CERTIFICATION OF APPROVAL

Vermicomposting of Municipal Sludge Using *Eisenia Foetida*

by

Nor Fazliana Binti Abdul Jabar

A project dissertation submitted to the
Civil Engineering Department
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

(Assoc. Prof. Dr. Shamsul Rahman Mohamed Kutty)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2008

CERTIFICATION OF ORIGINALITY

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

NOR FAZLIANA ABDUL JABAR

ACKNOWLEDGEMENT

In the Name of ALLAH the Most Merciful,

First of all thanks to Allah for the blessings and opportunity given to undertake this project. Without His blessings and mercy, the project will not be successfully completed.

Highest gratitude to the supervisor, Assoc. Prof. Dr Shamsul Rahman Mohamed Kutty for the acceptance of supervising the project, his guidance, encouragement and useful knowledge in overcoming the many problems encountered during this project.

Thanks also to all Civil Engineering Department lecturers and technicians, especially Mr. Khairul Anuar for the help and assistance in completion of this project study. Not forgetting the FYP committee and coordinators who are responsible to ensure the success in conducting the final year project for these two semesters.

Last but not least, thanks to everyone who involved directly and indirectly in order to ensure the success of this final year project. Their help, support and guidance are highly appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Project

Municipal sludge is a by-product of municipal wastewater treatment. It is one of the major contributors to waste generation [Molla, 2006]. Sludge, mostly rich in organic compounds as well as pathogenic organisms and toxic chemicals can easily affect air, land and water [Metcalf & Eddy 2004]. In Malaysia municipal sludge is the largest contributor of organic pollution to water resources and environment. It is evident from Figure 1 that the contribution is top listed with an estimate of 64.4% followed by animal husbandry wastes (32.2%), agro-based (1.7%) and industrial effluent (1.3%) [DOE, 2004]. Therefore, its disposal and management requires proper attention for human and animal health and protection of groundwater.

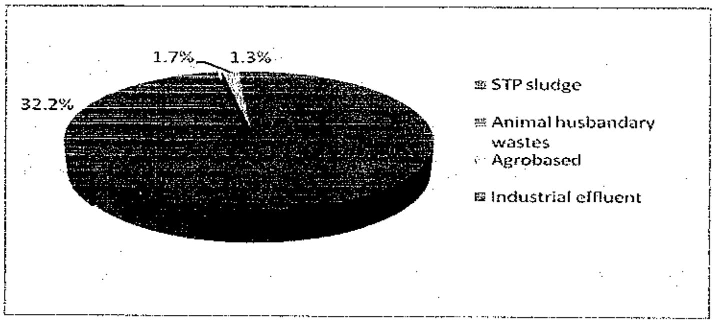


Figure 1: Distribution of organic pollutant to water resources and environment. (Source: DOE, 2004)

Malaysia produces an estimated volume of 3 million cubic meters of municipal sludge yearly. By the year of 2020, the volume of sludge produced annually will be increased through rapid growth in urbanization [Indah Water, 2008]. As a result, many new sludge treatment and disposal facilities will be needed to manage the large volume. Environmentally-sound sludge management is the cornerstone of Malaysia's new approach to sewerage services. Effective and efficient sludge management will significantly contribute to provide a cleaner and safer Malaysia for future generations. Therefore, this paper provides an efficient and ecologically safe alternative method for the sludge management which is vermicomposting.

Used of the earthworm in different types of waste [Payal, 2006] and primary sewage sludge [Renuka et al., 2007] had been reported with varied degree of success. Vermicomposting is a natural decomposition process involves the use of earthworms to process and stabilizes waste [Rola, 2000]. Most of research studies of this technology focused on physiochemical factors for the survival and growth of the earthworms. The research studies [Aaron, 1996] reported that this composting technology is economically viable because it produce beneficial end-product through recycling of sludge. Therefore, this research study tries to establish the applicability of this technology to decompose municipal sludge in valuable end product.

1.2 Problem Statement

Until about five decades ago, sludge management system in Malaysia was not different from what is still found in many developing countries. Increased urbanization and the growth in wastewater treatment plants in Malaysia have led to a very large increase in the production of municipal sludge [Indah Water, 2008]. The municipal sludge which contain high amount of organic matter and pathogenic microorganisms has to be treated and disposed off to maintain healthy environment. There are a lot of traditional techniques are widely applied for the treatment and disposal of the sludge such as landfill and land application. However, many environmental problems are still raised from all those techniques and pose a threat to human health. For example, land application has caused odor and disease-causing problem and landfill has caused surface or groundwater pollution causing public health hazards. Incineration once considered an alternative and most effective method as it can disperse bulk of sludge in one time. However, incinerating is a complex, costly and highly polluting method of disposal. Rather than making the sludge disappear, incinerators create more toxic waste.

1.3 Objectives

The purposes of this research are as follows:

i. To evaluate the ability of earthworms, Eisenia Foetida to stabilize and decompose the municipal sludge. Thus, the sludge is recycled naturally.

ii. To compare decomposition of municipal sludge with the presence and absence of earthworms for difference carbon to nitrogen ratio (C/N ratio) by laboratory analyses. The C/N ratio was adjusted by adding bulking agent which is shredded paper.

1.4 Scope of Study

The objectives were achieved by conducting experiment using municipal sludge obtained from sewage treatment plant of UTP. The following laboratory analyses were carried out to determine the change in characteristic of sample tested:

i. Total Organic Carbon (TOC)
ii. Total Kjeldahl Nitrogen (TKN)
iii. Total Phosphorus
iv. Potassium
v. pH

CHAPTER 2

LITERATURE REVIEW

2.1 Existing Sludge Management Practices

Sludge management is the collection, transport, processing, recycling or disposal of sludge. The term usually relates to materials produced by human [George, 1993]. Commonly methods used for disposal of sludge are landfill, land application, ocean dumping and incineration.

Disposing of sludge in a landfill involves burying sludge to dispose of it. A landfill is a carefully designed structure built into or on top of the ground in which trash is isolated from the surrounding environment. The purpose is to avoid any water related connection between the sludge and the surrounding environment, particularly groundwater [George, 1993]. Landfills were often established in disused quarries, mining voids or borrow pits. A properly-designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly-designed or poorly-managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid leachate. Another common byproduct of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odor problems, kill surface vegetation, and is a greenhouse gas [Aaron, 1996].

Land application is defined ad the spreading of sludge on or just below the surface of the land. Usually sludge is applied on agricultural lands, forest lands, drastically disturbed land [George, 1993]. The beneficial use of sludge not only serves to provide an effective soil amendment, but also helps divert thousands of tons of sludge from landfills and incinerators, saving cost of disposal, while preserving valuable landfill space and eliminating the potential for harmful emissions to the air we breathe. However, along will with the nutrients, the soil receives whatever pathogens and pollutant that might be in the sludge through loss by leaching or runoff. If not properly monitored and managed, these could adversely affect human and animal health, soil quality, plant growth and water quality [Aaron, 1996].

Incineration is a disposal method that involves combustion of sludge material. Incinerators convert sludge materials into heat, gas, steam, and ash. Incinerators reduce the volume of the original sludge by 95-96 %, depending upon composition. This means that while incineration does not completely replace landfilling, it reduces the necessary volume for disposal significantly. Combustion in an incinerator is not always perfect and there have been concerns about micro-pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some very persistent organics such as dioxins which may be created within the incinerator and which may have serious environmental consequences in the area immediately around the incinerator [Metcalf & Eddy 2004].

2.2 Vermicomposting

Vermes in Latin for worm and vermicomposting is an aerobic decomposition organic material by using earthworms into elements or smaller compounds that readily available to plants [Renuka and Garg, 2007]. Basically, vermicomposting is technology of using earthworms for waste management and vermiculture is a practice of raising earthworms [Aaron, 1996]. Earthworms feed on organic material contain in sludge for energy and nutrients, break it down and then excrete it as earthworm castings or a richer end-product [Nancy, 1998]. The castings are in the form of tiny pellets which are coated with a gel or mucus. It is also known as vermicompost.

There is also a symbiotic relationship between the earthworms and microorganisms [Manuel, 2004]. Earthworms help in accelerating rate of decomposition of organic matter by microorganisms as they use mucus in earthworm's gut as substrate to decompose complex organic compounds into simpler substances that are digestible by

c) Thus, it control pollution caused by disposal of sludge [Renuka and Garg, 2007].

