

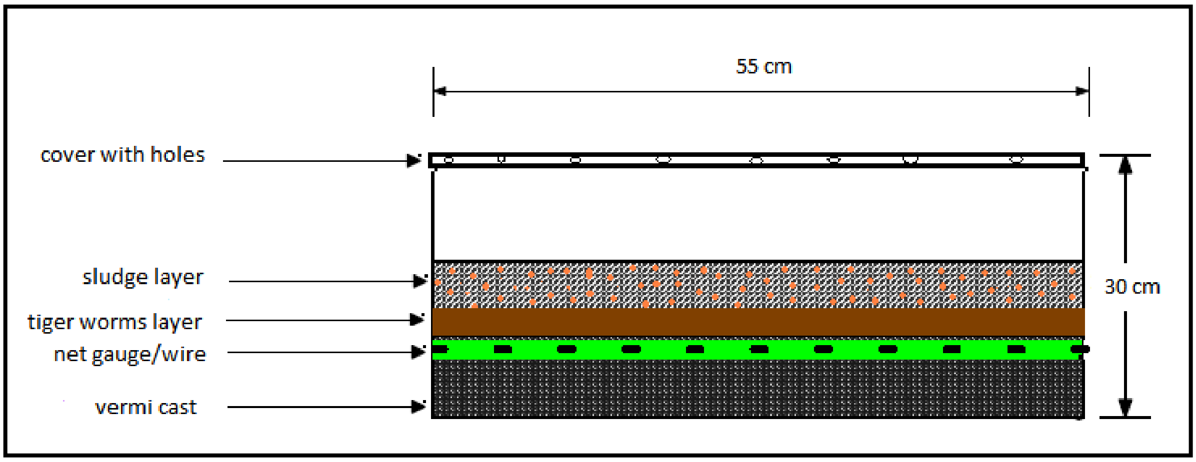
Figure 3.4 Experimental apparatus

Reagent powder pillow DR5000 pH Meter

3.5 Vermibin design and set up.

Another study was carried out parallel to the Vermibin as shown below. Using this vermibin we have investigated the actual mass reduction in the municipal sewage slude after vermicomposting.

Figure 3.5 Vermibin design



This volume and mass reduction of the waste depends lot on certain specific parameters specially pH and the loading rate. By using the data obtained from the vermirbin we can calculate the amount of waste consumed by the worms, which is given by the difference in the mass of the initial and final waste product. This vermibin was also used to study the stabilization of the sewage sludge and also to run a vermicomposting process with tigerworms. Parameters mentioned in table 3.1 were also analyzed from the vermicast from this vermibin.

3.6 Determination of physical variables

3.6.1 pH

The pH of sludge and vermicast are determined using pH meter in the Environmental laboratory.

3.6.2 Weight of vermicast

After 21 days the vermicast material will be collect and sieve. The vermi casting is sieve with the hand sorter (net or gauge wire) softly to separate the earthworm and the vermi casting. Then the final product that had been sieved is weight by the measuring scale.

3.7 Determination of chemical variables

3.7.1 Total nitrogen

Total nitrogen will be determined by Method 10071 in HACH.DR 5000 and Total Nirogen Persulfate Reagent Powder Pillow were used in this method.

3.7.2 Total Phosphorus

Total Phosphorus will be determined by Method 8190 in HACH.DR 5000 and Total Phosphorus Test “N” Tube Reagent Set were used in this method.

3.7.3 Total Potassium

Total Potassium will be determined by Method 8049 in HACH.DR 5000 and Potassium Reagent Powder Pillow were used in this method.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Vermicomposting study

Vermicomposting study for the pretreatment of Municipal Sewage Sludge was started by first vermicomposting process the tiger worms in a suitable vermibins for an approximately three weeks. After three weeks, the parameters such as weight of final vermi casting, pH, Total nitrogen, Total phosphorus, and Total potassium are obtained from several experimental testing that had been conducted. The sample is taken every week starting at 1st day, 7th day, 14th day and lastly 21st day. The 1 g sample (vermicompost) is add into 1 L of distilled water for more easier to be tested in laboratory and all the result is been recorded.

4.1.1 Observation of earthworms

The tiger worms are bought in the vermibins for a period of three weeks and lived with Municipal sewage sludge. It was found that the tiger worms were sensitive to variation in pH, temperature and the moisture of the bedding material (MSS). The temperatures and the moisture are maintained and the data is recorded thrice a week as shown in Table 4.1.

Table 4. 1 Average measured range of parameters

Parameter	Vermi-bin	Unit	Method
Temperature	29-31	Celcius	Thermometer
Moisture	60-70	%	Standard method
pH	5.5-6.5	……	pH meter

4.1.2 Vermibin

Vermibin by the dimension of (0.55wide x 0.30high x 0.25long) metre was used to study the organic degradation of the sewage sludge , since the sludge has to be spread uniformly on the vermibin. Therefore a total waste of 20-25 Kg of sewage sludge was fed to the worms to a maximum height of 0.15 to 0.20 for 3 weeks. It was observed that the vermibin works better in reducing the organic parts of the mixed waste if compared to the aerobic composting. But to my dismal, during the sampling of sludge, it gets mixed up with the vermicompost and on top of it the moisture content of the sludge was never constant due to the watering of bin in order to maintain a moist environment for the worms.

4.1.3 Characteristic of sewage sludge

About 25 kg of sewage sludge are being collected from sewage treatment plant at Indera Makhota, Kuantan. A brief characteristic of the sludge is given in Table 4.2. The experiment test is conduct before starting the vermicomposting process.

Table 4.2 Characteristics of the sewage sludge

Content (parameter)	Measuring unit	Sewage sludge
pH	…….	7.30
Total Nitrogen (TN)	mg/L	19.6
Total Phosphorus (TP)	mg/L	9.46
Total Potassium(TK)	mg/L	3.47

The pH in sewage sludge is lies in alkali range this might be due to the mineralisation of organic alkalinity that might have taken place at the source and during transportation. From the experiment test results, the parameter of TN, TK, TP have determined and shows as in Table 4.2.This evidences show the chemical and physical characteristic is present in sewage sludge.

4.1.4 Vermicast study and analysis

4.1.4.1 Biomass of Earthworms

As explained above, the weight of the tiger worms(including the adults and the young ones) was higher when the sewage sludge were fed in vermibin. The final weight worms were recorded as shown (Table 4.3). Ronald et al (1977) reported that the worms perform best in neutral pH and the tiger worms generally prefer the pH of their bedding soil slightly acidic or neutral then to alkaline. It was found that the local worms could not breed that fast as compared to the red worms (tiger worms) and were sensitive to variation in pH, temperature and the moisture of the bedding soil. The breeding potentials of the red worms greatly increased when they are shifted to an open vermibin. It was not at all an easy task to count the initial and final worms on a bin scale, even if so the results so obtained would have lots of error. The precaution is takes place by taking the reading for several of time. But it was seen that the biomass rate of the tiger worms was increased as compared to the initial and final biomass during the vermicomposting process.