The biology of earthworm is quite simple. The earthworm ingests waste at the front, through a soft mouth with a lip that can grasp. With help of pharynx (throat) the food can be pushed in. Since they have no teeth, they used saliva to help in softening and digesting of food. The food then passed through esophagus to the crop and then to gizzard for [George, 2003]. Lastly, the end product, casting passed out from earthworm's body through anus.

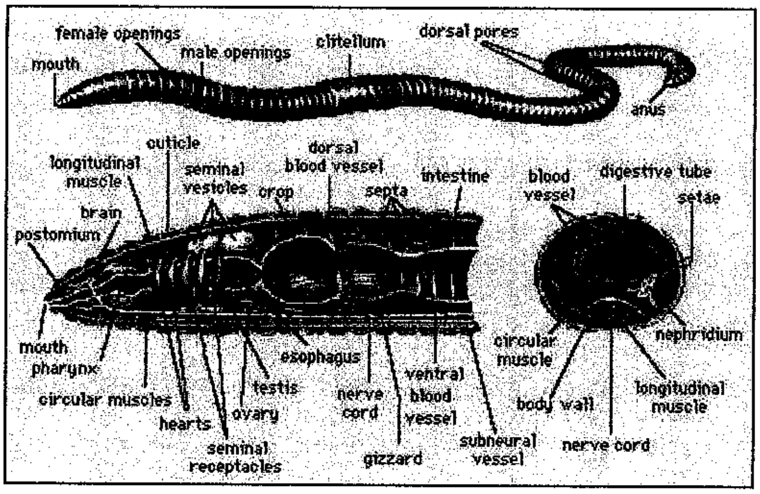


Figure 3: Anatomy of Earthworm.
(Sources: George W.Dickerson, 2003)

There are an estimated 1800 species of earthworm worldwide [Fuad, 2007]. They can be divided into three (3) broad groups to make identification easier as follows:

i. *Epigeic* species live in the surface litter above mineral soil and make no permanent burrows. They feed on surface litter, digesting it and the microorganisms found there. There are reddish brown in color and small in size, usually less than 7.5 cm long when mature.
ii. *Endogeic* species make extensive branching burrow systems in the top of 50 cm of the soil. They feed by ingesting large amounts of soil and digest the soil organic matter and microorganisms found there. They are easily separated

from epigeic and anecic species by their color: no red-brown skin pigmentation. Size ranges are from 3cm to 12.5 cm.

iii. *Anecic* species make vertical burrows up to 2 meters deep in the soil, but they feed on fresh surface litter. They are reddish brown in color and larger than either of the other two groups. Adults are usually 12.5-20cm long.

Several earthworm species e.g. *Eisenia foetida, Eisenie andrei, Eudrilus eugeniae* and *Perionyx excavatus* has been identified as potential candidates for managing organic waste resources. However, *Eisenia foetida* is commercially used for composting as they are found to be concentrated in the forest duff layer or organic debris rather than in soil [Gajalakshimi, 2005]. This characteristic makes it suitable for vermin degradation as the earthworm preferred environment can duplicate in the bin or reactor. As their environment is available, they will not migrate to other places or burrows into soil as they are *Epigeic* species. Thus, it is easy to control these species.

Worldwide spread *Eisenia foetida* was and still remains a favoured earthworm species for vermicomposting operation. The growth patterns of *Eisenia foetida* in number of different waste resources have been investigated by various authors through laboratory analyses [Payal, 2006, Aaron, 1996, Hou 2005].

Eisenia foetida its closely related species *Eisenia andrei* [Rola, 2000], known under various common names, including tiger worms is a species of earthworm adapted to environment of decaying organic matter. It is found that this type of earthworms is the most commonly used for vermicomposting [George, 2003] because they are tough, easily handled and can tolerate a wide range of temperatures conditions [Rola, 2000]. They have ability to degrade different types of organic substances and produce good source of end product which contain nutrient such as nitrogen and phosphorus [Payal, 2006]. This species usually dominate in many organic wastes environment [Rola, 2000].

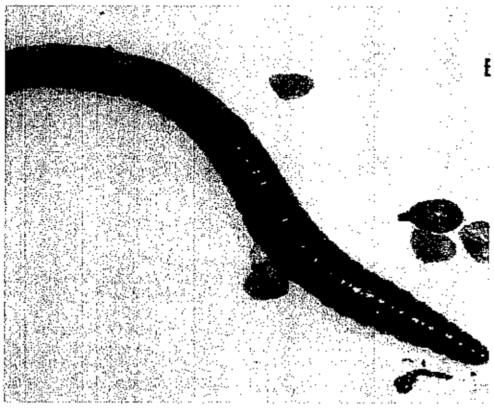


Figure 4: *Eisenia foetida*

(Sources: George W.Dickerson, 2003)

2.3 Growth and Cocoon Production of Earthworms

A cocoon is a pupal casing made by an earthworm. Under ideal conditions earthworm can double in volume every 90 days. The average incubation period for earthworm is between 30 and 80 days, depending on environmental conditions. It is found that the development time of cocoons for *Epigeic* earthworm was very short (13-14 days) compared to other type of earthworms. The longest development time of cocoons was observed in *Anecic* earthworms (110 days) [Gautum, 2002].

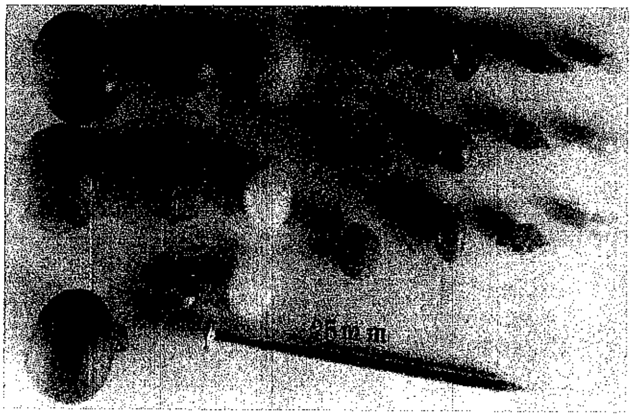


Figure 5: Cocoons of earthworms

(Source: Gautum, 2002]

Once the new worms hatch, it will take about 8 to 10 weeks to become sexually mature and begin producing cocoons [George, 2003]. *Eisenia Foetida* produces 3.8 cocoons per adult per week and it is 83.2% of hatching rate success.

2.4 Environmental Requirements

The growth of both earthworms and mesophilic bacteria is essential to a successful vermicomposting operation. Mesophilic bacteria feed on the organic matter within the waste and earthworms feed on the bacteria [Mansfield, 2003]. For optimal growth, several operating conditions must be maintained such as moisture content, pH and temperature.

Vermicomposting proceeds best at moisture content of 50-80% as it is very important for the survival and growth of the earthworm [Aaron, 1996]. Since earthworm breathes through its skin, respiration of earthworm replies on the moist surface as moisture helps the earthworm's ability to absorb oxygen. Most of study conducted for vermicomposting stated the same condition [Payal, 2006]. If the moisture content falls below 40 percent, the system may become too dry for the microbial activity. In most of the research studies, the moisture content was maintained by periodic sprinkling water to the vermin system [Renuka and Garg, 2007]. If there is excess moisture in the bin, the bin is open for evaporation [Mansfield, 2003].

Temperature is another important parameter in vermicomposting. Best temperature range for vermicomposting is between 15-25°C [Aaron, 1996]. As mention previously, the decomposition of organic matter is done through the help of microbial such as fungi, bacteria and protozoa. Thus, is it important to maintain the temperature at optimum conditions for the growth of microbial population. Furthermore, *Eisensia foetida* reproduces and process waste at optimum temperature of 25 °C [Hou, 2005].

The optimum pH value for vermicomposting is in the range of 6-8 [Hou, 2005]. Earthworm cannot survive at pH below 5 and above 8 [Aaron, 1996]. As degradation proceeds, the pH drops to acidic. The drop is pH is because of the present of organic acid as a by-product of organic matter during vermicomposting [Nancy, 1998].

The most critical factor for vermicomposting is carbon to nitrogen (C/N ratio). Organic carbon which makes up about 50 percent of the mass of microbial cells provides both an energy source and a basic cellular building block. The maturity of decomposed organic wastes can be determined from the C/N ratio [Renuka and Garg, 2007]. Nitrogen is a crucial component of the proteins, nucleic acids, amino acids and enzymes necessary for cell growth and function [Mansfield, 2003]. At lower ratios, nitrogen will be supplied in excess and will be lost as ammonia gas, causing undesirable odors. Higher ratios mean that there is not sufficient nitrogen for optimal growth of the microbial populations, so the compost will remain relatively cool and degradation will proceed at a slow rate [George, 1993]. The optimum range of C/N ratio by mass for efficient cell growth are 25 to 40 parts carbon to 1 part nitrogen [25-40:1] [Mansfield, 2003]. Some researcher reported that 25 is the suitable C/N ratio on the growth and survival of earthworms [Hou, 2005]. The range of most organic waste is from 20-25 to 1. Sludge have low C/N ratio whereas yard waste such as newspaper, paper, leaves have relatively high C/N ratios. In order to provide a near optimum C/N ratio, the sludge from wastewater treatment plant and yard wastes can be blended. The blending of wastes to optimize the C/N ratio is illustrated in the following equation [George, 1993]:

$$\frac{C}{N} = (25 \sim 30) = \frac{\text{C in 1kg YardWaste} + x(\text{C in 1kg of Sludge})}{\text{N in 1kg YardWaste} + x(\text{N in 1kg of Sludge})}$$

where

x = weight of sludge used, kg

Note: Assume the weight of yard waste used is 1 kg.

(Source: George, 1993)

As composting proceeds, the C/N ratio gradually decreases for the end product and it is found that the value of C/N ratio decrease rapidly with the presence of earthworm [Renuka and Garg, 2007]. This occurs because each time the organic compounds are consumed by microorganisms, two-thirds of the carbon is given off as carbon dioxide. The remaining third is incorporated along with nitrogen into microbial cells which lower the C/N ratio [Renuka, 2007].

2.5 Earthworm Bin

Earthworm bins can be made from plastic tubs by drilling air holes in the tub or by following the directions in this fact sheet to build a large plywood bin. Plastic tub bins tend to get wetter than wooden bins [George, 2003]. If the bin is too wet, odor problems occur and worms die or leave the bin. Holes can be drilled in the bottom of the tub. Set the bin on wooden blocks or attach legs to the tub to increase air circulation. Manufactured worm bins are available from a variety of vendors.

2.6 Characteristic of Vermicompost

During vermicomposting, organic matter is subjected to a series of physical, chemical and biological transformation resulting in the formation of worm cast. Vermicompost consists mostly of worm casts plus some decayed organic matter. It is usually dark, homogeneous and with a mull-like soil odor. The color and physical vermicompost depends on the nature of parent materials and the degree of composting by earthworms Vermicompost is a finely divided material that has the appearance and many characteristics of peat [Rola, 2000] with high porosity, aeration drainage and water-holding capacity [George, 2003].

During the passage of organic waste through the earthworm gut, nutrients such as nitrogen, phosphorus are transformed to more readily available to plants such as nitrate, ammonium biologically [Rola, 2000]. In some studies, it has been shown that there are increases in total nitrogen, phosphorus and potassium of the original material [Renuka and Garg, 2007]. Payal in 2006 found that an increase of 83% in total nitrogen, 550% in phosphorus and 130% in potassium of textile industry sludge after 100 days of vermicomposting period. Renuka and Varg in 2007 also found the same result in vermicomposting of primary sludge where there was an increase of 113% in potassium and 94% in total phosphorus after 105 days.

During vermicomposting, the pH organic waste decrease to acidic (6 to 6.5) due to production of organic acids by microbial metabolism. Renuka and Garg in 2007 reported that there were pH changes from alkaline (8.0-8.2) to acidic (6.87±0.05 to 7.70±0.05) due to conversion of organic material into intermediate organic acids during the decomposition process. It also been reported that the pH shift might have been due to the production of CO_2 and organic acids by microbial activity [Payal, 2006]. This pH condition enhances the growth of plant because most plant prefers a growth medium that is slightly acidic [Nancy, 1998].

Figure 6: Vermicompost produced form decomposition of animal waste.
(Source: Greenfield Agrotech Sdn. Bhd)

Vermicompost is usually much more stable than its parent materials [Rola, 2000]. Because of the changes in organic matter chemistry, physical characteristics and biology brought about by earthworms, vermicompost can be used as soil conditioner of organic fertilizer that enhances plant growth. Payal in 2006 found a decrease in total organic carbon by 36% in textile industry sludge, 55% in kitchen waste and 67% in agro-residues waste. It is found that vermicompost contain 5-11 times more nitrogen, phosphorus and potassium as the surrounding soil. Below are comparison between garden compost and vermicompost and chemical compostition for the other vermicompost:

Table 1: Chemical characteristics comparison between garden compost and vermicompost, 1994.

Parameter	Garden compost[1]	Vermicompost[2]
pH	7.80	6.80
EC (mmhos/cm)*	3.60	11.70
Total Kjeldahl Nitrogen (%)	0.80	1.94
Nitrate Nitrogen (ppm)**	156.50	902.20
Phosphorus (%)	0.35	0.47
Potassium (%)	0.48	0.70
Calcium (%)	2.27	4.40
Sodium (%)	<0.01	0.02
Iron (ppm)	11690.00	7563.00
Zinc (ppm)	128.00	278.00
Manganese (ppm)	414.00	475.00

[1] Albuquerque sample [2] Tijeras sample

Unit
ppm = parts per million

mmhos/cm = millimhos per centimeter

*EC= electrical conductivity is a measure of the relative salinity of soil.

**Nitrate Nitrogen = that nitrogen in the sample that is immediately available for plant uptake by the roots.

(Source: George W.Dickerson, 2003)

CHAPTER 3

METHODOLOGY

The main analysis is to evaluate the degree of decomposition of municipal sludge at different carbon to nitrogen ratio (C/N) with the presence and absence of earthworms. In the analysis, the municipal sludge is amended with yard waste which is shredded paper in order to provide optimum C/N ratio for the sludge. Instead of that, shredded paper also acted as a bulking agent. The overall methodology of this research project is summarized as follows:

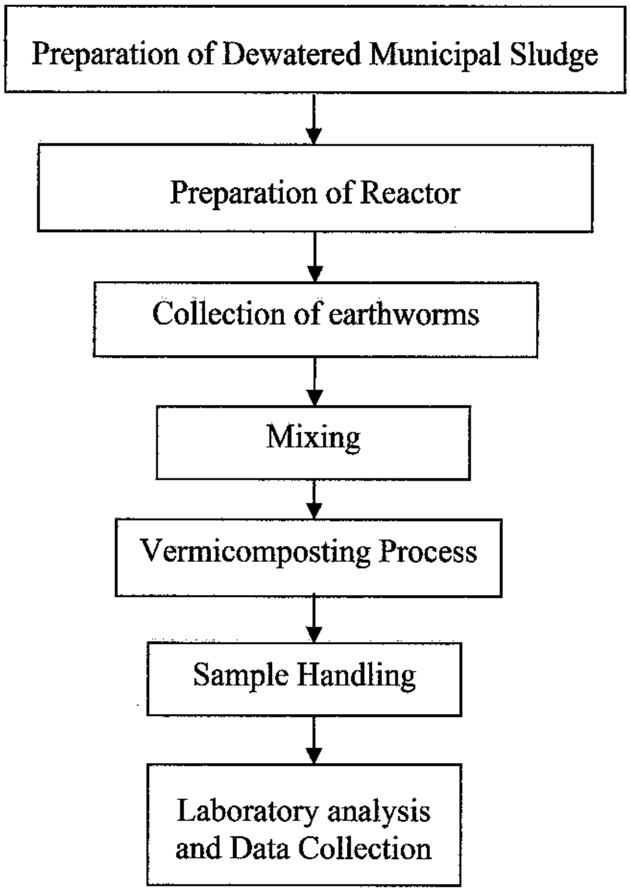


Figure 7: Overall Methodology

3.1 Preparation of Dewatered Municipal Sludge

Sludge was obtained from sewage treatment plant of Universiti Tecknologi PETRONAS. Separation into dewatered sludge and liquid fraction was done by allowing the sludge to settle down to the bottom of bin as shown in Figure 8 (a). The liquid fraction was collected at the top layer of the plastic bin and while the settled sludge was filtered using fabric. The dewatered sludge in Figure 8(b) was aerated and stabilized for 21 days by manually turning [Renuka, 2007] in order to eliminate volatile gases, ammonia which is toxic to the earthworms [Aaron, 1996].

(a) (b)

Figure 8: (a) Municipal sludge from top layer of the plastic bin (b) Municipal sludge after filtered with fabric

3.2 Preparation of Reactor

Plastic reactor in Figure 9 is used to accommodate the worm and the sludge sample for experimental purpose of this project. This is the cheapest and easier earthworm bin system. Ultraviolet light is toxic to earthworms, so the container should be made from an opaque material. Basically, the internal dimensions of plastic container are 33 cm (length) x 25 cm (width) x 13 cm (height). Polymer sack was used to cover the holes in the container.