Table 4. 3 Growth rate of earthworms in vermibin

Vermibin	Time (days)	Initial weight of worms (g)	Final weight of worms (g)
Tigerworm + treated sewage sludge	21	1000.00	1371.64
	Weight of sewage sludge/21 days (g)	Weight of vermicompost/21 days (g)	Weight of assumption vermicompost /21 days (g)
	25000.00	23416.10	21000.00

Devliegher andVerstraete (1996) studied the effects of nutrient enrichment processes (i.e. enzymatic activities in the earthworm gut that increase the nutrient content of the ingested residues). They concluded that if the weight-increase of the worms is accounted for, the nutrient content of ingested organic material largely makes up for the nutrient content of the same material when simply incorporated in the soil.

Suthar (2007) summarized that the factors relating to the growth of earthworms may also be considered in terms of physiochemical and nutrient characteristics of waste feed stocks. Thus organic waste palatability for earthworms is directly related to the chemical nature of the organic waste that consequently affects reproduction performance of the earthworm.

4.1.4.2 Weight of Vermicast

21 days are required for complete vermicomposition. After 21 days the vermicast material is collected and sieved. The vermi casting is sieved with the hand sorter (net or gauge wire) softly to separate the earthworm and the vermi casting. Then the final product that had been sieved is weight. The end product resembles dark brown colour humus or soil.

The net weight of harvest from the bin is estimated as 10 – 15 % higher from the assumption of initial weight of vermicast. For the weight of vermicast is nearly not different with the weight of the initial earthworm feeding material (sewage sludge). Earthworms eat each day is equals to their weight. That means, for 1000 g earthworms eat almost about 1000 g feeding material to the bin each day.

Sewage sludge can be seeded with *E. fetida* by calculating a consumption rate of 1.5 times their biomass every 24 hours proportionally. Earthworms should not be harvested before this time.(Eastman et.al ,2001).

Figure 4.1 Eastman equation

$$\frac{\text{Kg sewage sludge}}{\text{Composting day}} = \frac{\text{sewage sludge/days}}{\text{1.5 (consumptive rate of earthworms)}} = \text{Kg of earthworms required for VC}$$

From the Eastman equation (Figure 4.1), the Kg of sewage sludge must required is 31500 g but from the results, the study records does not match with the Eastman equation because the final weight of vermicast is recorded only 23416.10g. This mean the consumption rate of tiger worms in this study is only around 1.2 times their biomass every day.

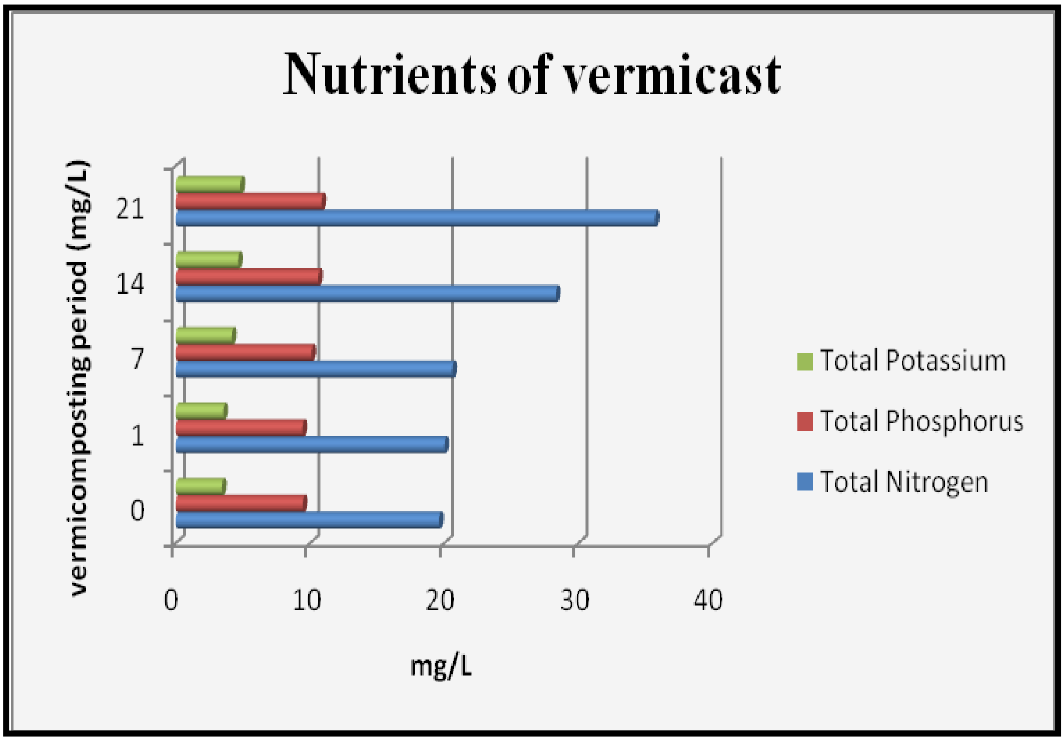
4.1.5 Nutrients in vermicast

In the next run, using the same vermibin result other parameters namely, total nitrogen, total phosphorus, total potassium and pH were determined and analysed in this study. The amount of organic matter, total nitrogen, phosphorous and potassium in the vermicomposting process is increased. It was found that the total nitrogen of the vermicast were high at the end of 21 days which is from 20.2 mg/L to 35.7 mg/L. Total of phosphorus increased by the end of the vermicomposting process which is from 9.43 mg/L to 10.87 mg/L. A similar increase in total potassium was recorded in this result at the end of 21 days which is from 3.53mg/L to 4.80 mg/L. There were slight changes in pH value of the vermicomposting process. The pH value is decreased during vermicomposting which is 6.05 to 5.90. Many studies were conducted on the process by which earthworms transform organic matter after ingesting it and on the properties of the resulting material, but very few were based on stabilized casts, compared to synthetic fertilizers and compost.

Table 4.4 The characteristics of vermicast from the vermicomposting process.

Dates	Compost period (day)	pH	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Potassium (mg/L)
20/08/2009	1	6.05	20.0	9.43	3.53
26/08/2009	7	6.02	20.6	10.1	4.16
02/09/2009	14	5.92	28.3	10.6	4.63
09/09/2009	21	5.40	35.7	10.87	4.80

Figure 4.2 Graph of data obtained during the vermicomposting process.