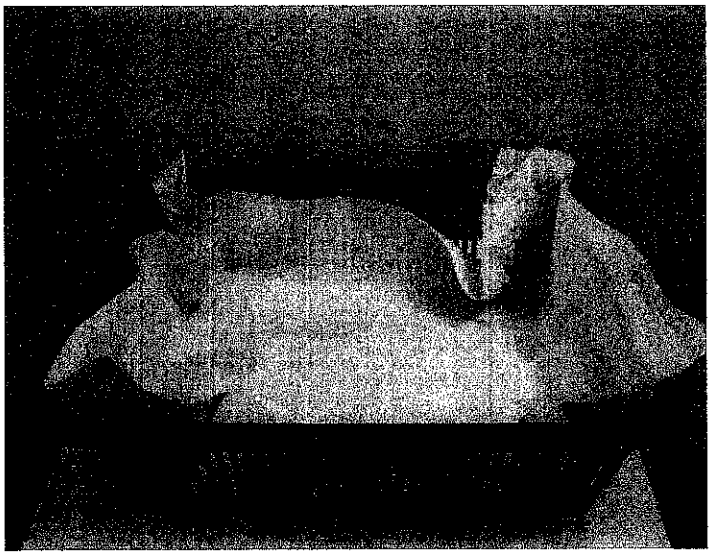


Figure 9: Plastic reactor covered with polymer sack

3.3 Collection of Earthworm

Eisenia foetida is species used in this study. These earthworms are supplied by ESI Agrotech Farm, Kajang, and Selangor. Basically, based on visual observation there are three (3) categories which are small, medium and large.

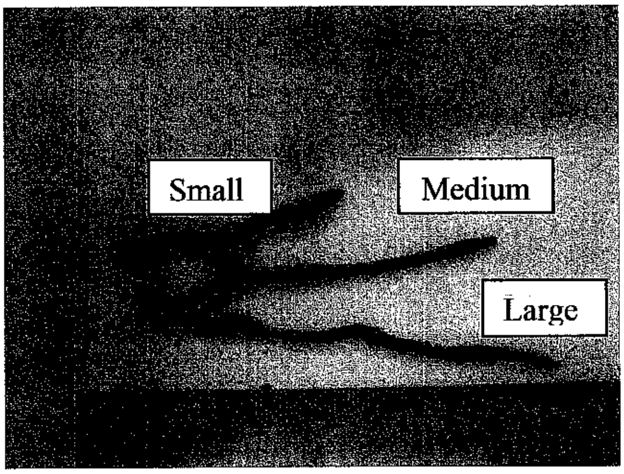


Figure 10: Categories of *Eisenia foetida*

3.4 Experimental Setup

Twelve (12) plastic reactors were prepared. Four different C/N ratios were analyzed for this project. There were three (3) replicates for each C/N ratio with 0 (control), 30, and 40 earthworms. The experiment setup is shown as in the table below:

Table 2: Experiment Setup

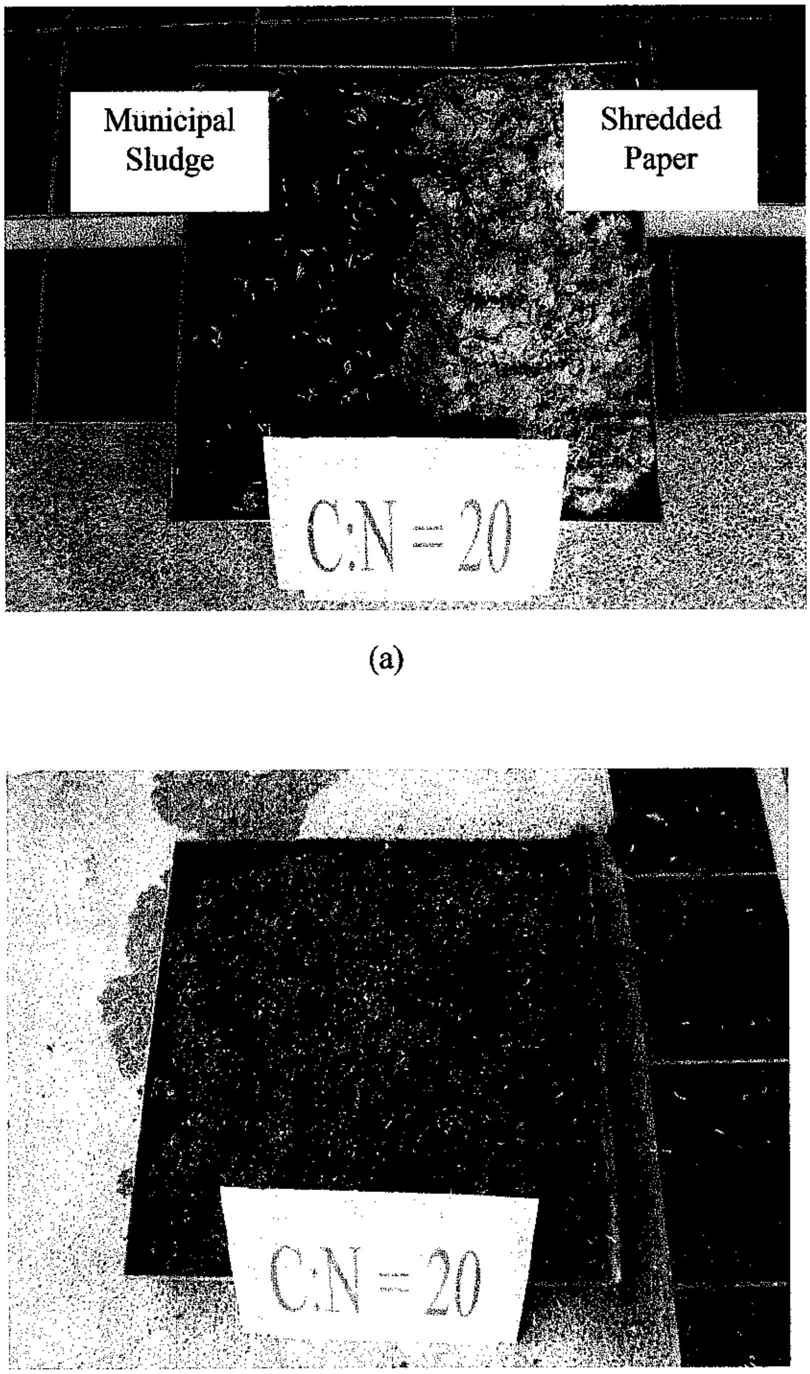
C/N	No of Earthworms		
	Control	20	40
20	R1a	R2a	R3a
25	R1b	R2b	R3b
30	R1c	R2c	R3c
35	R1d	R2d	R3d

3.4.1 Blending of Municipal Sludge and Shredded Paper

For each C/N ratios there will be blended of STP sludge and yard waste as shown in Figure 11-14. One kg of mixture (on dry weight basis) was put in each plastic reactor. The composition of STP sludge blended with shredded paper in different reactors was done as follows:

Table 3: The composition of STP sludge and shredded paper in each reactor.

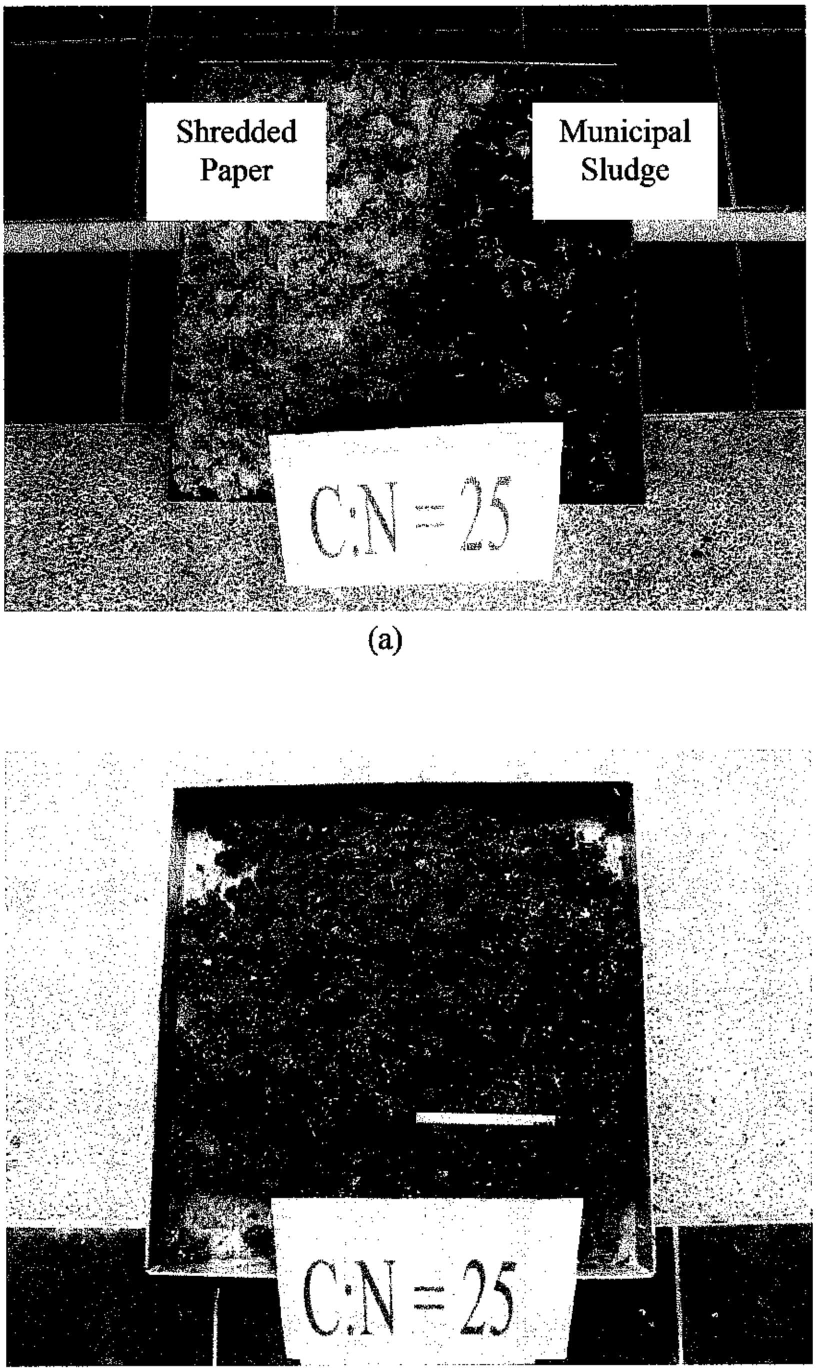
C/N	Dry weight (kg)		
	Sludge	Paper	Total
20	0.42	0.58	1.00
25	0.34	0.66	1.00
30	0.29	0.71	1.00
35	0.25	0.75	1.00



(a)

(b)

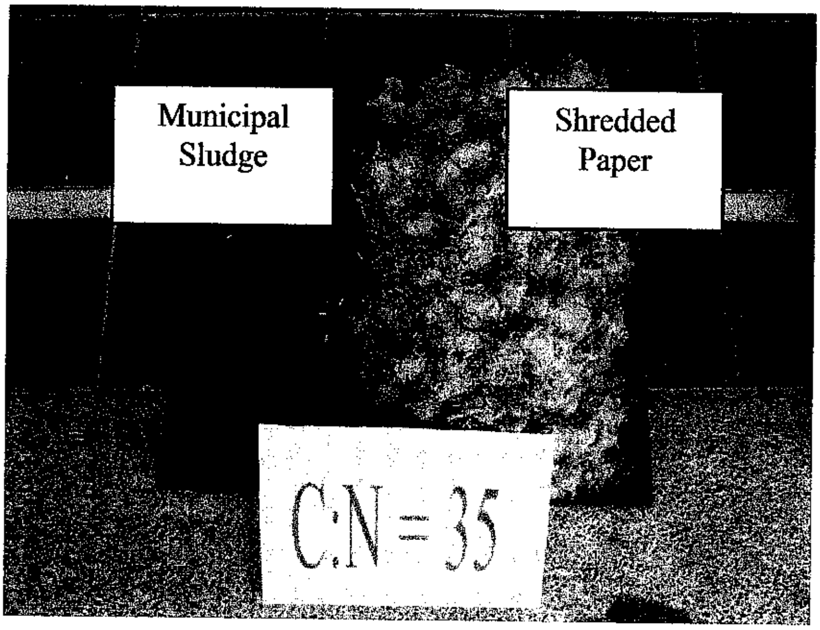
Figure 11: (a) Tray for C/N ratio 20 before mixing process (b) Tray for C/N ratio 20 after blending process



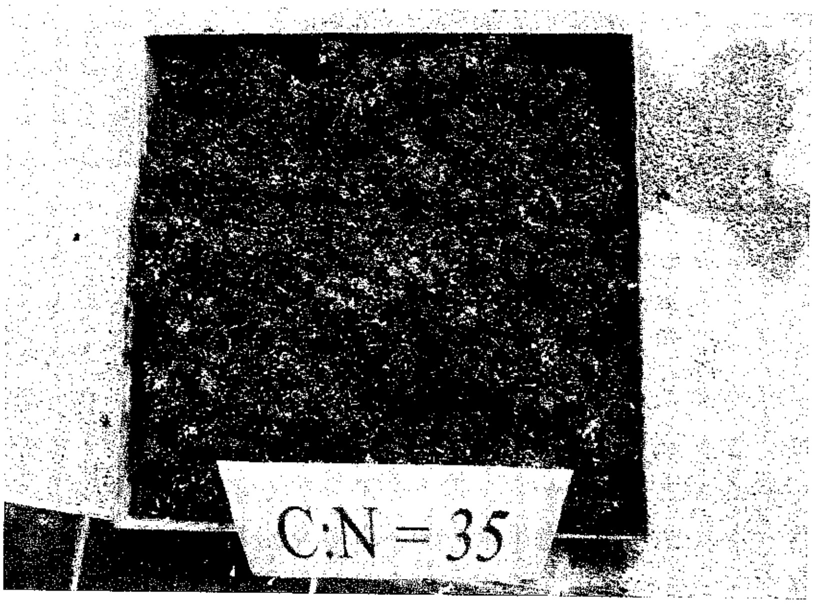
(a)

(b)

Figure 12: (a) Tray for C/N ratio 25 before mixing process (b) Tray for C/N ratio 25 after blending process



(a)



(b)

Figure 13: (a) Tray for C/N ratio 35 before mixing process (b) Tray for C/N ratio 35 after blending process

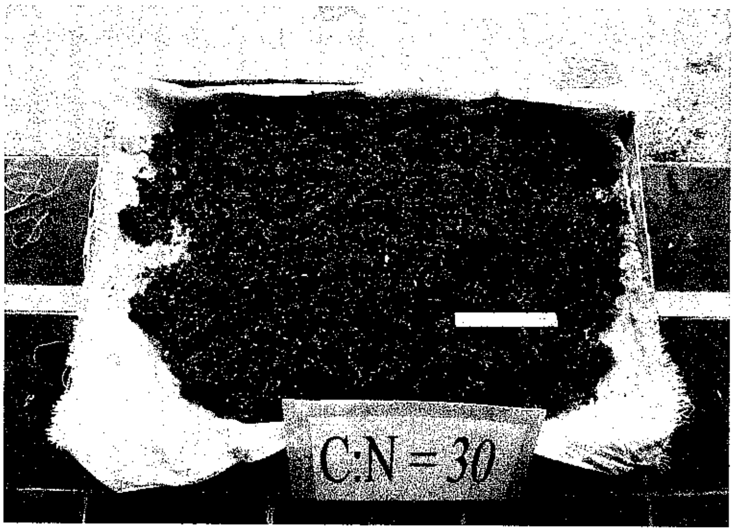


Figure 14: Tray for C/N ratio 30 after blending process

3.4.2 Vermicomposting Process

Homogenized samples are drawn at 0, 14, 21, 28, 35, 42, 49, 56 and 63 days. All reactors were kept in dark under room temperature 25±3°C (R.Gupta et al., 2007). To maintain moisture content, periodic sprinkling of an adequate quantity of distilled water was done. Since there is no direct equipment to measure moisture content of sludge during the experiment, the change of moisture content was based on visual examination only.

3.4.3 Sampling

Samples are collected and stored for detail laboratory analysis. The samples are air dried at room temperature, ground in blender and stored in the plastic vials.