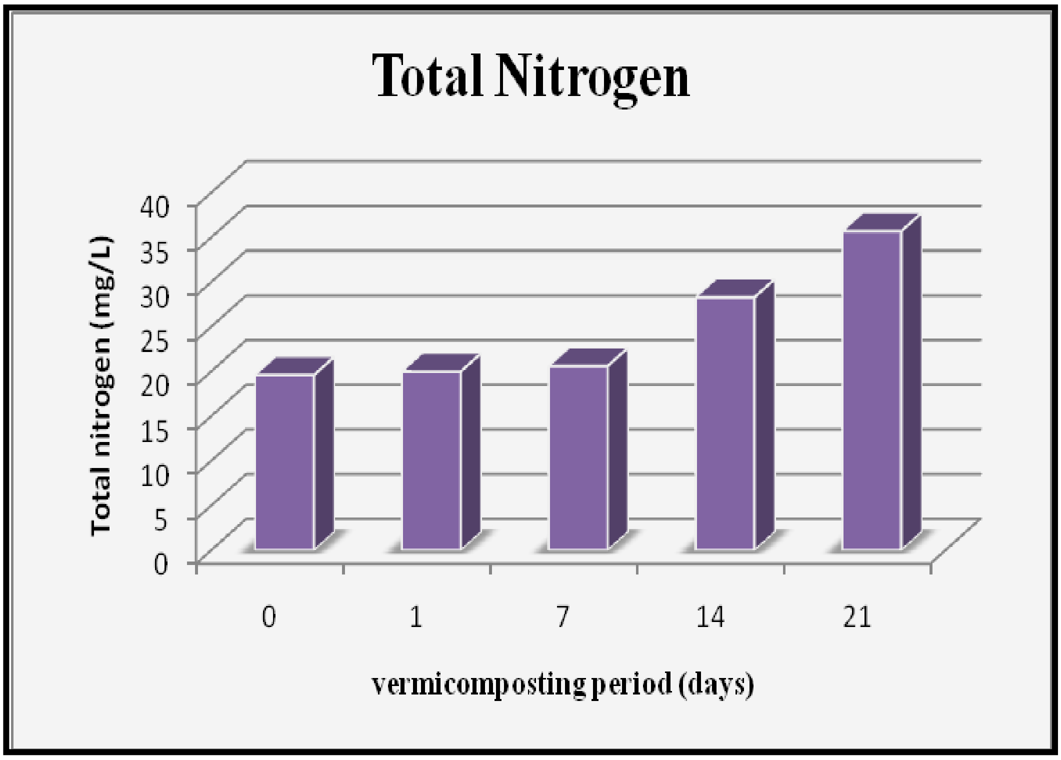


From earlier studies also it is evident that vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants. Sreenivas et al. (2000) studied the integrated effect of application of fertilizer and vermicompost on soil available nitrozen (N) and uptake of ridge gourd (*Luffa acutangula*) at Rajendranagar, Andhra Pradesh, India. Soil available N increased significantly with increasing levels of vermicompost and highest N uptake was obtained at 50% of the recommended fertilizer rate plus 10 t ha-1 vermicompost. Similarly, the uptake of Nitrogen (N), phosphorus (P), potassium (K) and by rice (*Oryza sativa*) plant was highest when fertilizer was applied in combination with vermicompost (Jadhav et al. 1997).

An increase in soil productivity, which cannot be explained by mineral nutrients alone, is often recorded when composted organic wastes are supplied to croplands. This is the so-called "organic matter effect" suggests that mechanisms other than simple nutrient supply can contribute to plant growth (Galli et al. 1992). Hountin et al. (1995) studied the effect of peat moss-shrimp wastes compost on barley (Hordeum vulgare L.) applied alone or with NPK, and he concluded that the main effect of compost on straw yield, numbers of tillers, plant height, and number of ears was more important than that of fertilizer.

4.1.5.1 Total nitrogen

Figure 4.3 Graph of total nitrogen during the vermicomposting process.



The application of earthworm casts (1000 g per 2.5 kg sludge) increased total nitrogen value shows in Figure 4.3. Composted sewage sludge is obtained by aerobic digestion of municipal refuse and anaerobically digested sewage sludge. Nitrogen immobilization can be a problem in these composts. According to khwairakpam and bhargava (2007) the reduction in dry mass (organic carbon in term of CO_2) due to substrate utilization by microbes and worms and their metabolic activities as well as water loss by evaporation during mineralization of organic matter might have led to relative increase in nitrogen. Available N increased irrespective of the residues the earthworms feed on or the growth temperature, which was attributed to the increase in oxidized C due to soil ingestion, and not to change in soil texture since the soil was not mixed (Ruz-Jerez, 1992). Extractable carbon was found to increase in soil material ingested by earthworms, which was explained by the possible effect of indigenous enzymes in the gut and the incomplete resorbtion of organic C before excretion (Daniel, 1992). This shows that earthworm activity enriches the nitrogen profile of vermicompost through microbial mediated nitrogen transformation, through addition of mucus and nitrogenous wastes secreted by earthworms. It is suggested that in addition to releasing N from compost material, earthworms also enhance nitrogen levels by adding their excretory products, mucus, body fluid, enzymes etc. to the substrate.

Suthar (2006) suggested that decaying tissues of dead worms also add a significant amount of N to vermicomposting sub-system. In general, nitrogen enrichment pattern and mineralization activities mainly depend upon the total amount of N in the initial waste material (e.g., sludge) and on the earthworm activity in the waste decomposition sub-system (Kale, 1998; Suthar, 2007). It is also suggested that the differences for N content in end product (vermicompost) could be related to the availability of metals in vermibin, which directly affects the N mineralization rate. Recently, Suthar (2008) demonstrated a significant impact of high metal contents on mineralization rate during vermicomposting of sewage sludge.

However, there are contradictory reports on nitrogen content and its variation in vermicomposting. Ndegwa et al. and Mitchell found no significant difference between total nitrogen concentrations in the original substrate and the resulting vermicompost. Where as, Parvaresh et al have reported a great variation in nitrogen concentrations over the whole vermicomposting period. The reason for discrepancies observed in total nitrogen variations in vermicomposting of different wastes lies in the fact that the quality of substrate in feeding the earthworms together with their physical structure and chemical composition affects mineralization of nitrogenous organic compounds and the amount of nitrogen from the compounds.

Earthworms play an important role in the recycling of N in different agro ecosystems, especially under *jhum* (shifting cultivation) where the use of agrochemicals is minimal. Bhadauria and Ramakrishnan (1996) reported that during the fallow period intervening between two crops at the same site in 5- to 15-year *jhum* system, earthworms participated in N cycle through cast-egestion, mucus production and dead tissue decomposition. Soil N losses were more pronounced over a period of 15-year *jhum* system. The total soil N made available for plant uptake was higher than the total input of N to the soil through the addition of slashed vegetation, inorganic and organic manure, recycled crop residues and weeds.