3.5 Measurement of Parameters

Table 4: Methods for laboratory analyses

Analysis	Method	Reference
pH	Electrometric measurement	ASTM for Soil and Peat (D 2974 – 87)
TOC	TOC Analyzer	-
TKN	Sulfuric acid digestion with alkali distillation.	ASTM for Soil and Peat (D 4972 – 95a)
Total Phosphorus	Spectrophotometer with Sulfuric Acid-Nitric Acid Digestion	Modified Standard Methods for the Examination of Water and Wastewater (4500-P B)
Potassium	Atomic Absorption Spectrophotometer (AAS) with Sulfuric Acid-Nitric Acid Digestion	Modified Standard Methods for the Examination of Water and Wastewater (4500-P B)

3.5.1 pH

The pH was determined using a double distilled water suspension in the ratio of 1:100. A volume of sample representing 10 g was placed in a 250 ml beaker, 100 ml distilled water were added and the sample mixed (R.Gupta and V.K Garg, 2007). The sample was allowed to sit for 30 minutes to permit the soil and water equilibrates. The pH meter as shown in Figure 15 was standardized with pH buffer solution at approximately pH 4.0. Then, the pH meter was placed in the beaker containing mixture of sludge and distilled water. The pH obtained was recorded.

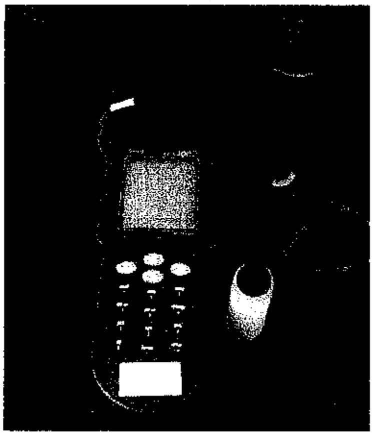


Figure 15 : pH meter

3.5.2 Total Organic Carbon (TOC)

Approximately 60 mg of dried sample was prepared. Then the sample was analyzed using total carbon analyzer as shown in Figure 16. This method was based on the combustion of organic compounds and further detection of CO_2 with non-dispersive infrared analysis.

Figure 16: TOC Analyzer

3.5.3 Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl Nitrogen was determined based on chemical test method obtained from ASTM D2973 for Peat Material. Approximately 0.6g dried sample were prepared and placed in a 600 ml Kjeldahl flask. About 0.25g selenium and 20ml of concentrated acid were added. The acid was added down the side of the flask to wash down all material adhering to the sides of the flask. The sample was digested on the digestion rack until it turned green and this was continued for 30 minutes to ensure complete ensure complete digestion. The solution was cooled for 10-15 minutes and then 125 ml of distilled water was added.

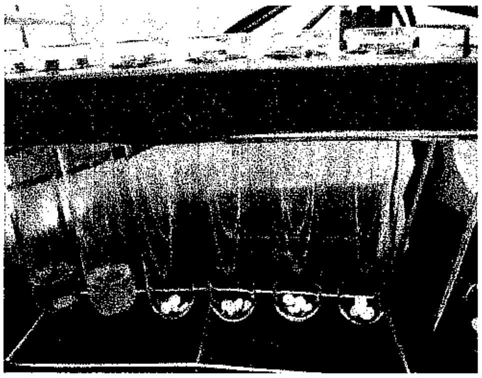


Figure 17: Preparation for digestion.

Fifty (50) ml of 4% boric acid were placed in a 500 ml Erlenmeyer flask. The flask was placed on the distillation rack so that the end of the tube of the distillation apparatus is under the surface of the boric acid in the flask. Cooling water was turned on the distillation apparatus. Kjeldahl flask was held at a 45° angle and 100 ml of sodium hydroxide was added. The flask was then connected without mixing to a trap which is connected to the distillation column. The solution was heated until 150 ml of distillate had been collected in the collection flask. The collected solution was titrated using titrator with 0.02 N of sulfuric acid as shown in Figure 19. The volume titrated for sample was recorded.

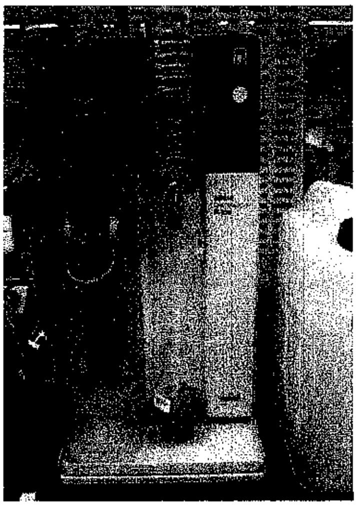


Figure 18: Distillation machine

Figure 19: Titrator

3.5.4 Total Phosphorus

Approximately 0.6g of 1 ml of concentrated sulfuric acid and 5ml of concentrated nitric acid were added in a 600 ml Kjeldahl flask. The sample was digested for about 30 minutes and continued until solution becomes colorless to remove nitric acid. Then, it was cooled and approximately 20 ml of distilled water, 0.05ml phenolphthalein indicator and as much as 1N NaOH solution as required to produce a faint pink tinge. 10 ml of digested sample was filtered and transferred to 100-ml volumetric flask. The volume of sample was adjusted to 100 ml with distilled water.

5 ml of diluted sample from 100-ml volumetric flask was pipette out into a Total Phosphorus Test N tube vial. One potassium persulfate powder pillow was added to the vial. The vial was digested in DRB 200 reactor for about 30 minutes. After that, the vial was carefully removed from the reactor and allowed to cool to room temperature (18-25°C). 2 ml of 1.54N sodium hydroxide was added to the vial and shaked. The vial was wiped with a damp towel to remove fingerprints or other marks. The vial was read for blank. Then, one PhosVer 3 powder pillow was added to the vial and shaked for about 20-30 seconds. After that, the sample was read after two-minute timer (reaction time) was expired.

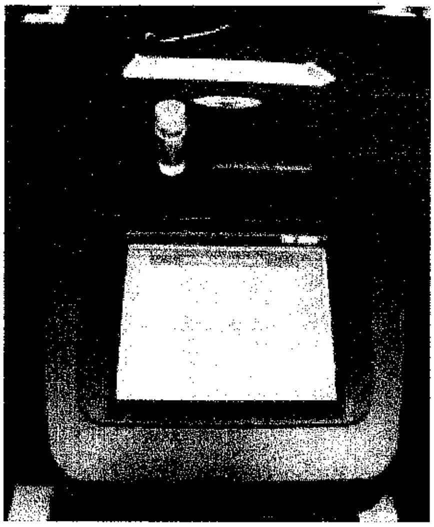


Figure 20: Spectrophotometer

3.5.5 Potassium

Approximately 0.6g of 1 ml of concentrated sulfuric acid and 5ml of concentrated nitric acid were added in a 600 ml Kjeldahl flask. The sample was digested for about 30 minutes and continued until solution becomes colorless to remove nitric acid. Then, it was cooled and approximately 20 ml of distilled water, 0.05ml phenolphthalein indicator and as much as 1N NaOH solution as required to produce a faint pink tinge. 10 ml of digested sample was filtered and transferred to 100-ml volumetric flask. The volume of sample was adjusted to 100 ml with distilled water.

The potassium contain in the sample was determined by atomic absorption spectrophotometer (AAS). Atomic absorption units have four basic parts: interchangeable lamps that emit light with element-specific wavelengths, a sample aspirator, a flame or furnace apparatus for volatilizing the sample, and a photon detector. In order to analyze for any given element, a lamp was chosen that produces a wavelength of light that was absorbed by that element. Sample solutions were aspirated into the flame. If any ions of the given element were present in the flame, they had absorbed light produced by the lamp before it reaches the detector. The amount of light absorbed depends on the amount of the element present in the sample.

Absorbance values for unknown samples were compared to calibration curves prepared by running known samples or standard samples.

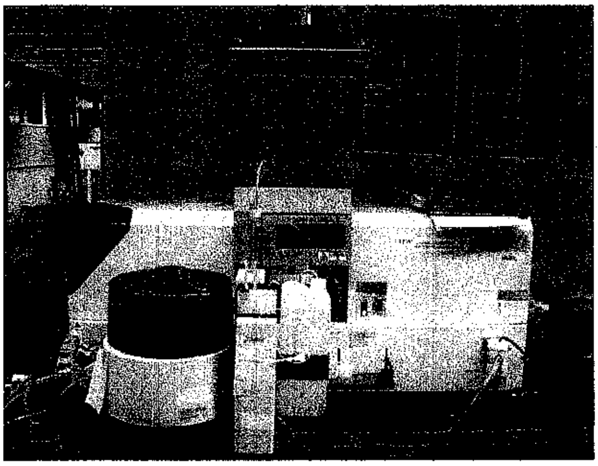


Figure 21: Atomic Absorption Spectrophotometer (AAS) machine.