4.1.5.1.1 Purpose of nitrogen to the soil and plant

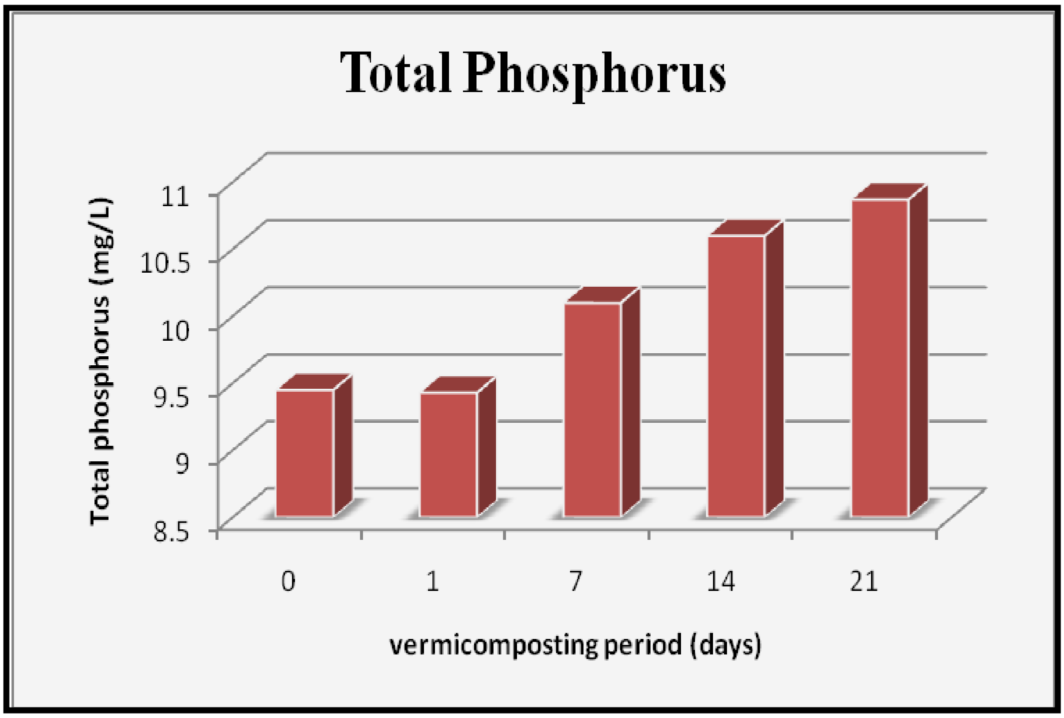
Nitrogen occurs in the chlorophyll of plants and is responsible for vegetative growth. The leaves of plants that receive sufficient nitrogen have a dark, blue-green colour, which promotes photosynthesis. Photosynthesis is the process by which light energy is intercepted by plants and stored in the form of starches and sugars. This process is essential to sustain normal plant growth.

A higher plant growth was observed in the presence of worms (Edwards & Bates, 1992). According to Haimi (1992) birch seedlings planted in soil with earthworms had 33% and 24% more leaf and stem biomass respectively than in those grown in pots without earthworms. Root biomass was slightly lower in the earthworms than in the bare soil treatment and N content of leaves was twice higher in the treatment with earthworms. This was only partially explained by earthworm mortality. N uptake increases in the presence of earthworms and is correlated ($r = 0.85$) with the increase in CO_2 production (Ruz – Jerez, 1992).

It n fresh casts, NH_4 levels were very high (294.2-233.98 g g^{-1} dry cast) due mineralization in the earthworm gut. During the first week of cast aging, NH_4 levels decreased while NH_3 levels increased, due to rapid nitrification in the fresh casts. After two weeks the levels of NH_4 and NO_3 were stabilized, probably due to organic matter protection in dry casts (Decaens, 1999). Casts tend to stabilize through nitrification after being deposited; in a garden soil processed by earthworm ammonium underwent complete nitrification compared with 33 and 9% nitrification in loam and sand, respectively (Borowski, 1995). After a 21 days long incubation of fresh casts a rapid increase in mineral N was observed during the first few days after deposition, and then a decrease to a level 4.5 times higher than in the soil. Also the NH_4 level was higher in fresh casts than in the control (Rangel, 1999). The decrease of mineral N in time in casts can be due to N becoming microbial biomass, volatilized, denitrified, or leached (Lavelle, 1992). Haynes (1999) concluded that mineral N increases because of mineralization in the gut, but P and S levels increase due to mineralization after digestion. InLavelle (1992) mineral N in casts was mostly in the form of ammonium, and after a 26 days long incubation $NH_4$was nitrified or immobilized in biomass.

4.1.5.2 Total phosphorus

Figure 4.4 Graph of total phosphorus during the vermicomposting process



The available P content was significantly higher in vermicompost. The maximum increase was in day 21st . Studies have revealed that during vermicomposting the release of available TP content from organic waste is performed partly by earthworm gut phosphatases, and further release of TP might be attributed to the P-solubilizing microorganisms present in worm casts. In this study, the TP mineralization rate increased with increasing proportion of sewage sludge in vermibin. It indicates the adverse impact of greater concentrations of sewage sludge on microbial enzymes related to TP mineralization process in vermicomposting process.

Also, Martin found an increase of 25% in total P of paper-waste sludge, after worm activity. According to Lee, if the organic materials pass through the gut of earthworms, then some of phosphorus being converted to such forms that are available to plants. Moreover, he concluded that availability of TP to plants is mediated by phosphatase produced within the earthworms and further release of TP may be introduced by microorganisms in their casts, after their excretion. Similarly, Ghosh et al have reported that vermicomposting can be an efficient technology for the transformation of unavailable forms of phosphorus to easily available forms for plants.

Increase in TP during vermicomposting is probably through mineralization and mobilization of phosphorus by bacterial and fecal phosphatase activity or earthworms. An increase of 25% in TP of paper waste sludge, after worm activity was found by Satchell et.al 1984.Increase in TP also was attributed to direct action of worm gut enzymes and indirectly by stimulation of the micro flora.

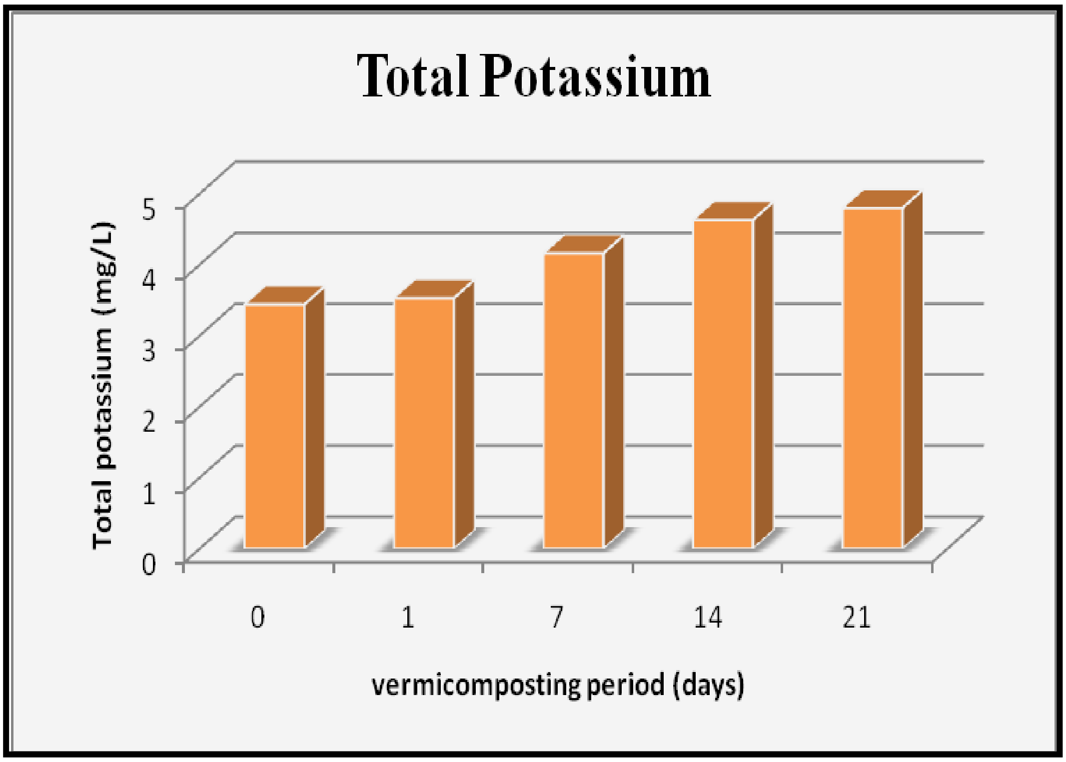
4.1.5.2.1 Purpose of phosphorus to soil and plant

The nitrogen mineralisation response to phosphorus was examined in the presence or absence of plants in three grassland soils. Responses to phosphorus of 95% and 33% were recorded in two of the soils, but only in the presence of plants. The mineralisation response was proportional to the plant growth response to phosphorus. The stimulatory effect of P on N mineralisation in the presence of plants appears to result from an increase in root growth. Root weight is positively correlated with root length (Cornish, unpublished), and greater root length results in all increase ill the volume of the rhizosphere per unit of soil volume.

Numbers of ammonifying and nitrifying organisms are higher in rhizosphere as compared to non-rhizosphere soil 13 16 22. Furthermore, N mineralised near roots may be absorbed before competing micro-organisms can re-immobilize it. Under a grass sward a large proportion of soil will be influenced by plant roots. At a depth of 2 cm under an Italian ryegrass sward a mean distance between lateral roots of 3 mm on a horizontal plane has been recorded 3. Hence the effect of roots on N mineralisation is potentially significant. The presence of the plant may account for the difference between mineralization rates in the field and laboratory.

4.1.5.3 Total potassium

Figure 4.5 Graph of total potassium during the vermicomposting process.



In Figure 4.5, the present of TK in vermicast is increased in ending period of vermicomposting process. Delgado et al have reported higher TK content in the vermicomposts prepared while using sewage sludge as feed mixture. In addition, Suthar suggested that earthworm processed waste material contains higher concentration of exchangeable K due to enhanced microbial activity during the vermicomposting process, which consequently enhances the rate of mineralization. Acid production by the microorganisms is the major mechanism for solubilizing of insoluble potassium. The enhanced number of micro flora present in the gut of earthworms in the case of vermicomposting might have played an important role in this process and increased potassium over control. Leachate collected during vermicomposting process had higher potassium concentration (E.Benitez et el 1999).The increase in TKN content was higher in earthworm- inoculated vermicomposters than controls without earthworms . According to Viel et al. (1987) losses in organic carbon might be responsible for nitrogen addition. Addition of nitrogen in the form of mucous, nitrogenous excretory substances has been reported which were not initially present in feed substrates.A increased in total potassium (TK) was reported in the vermicompost than the initial feed mixtures. Our data is supported by Orozco et al. (1996) and Kaushik and Garg (2003) who reported a increased in TK in coffee pulp and textile mill sludge, respectively, during vermicomposting. This increased maybe due to no leaching of soluble potassium by excess water.

The higher K content, data clearly indicate that the mineralization rate was higher in the reactor with *L. mauritii*. The earthworm primes its symbiotic gut microflora with secreted mucus and water to increase their degradation of ingested organic matter and the release of metabolites. Suthar (2007) and Garg et al. (2006) reported a similar result of enhanced potassium content in vermicompost material. This study suggests that earthworm drives the mineralization rate differently in vermireactors mainly due to different profiles of microbial communities in polyculture reactor than monoculture.

4.1.5.3.1 Purpose of potassium to soil and plant :

Many plant physiologists consider potassium second only to nitrogen in importance for plant growth. Potassium is second to nitrogen in plant tissue levels with ranges of 1 to 3% by weight. As a trivia, potassium is the only essential plant nutrient that is not a constituent of any plant part. Potassium is a key nutrient in the plants tolerance to stresses such as cold/hot temperatures, drought, wear and pest problems. Potassium acts as catalysts for many of the enzymatic processes in the plant that are necessary for plant growth to take place. Another key role of potassium is the regulation of water use in the plant (osmoregulation). This osmoregulation process affects water transport in the xylem, maintains high daily cell turgor pressure which affects wear tolerance, affects cell elongation for growth and most importantly it regulates the opening and closing of the stomates which affect transpirational cooling and carbon dioxide uptake for photosynthesis.

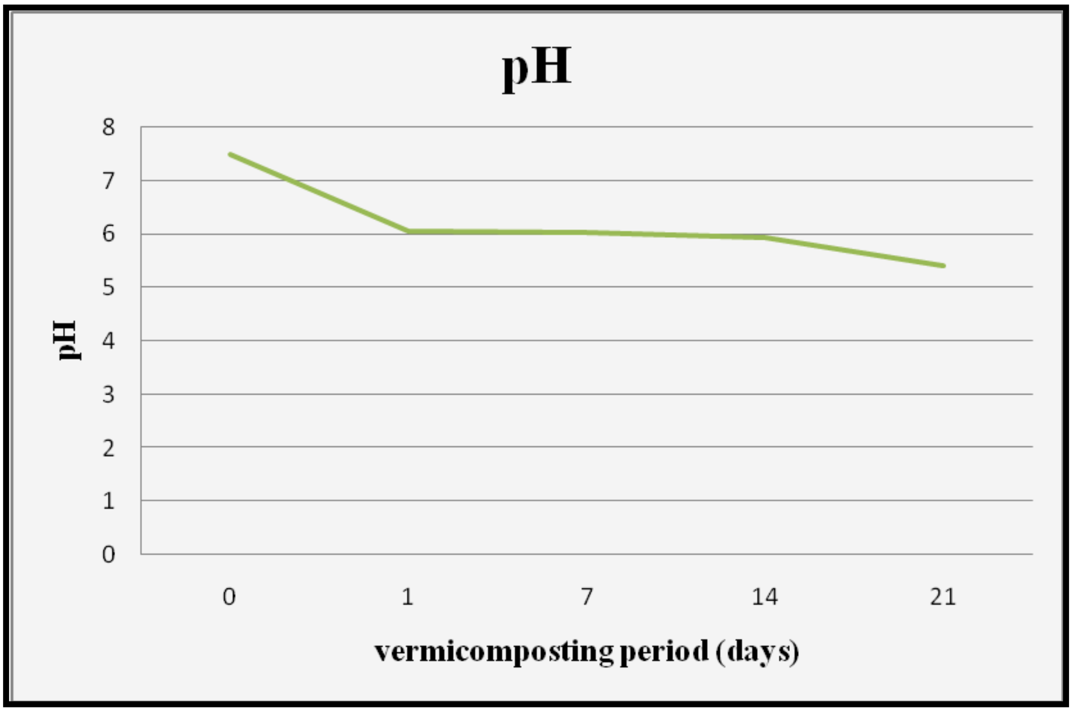
Unless truly deficiency occurs, potassium has very little effect on turf grass quality such as color and density. However, once potassium deficiency occurs, it can have a dramatic affect on the plants ability to survive and function during stress periods such as high temperatures, drought and wear. Initial potassium deficiency shows up as yellowing of older leaf blades, lower leaf blades, which is then followed by dieback of the leaf tip and scorching of leaf margins as the deficiency problem becomes worse. Once these conditions occur, wear injury for the turf plants will increase significantly. Factors which can lead to potassium deficiency include: leaching in sandy soils or soils with low CEC values, sites being irrigated with water that is high in sodium and where high rates of calcium and magnesium or added through the irrigation water or through the fertilization program.