3.6 Hazard Analysis

A hazard is defined as an event, or circumstance that could lead to or contribute to an unplanned or undesirable event. Seldom does a single hazard cause an accident. More often, an accident occurs as the result of a sequence of causes. A hazard analysis is a process used to assess risk. The results of a hazard analysis are the identification of unacceptable risks and the selection of means of controlling or eliminating them. Below are the hazard analysis made for this research project:

Table 5: Hazard Analysis

Area	Activities	Potential Hazard	Recommended PPE
Concrete Lab	Drilling holes for vermireactor using drilling equipment.	Noise, dust, accident.	Safety earplugs; be aware while using drilling equipment.
Wastewater Treatment Plant	Collecting of sludge sample	Offensive odor, bacteria, accident.	Gloves mask and covered shoes.
Environmental Lab	Working with small volumes of corrosive liquid (boric acid)	Eye or skin damage	Safety glasses, Light chemical-resistant gloves, lab coat.
	Working with toxic or hazardous chemicals (solid or liquid)	Eye or skin damage, potential poisoning through skin contact	Safety glasses (for large quantity) Light chemical-resistant gloves, lab coat.
	Working with an apparatus with contents under pressure (such as distillation).	Eye or skin damage	Safety glasses (for large quantity) Light chemical-resistant gloves, lab coat.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Characteristics of Sludge from Sewage Treatment Plant of UTP

Municipal Sludge obtained from Sewage Treatment Plant of UTP was tested for several laboratory analyses such as Total Organic Carbon (TOC), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Potassium, pH and moisture content test to determine the characteristics of the sludge. The results from those tests had proved that our STP sludge contained 22.55% TOC, 3.36% TKN, 2.34% TP, 0.53% Potassium and 84.14% moisture content. The average pH of the sludge is 7.83±0.04.

4.2 Characteristics of Shredded Paper

Shredded paper was obtained form Exam Unit of UTP. The shredded paper also was tested to determine its characteristics. The results from those tests had proved that the shredded paper contained 32.67% TOC, 0.03% TKN, 0.03% TP, 0.01% Potassium and 5.47% moisture content with the average pH of 6.95±0.03.

4.3 Characteristics of Mixture of STP Sludge and Shredded Paper

Based on both characteristics of STP sludge and shredded paper, it is observed that STP sludge can be blended with shredded paper in order to provide optimum carbon to nitrogen ratio. The composition of the sludge and shredded paper for each C/N ratio was calculated using mass balance equation. After the blending process, the mixture for each C/N ratio was tested to ensure that it meet the required C/N ratio. Table 6 showed the results for those tests conducted:

Table 6: Characteristics of initial mixture of different C/N ratio after blending

Analysis	Carbon to Nitrogen ratio (C/N ratio)			
	20	25	30	35
Total Organic Carbon, TOC (%)	26.44	27.31	28.44	28.58
Total Kjeldahl Nitrogen (TKN)	1.33	1.19	0.97	0.79
Total Phosphorus, TP (%)	1.25	1.12	0.87	0.75
Potassium (%)	0.26	0.24	0.22	0.16
pH	8.12	7.86	7.79	7.76
Observed C/N ratio	19.88	22.95	29.32	36.18

Results form Table 6 showed that there was slightly difference between the required and observed C/N ratio due to non-homogeneous blending process.

4.4 pH Results

pH is the important environment requirement in vermicomposting. Therefore, during vermicomposting period, the pH of STP sludge blended with shredded paper was observed to ensure that it is within optimum condition. pH was determined using a double distilled water suspension in the ratio of 1:100. There were changes in pH of vermicompost as compared to initial value. The pH shifted from alkaline to acidic. The production of CO_2 and intermediate organic acid by microbial metabolism during the decomposition might be the reason of pH reduction [Payal, 2006][Renuka, 2007].

Based on Table 7, there are reductions of pH in all reactors including control for each C/N ratio. However, the faster reduction was observed in reactors with the presence of earthworms for all C/N ratios. The average percentage of pH reduction for all C/N ratio in R3 (N=40 earthworms) is 14.6%, R2 (N=30 earthworms) is 12.1% and R1 (no earthworms) is 9.9%. From those results, it is proved that earthworms promote faster decomposition of STP sludge because reactor with the presence of earthworms recorded higher reduction in pH. The higher reduction was observed in reactor with greater number of earthworms.

Table 7: pH recorded for 9 weeks of vermicomposting periods

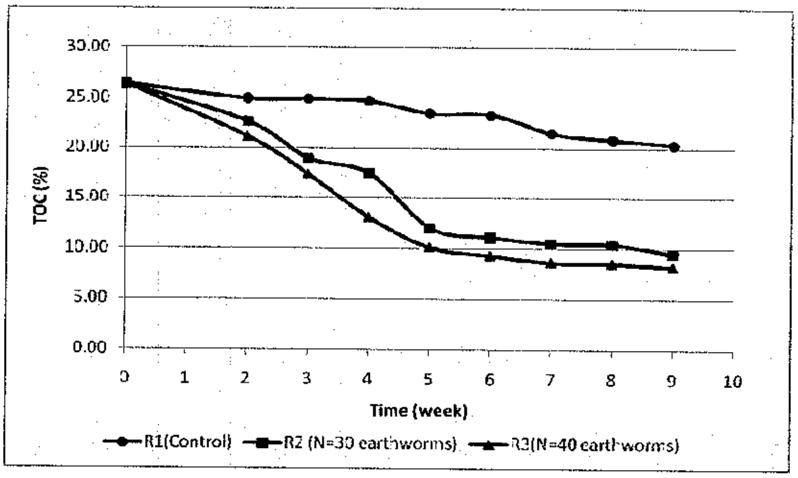
C/N Ratio	Reactor	pH								
		Week								
		0	2	3	4	5	6	7	8	9
20	R1(Control)	8.12	8.35	8.46	7.89	7.75	7.65	7.26	7.19	7.16
	R2 (N=30 earthworms)	8.12	8.25	7.78	7.52	7.25	7.02	6.88	6.84	6.83
	R3(N=40 earthworms)	8.12	7.98	7.63	7.43	6.75	6.65	6.59	6.52	6.46
25	R1(Control)	7.86	7.68	7.71	7.69	7.56	7.44	7.45	7.38	7.22
	R2 (N=30 earthworms)	7.86	7.98	7.56	7.48	7.42	7.28	7.06	6.99	6.89
	R3(N=40 earthworms)	7.86	7.81	7.49	7.34	7.30	7.14	6.94	6.92	6.76
30	R1(Control)	7.79	7.72	7.69	7.66	7.55	7.45	7.32	7.21	7.11
	R2 (N=30 earthworms)	7.79	7.70	7.65	7.59	7.52	7.37	7.28	7.18	6.92
	R3(N=40 earthworms)	7.79	7.69	7.53	7.50	7.44	7.33	7.18	7.11	6.78
35	R1(Control)	7.76	7.73	7.70	7.66	7.62	7.58	7.56	7.41	7.32
	R2 (N=30 earthworms)	7.76	7.64	7.60	7.58	7.55	7.48	7.33	7.31	7.08
	R3(N=40 earthworms)	7.76	7.62	7.60	7.51	7.42	7.38	7.20	7.07	6.85

4.4 Effect of Initial Number of Earthworms with Fixed Initial C/N Ratio

For each initial C/N ratio, there were three (3) replicate reactors with the presence and absence of *Eisenia foetida*. The reactor are R1 (no earthworm), R2 (N=30 earthworms) and R3 (N=40 earthworms). The experiment was conducted for nine (9) weeks. Every week, samples were taken from each reactor for detail laboratory analyses such as Total Organic Carbon, Total Kjeldahl Nitrogen, Total Phosphorus, Potassium and pH. The changes in characteristics of sample were observed to evaluate the ability of *Eisenia foetida* to decompose STP sludge.