There are four different sources of potassium in the soil. The largest soil component of potassium, 90 to 98%, is the soil minerals such as feldspar and mica. Very little of this potassium source is available for plant use. The second soil potassium source is the nonexchangeable potassium, 1 to lo%, and is associated with the 2: 1 clay minerals. The nonexchangeable potassium source acts as a reserve source of potassium in the soil. The third soil potassium source, 1 to 2%, is called the exchangeable or readily available potassium and is found on the cation exchange sites or in the soil solution. The soil solution potassium is readily taken up by the plants root system and is then replaced by the potassium on the exchange sites. A fourth source of potassium in the soil is the potassium contained in organic matter and within the soil microbial population. This soil source of potassium provides very little of the potassium needed for plant growth. Potassium uptake is most rapid on warm, moist soils that are well aerated and have a slightly acidic to neutral pH. As soil temperature increases, plant metabolic activity increases which increases root growth and root activity. Warmer soil temperatures also increase the diffusion rate of potassium in the soil solution which increases potassium uptake by the root system.

Excess soil moisture can lower soil oxygen levels which in turn decrease the respiration rate for the plants root system and thus lowers potassium uptake. Also, excess water can increase the amount of leaching of potassium, particularly in sandy soils. In alkaline soils, increased levels of other cations such as calcium, potassium and sodium can affect the availability of potassium in the soil. The calcium and magnesium cations can displace the potassium from the exchange sites on the clay particles and sodium competes with potassium for uptake by the plants root system.

4.1.5.4 pH value

Figure 4.6 Graph of pH value during the vermicomposting process.



As presented in Figure 4.6, pH in all treatments was lower at the end period of vermicompost. Vermicomposting significantly lowered the pH of substrates at end of vermicompost period . The difference between composted and vermicompost material for pH level was significant . The shift in pH during the study could be due to microbial decomposition during the process of vermicomposting. Elvira et al. (1998) concluded that production of CO_2 and organic acids by microbial decomposition during vermicomposting lowers the pH of substrate. The pH decreased from alkali (7.50-5.4) to acidic in the vermibin. This corroborates with the findings of other researchers . The pH shift towards acidic conditions has been attributed to mineralization of the nitrogen and phosphorus into nitrites/nitrates and orthophosphates; bioconversion of the organic material into intermediate species of organic acids. It has also been reported that different substrates could result in the production of different intermediate species and different wastes showed a different behavior in pH shift. Haimi and Hutha postulated that lower pH in the final vermicomposts might have been due to the production of CO_2 and organic acids by microbial activity during the process of bioconversion of different substrates in the feed given to earthworms.

pH during the study could be due to microbial decomposition during the process of vermicomposting. Ndegwa et al. (2000) pointed out that a shift in pH might be relatedto the mineralization of the nitrogen and phosphorous into nitrites/nitrates and orthophosphates and bioconversion of the organic material into intermediate species of the organic acids. The great reduction in pH level for polyculture reactor suggests the greater mineralization rate in it possibly due to anecic worm.

4.2 Comparison between composting and vermicomposting

The results obtained from the aerobic composting and vermicomposting can be compared on the basis of their suitability on a pilot scale, the results may differ if applied on alarge scale. Regarding the stabilisation of the waste it was found that volatile solid reduction during the vermicomposting proved better than the aerobic composting, the difference of 7.3 % was recorded higher in the former case. Other chemical parameters so analysed between the two are given in a tabloid form below.

More decomposition (Lignolysis) occurs and higher levels of Nitrogen are reached when waste is fed to worms than in composting. Casts also increase protein synthesis in plants In Vinceslas-Akpa & Loquet (1997) lignocellulosic wastes (of maple) were composted and vermicompost (i.e. ingested by earthworms) for 10 months under controlled conditions. At first, total organic matter and carbon decreased rapidly, while cellulose was decomposing. Aromatic structures and lignin began to decompose after one month of composting. More ligninolysis occurred in the vermicompost. The C-to-N ratio decreased, showing changes in total C and higher levels of N in the vermicompost. The two materials evolved differently: casts had a lower aromaticity ratio, and a higher protein-to-organic matter ratio than in compost, which indicates a higher level of humification (Vinceslas-Akpa & Loquet, 1997).

When casts and compost were compared in a pot experiment casts increased protein synthesis in lettuce seedlings by approximately 30%, whereas no differences were recorded in the presence of compost (Galli et al. 1992). The process of vermicomposting can also result in a product with a lower pathogen level than compost (Eastman, 1999). Recycling organic waste through earthworms also results in a product with a lower pathogen level than compost

Table 4 .5 Comparative study between vermicomposting and composting

Day	**Nitrogen %**	
	Composting	Vermin composting
1	1.76	1.76
4	1.75	1.76
7	X	X
14	1.77	1.80
21	1.77	1.89

Greater increase in the nitrogen content of the vermicompost waste is the main reason behind the production of vermi-compost, since our scope was limited as with time, the nitrogen content in the waste can only be used to study the decrease in the carbon to nitrogen ratio.Both are organic products which provide the plant with nutrients, good soil aeration and other un-identified advantages (the “organic matter effect”).

4.2.1 Comparison as to plant nutrients

1. Plants treated with compost may still show N deficiency, even when synthetic fertilizer is added. His is due to N immobilization: microorganisms in compost use N for their metabolism .

2. More decomposition (Lignolysis) occurs and higher levels of Nitrogen are reached when waste is fed to worms than in composting. Casts also increase protein synthesis in plants .

3. Compost can be an incomplete fertilizer, most plants have a an increase in yield with the addition of compost, organic N sources can cause a short term yield decrease .

4.2.2 Comparison as to the timing of nutrient release

1. Slow nutrient release is more synchronized with plant needs, and leads to higher yields.

2. Casts have a structure that is similar to a slow release granule: it has an organic matter core and a clay casing.

3. In my master's thesis (Chaoui et al, 2003) I showed that casts show a slower nutrient release rate than compost, possibly explaining the higher plant weight to nutrient content ratio.

4.2.4 Comparison as to salinity level

1. Ammonium is the main contributor to salinity levels.

2. High salinity levels cause osmotic drought.

3. NH_4 levels are high in fresh casts but casts stabilize after 2 weeks of aging through nitrification. The acidity level in casts is slightly low, which reduces denitrification . Salinity levels are moderate in casts, since passage through the earthworm gut does not increase the level of some salts (Ca, Mg, Na) .

4. Some composts have high concentrations of ammonium or soluble salts . There are larger amounts of NH_4 than NO_3 in composted domestic waste. High Levels of NH_4 are due to non-stabilized substances . Immature (unfinished) compost can stunt or kill plants, and reduce germination and growth .

4.2.5 Comparison as to pathogens

1. Recycling organic waste through earthworms also results in a product with a lower pathogen level than compost .

2. Since high temperature are not part of the earthworm cast production process disease suppressing microorganisms that may be present in this material survives in the absence of heat .

3. Some composts are suppressive of plant pathogens but heating them to 60^oC for five days reduced suppressiveness. This is why some composts need to be inoculated with disease suppressing microorganisms. Adding nutrients (i.e. reducing competition) also reduces disease suppression by composts .

4.2.6 Comparison as to time and volume requirement

1. Earthworm biomass

   a. Earthworms eat 75% of their weight daily (Ndegwa, 1999) and the speed or earthworm casts production can be increased by increasing the amount of earthworms. The layer of waste needs to be 1 ft or thinner to prevent anaerobic conditions which hinder earthworm activity.
   b. A compost pile needs to be 3 cubed feet to hold heat in winter and takes 3-4 months to be cured.

2. Comparison as to odor problem

   a. Odorous gases are emitted as compost piles heat up. Specific layering of composting material needs to be used to prevent odor.
   b. Earthworms don’t require heat to process waste (heat is actually detrimental). In the correct waste to worms ratio fermentation and heat can be prevented, and also odor or flies.

3. Aeration requirements

   a. Compost needs aeration (and labor) to maintain aerobic conditions for microbial activity.
   b. Worms dig canals (burrows) as they process waste which indirectly aerate

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Disposal of sewage sludge by environmentally acceptable means is a serious problem. Sewage sludge is a major contributor of toxic heavy metals such as Cd, Pb, etc to soils due to its direct application as manure. These metals may enter the human and animal body through consumption of the crops. The present study inferred that the application of sewage sludge in the agricultural fields after vermicomposting would not have any adverse effect. Thus this method converts the hazardous sludge into non hazardous useful nutritious resource.

In this study, vermicomposting process reveals that the good quality of bio-compost was obtained from sewage sludge in 21 days. The growth or the biomass of tiger worms in the vermibin is increased since the sewage sludge is fed to them (1000g-1371.64g). This shows that the tiger worms *(E.fetida)* have a potential in converting sewage sludge to vermicast.

The conversion of organics into bio-compost in vermibin is in considerable duration of 21 days and the quality of compost gives the optimum values when compared with all the formulations. The important characteristics such as pH, TN, TP, and TK have determined in the sewage sludge. Vermistabilization benefits sewage sludge with the transformation of the sludge appearance from a sticky solid with fetid odor to granular soil that smells moist and which, at the moment of application, will not cause problems of smells and vectors.

The pH in sewage sludge is lies in alkali range(7.50) due to the mineralization of organic alkalinity have taken place at the source . From the experiment test results, the parameter of TN, TK, TP have also been characterized (TN-19.6mg/L, TP-9.46mg/L, TK- 3.47mg/L). This evidences show the chemical and physical parameter is present in sewage sludge. In this study, the total NPK value is increased (TN-82.1%, TP- 15.2%, TK- 38.3%) as well as decrease in pH (7.50-5.90) and the final weight of vermicast is also increased (0g-23416.10g). were recorded in 21 days. This shows that chemical and physical parameter is present in vermicast during vermicomposting process. The final weight of vermicast is recorded. The consumption rate of tiger worms in this study is only 1.2 times their biomass every day.

The sewage sludge without blending can be converted into good quality biofertilizer by using tiger worms (*E.fetida*) individually. Overall, the pure cultures were ahead in terms of TP, TK and TN. Industrial materials such as sewage sludge should not be treated as waste material but as a valuable resource. Sewage sludge has a high nutritive value and might be used as fertilizer as well as soil amendment on a low input basis. Vermicomposting of sewage sludge, changed in the availability of plant metabolites. However, in this study treatment increase in NPK value as well as decrease in pH and the final weight of vermicast was recorded in 21 days. This shows that chemical characterization is present in vermicast during vermicomposting process.

Based on experimental analysis from both the pilot and the full-scale operation, vermiculture can be used effectively as a process to treat pathogens. Sewage sludge can be seeded with *E. fetida* by calculating a consumption rate of 1.1 times their biomass every 24 hours proportionally with the percentage of earthworm biomass to sewage sludge at a 1:7 ratio weekly. Earthworms should not be harvested before this time. From the calculation of Eastman equation, the total of the weight reduction of the sewage sludge is 1583.90 g because the final weight of vermicast is recorded only 23416.10 g. This mean the consumption rate of tiger worms in this study is only 1.1 times their biomass every day.

This ratio is a baseline guide for quantity of earthworms and amount of sewage sludge to be stabilized as described. These population levels may not be practically sustainable. Therefore, due to earthworm population sustainability and fluctuation, the stabilization time will need to be proportionally adjusted until a stabilization equilibrium is obtained and maintained as confirmed by sampling analysis.

Earthworms refuse to stay in their own excreta (vermicast) for long periods and they die if no food is available. Vermiculture is a very convenient and odour free process and the operating costs are negligible as compared to the conventional methods of waste treatment. Industry can applied these method, therefore, both economic as well as ecological implications. The larger the population of the earthworms, the faster the biodegradation activity. But worm activity and multiplication also depends upon the carrying capacity of the immediate environment (*i.e.* sewage sludge). The larger number accelerated the waste degradation initially and multiplied. When sewage sludge became less available the worm activity slowed.

Earthworm biomass production was found excellent in bedding those contained lower proportions of sewage sludge in 21 days. It is suggested that at higher concentrations, sludge drastically affects the decomposition efficiency of composting earthworms. Results indicate that sewage sludge could be utilized as a biofertilizer which as an efficient soil conditioner for sustainable land restoration practices, renewable energy sources, sustainable in involving the use of natural products and substance that is biodegradable which are cheap, detrimental to the living soil and produces high agricultural yields as opposed to chemical fertilizer which harm to environment.

In this study, it is concluded that all the objectives are achieved. Finally, by harnessing vermitechnology, the transition from chemical nutrition can be quick, without a significant loss in yield. This helps in the management of land without affecting ecological processes. Thus it can help achieve sustainable land management , the foundation of sustainable agriculture. Engineering sector can applied these method, therefore, both economic as well as ecological implications.

5.2 Recommendation

The following aspects are recommended for future investigations and study,

1. To study the parameters governing the stabilization and the optimum conditions needed for the municipal solid waste using vermicomposting.

2. To compared the different used of earthworms in a vermicomposting process.

3. To study the other parameter succession in a vermicomposting, especially to test the BOD and COD value.

4. To investigate the possibilities and optimum conditions needed, in the reclamation of chemically polluted soil by vermiculturing

To provide a more indicative analysis regarding the conversion of municipal solid waste to vermicompost for future study.

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APPENDIX A

Constructing a vermibin

Figure A-1 : Net and wire

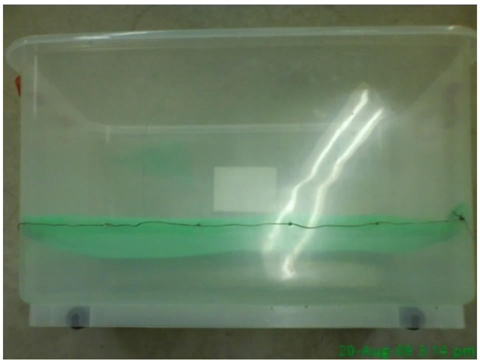

Figure A-2 : net and wire attach in the plastic container

Figure A-3 : Net and wire installation

Figure A-4 : net and wire is tied together neatly

Starting a vermicomposting process

Figure A-5 : Sewage sludge added in vermibin

Figure A-6 : Tiger worms *(Eisenia fetida)*

Figure A-7 : Tiger worms is added in sewage sludge.

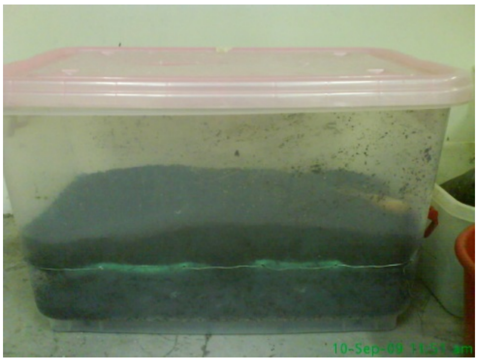

Figure A-8 : During a vermicomposting process

Samples collection

Figure A-9 : Day 1 vermicast

Figure A-10 : Day 7 vermicast

Figure A-11 : Day 14 vermicast

Figure A-12 : Day 21 vermicast

Samples preparation

Figure A-13 : Sewage sludge

Figure A-14 : 1g of sample dissolve in 1L of distilled water ready to test.

Figure A-15 : All the sample is kept in the to slow the bacterial activities

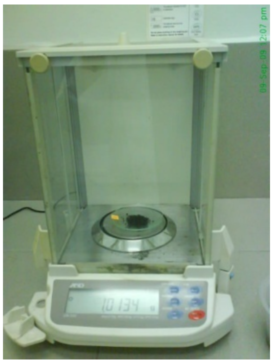

Figure A-16 : Sample is measured

Conduct the experiment

Figure A-17 : DR 2500 reads the parameters NPK value

Figure A-18 : Chemical reagent used in the experiment

Figure A-19 : Determined pH value

Figure A-20 : Determined other parameters

Conduct the experiment

Figure A-21 : Using a chemical reagent carefully

Figure A-22 : Conduct the experiment based on the Hach manual

Figure A-23 : Using a DR2500

Figure A-24 : Determined pH value

Earthworm Farm (Indera Makhota, Kuantan)

Figure A-25 : Mr. Farhan is explained about the vermicomposting process

Figure A-26 : Discussed about the cost of earthworm

Figure A-27 : Mr.Farhan show the vermicast

Figure A-28 : Earthworm observation

Earthworm Farm (Indera Makhota, Kuantan)

Figure A-29 : Collect the 25kg of sewage sludge

Figure A-10 : Sewage treatment plant

Figure A-15 : Machine that used in sewage treatment plant

Figure A-16 : Sewage sludge tank

APPENDIX B

Table of vermicast parameters

DATES	VERMI COMPOST PERIOD	TEMPERATURE /MOSTURE CONTENT	pH	TOTAL NITROGEN (TN) (mg/L)			Avg (TN)	TOTAL PHOSPHORUS (TP) (mg/L)			Avg (TP)	TOTAL POTASSIUM (TK) (mg/L)			Avg (TK)
18/08/09	0-Sludge	Room temperature (29°-31°) moisture 60-70%	7.50	23	20	16	19.6	9.3	10.9	8.2	9.46	2.8	4.1	3.5	3.47
20/08/09	1		6.05	NL	14	26	20.0	10.1	9.0	9.2	9.43	3.4	3.5	3.7	3.53
21/08/09	2														
22/08/09	3														
23/08/09	4														
24/08/09	5														
25/08/09	6														
26/08/09	7		6.02	18	19	25	20.6	9.9	9.6	10.8	10.1	5.1	3.9	3.5	4.16
27/08/09	8														
28/08/09	9														
29/08/09	10														
30/08/09	11														
31/08/09	12														
01/09/09	13														
02/09/09	14		5.92	31	24	30	28.3	10.4	12.3	9.0	10.6	4.6	4.6	4.7	4.63
03/09/09	15														
04/09/09	16														
05/09/09	17														
06/09/09	18														
07/09/09	19														
08/09/09	20														
09/09/09	21		5.90	47	29	31	35.7	7.2	12.9	12.5	10.9	4.7	4.9	4.8	4.80

APPENDIX C

Table of growth rate of earthworms in vermibin

DATES	VERMI COMPOSTING PERIOD	WEIGHT OF SLUDGE (g)	WEIGHT OF VERMICAST (g)	WEIGHT OF SLUDGE (g)
18/08/09	0	25000.00	0.00	1000.00
20/08/09	1	25000.00	0.00	1000.00
21/08/09	2			
22/08/09	3			
23/08/09	4			
24/08/09	5			
25/08/09	6			
26/08/09	7	17689.90	7310.10	1156.00
27/08/09	8			
28/08/09	9			
29/08/09	10			
30/08/09	11			
31/08/09	12			
01/09/09	13			
02/09/09	14	9400.00	15600.00	1302.30
03/09/09	15			
04/09/09	16			
05/09/09	17			
06/09/09	18			
07/09/09	19			
08/09/09	20			
09/09/09	21	1583.90	23416.10	1371.64

APPENDIX D

Calculation of Eastman equation

$$\boxed{\frac{\text{Kg sewage sludge}}{\text{21 days}} = \frac{\text{sewage sludge/21 days}}{\text{1.5 (consumptive rate of earthworms)}} = \text{Kg of earthworms required for VC}}$$

$$\frac{\text{Kg sewage sludge}}{\text{21 days}} = \frac{25\text{kg}}{21} = 1.120\ \text{kg/21days}$$

$$\text{Comsumption rate of earthworms} = \frac{\text{sewage sludge/21 days}}{\text{Kg of earthworms required in vermicomposting}}$$

$$= \frac{1.120\ \text{kg/21days}}{1000\text{g}}$$

$$= 1.2$$