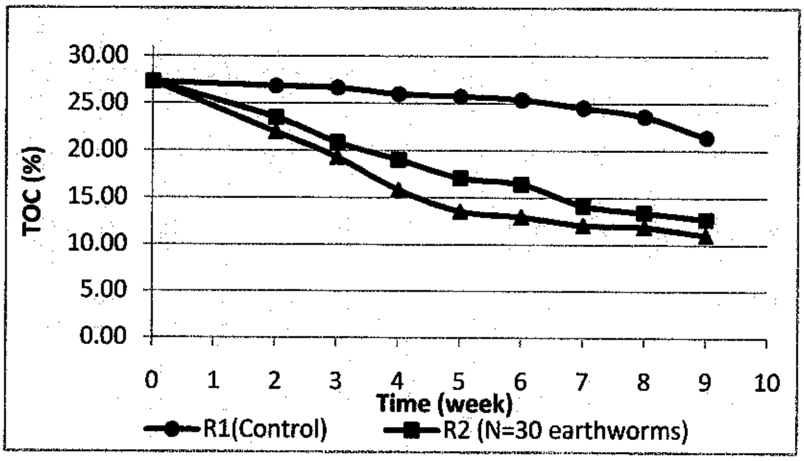
4.41 Total Organic Carbon (TOC) Results

Total Organic Carbon (TOC) was determined using TOC analyzer. From the results, it showed that there was reduction in TOC every week.

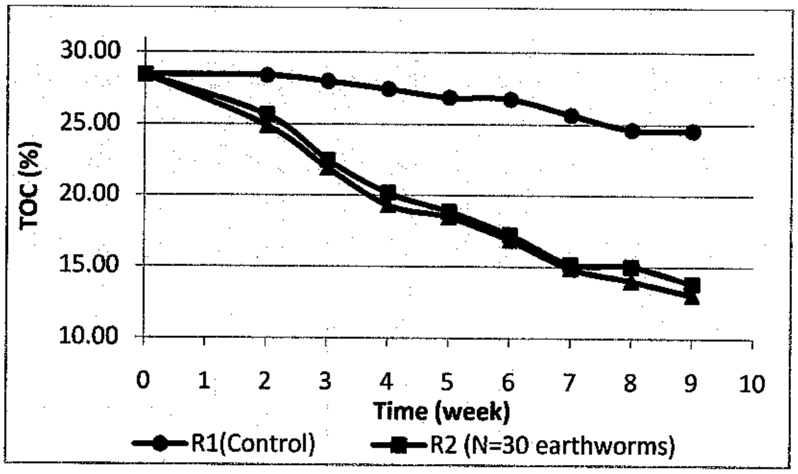


(a)

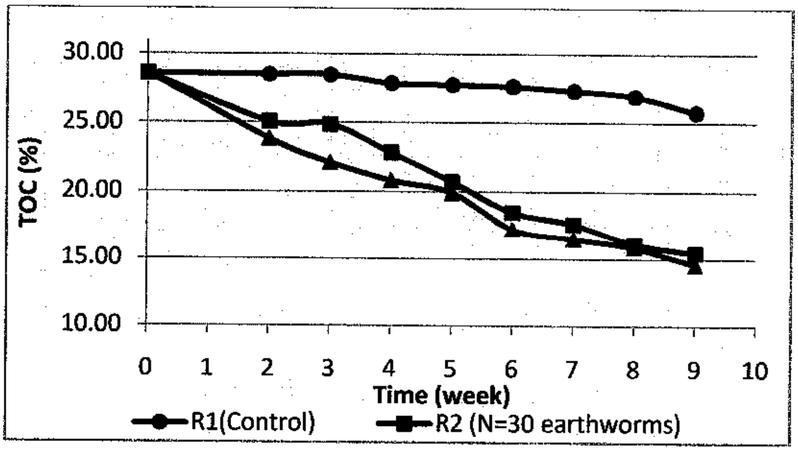
Figure 22 (a): Total Organic Carbon (% TOC) vs. Vermicomposting period (week) of C/N ratio 20.



(b)



(c)



(d)

Figure 22 (b), (c) and (d): Total Organic Carbon (% TOC) vs Vermicomposting period (week) of C/N ratio 25, 30 and 35.

Based on statistical analysis, Figure 22 (a) showed that there is significant difference of TOC at 5% level of significance between R1 (no earthworms) and R2 (N=30 earthworms) for C/N ratio 20. However, there is no big difference in reduction of TOC between R2 (N=30 earthworms) and R3 (N=40 earthworms). The highest reduction of TOC is in R3 (N=40 earthworms) with 68.87% followed by R2 (N=30 earthworms) with 64.03% and R1 (no earthworms) with 22.69%.

From Figure 22 (b), there is significant difference of TOC reduction between R1 (no earthworms) and R2 (N=30 earthworms) but there is no significant difference of TOC between R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 25. The highest reduction of TOC is in R3 (N=40 earthworms) with 59.69% followed by R2 (N=30 earthworms) with 53.35% and R1 (no earthworms) with 21.60%.

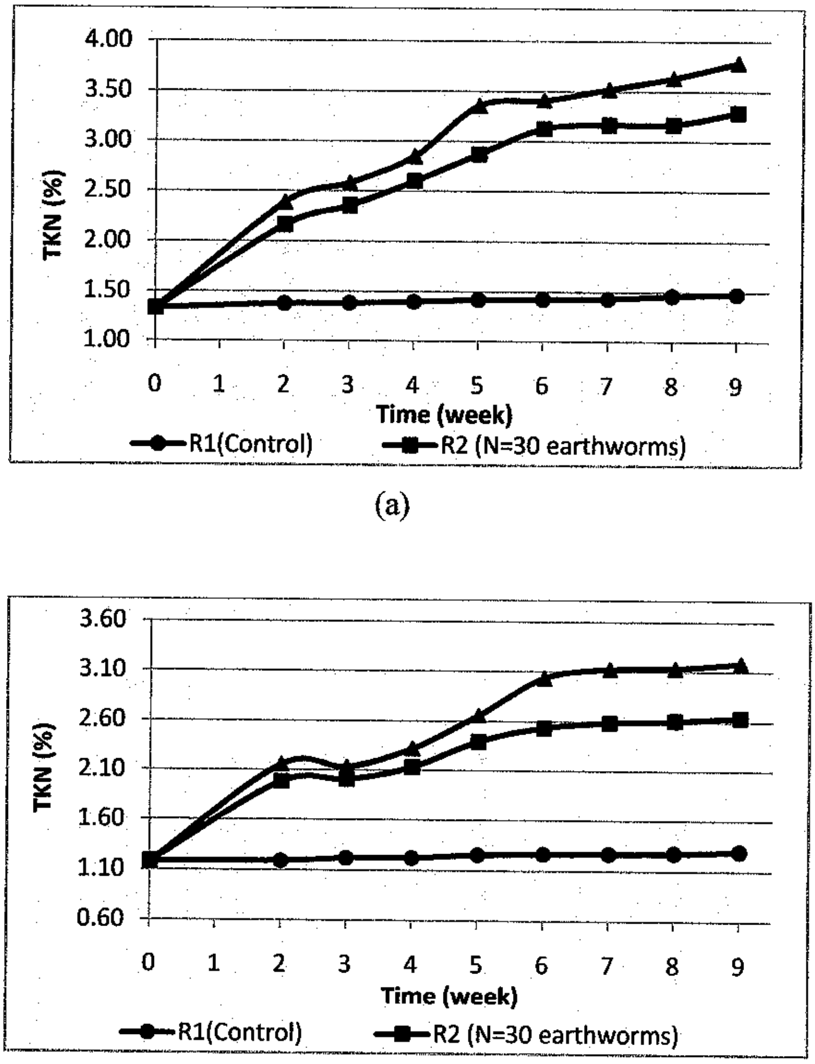
Based on statistical analysis, Figure 22 (c) showed that there is significant difference of TOC at 5% level of significance between R1 (no earthworms) and R2 (N=30 earthworms) for C/N ratio 30. However, there is no big difference in reduction of TOC between R2 (N=30 earthworms) and R3 (N=40 earthworms). The highest reduction of TOC is in R3 (N=40 earthworms) with 54.22% followed by R2 (N=30 earthworms) with 51.30% and R1 (no earthworms) with 13.64%.

From Figure 22 (d), there is significant difference of TOC between R1 (no earthworms) and R2 (N=30 earthworms) but there is no significant difference of TOC between R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 35. The highest reduction of TOC is in R3 (N=40 earthworms) with 49.05% followed by R2 (N=30 earthworms) with 45.91% and R1 (no earthworms) with 9.87%.

The results presented above showed that organic carbon decreased more significantly with time in all reactors with presence of earthworms as compared to control. The reduction of TOC is because of conversion of organic material to carbon dioxide, water and energy during decomposition [Renuka, 2007].

4.4.2 Total Kjeldahl Nitrogen (TKN) Results

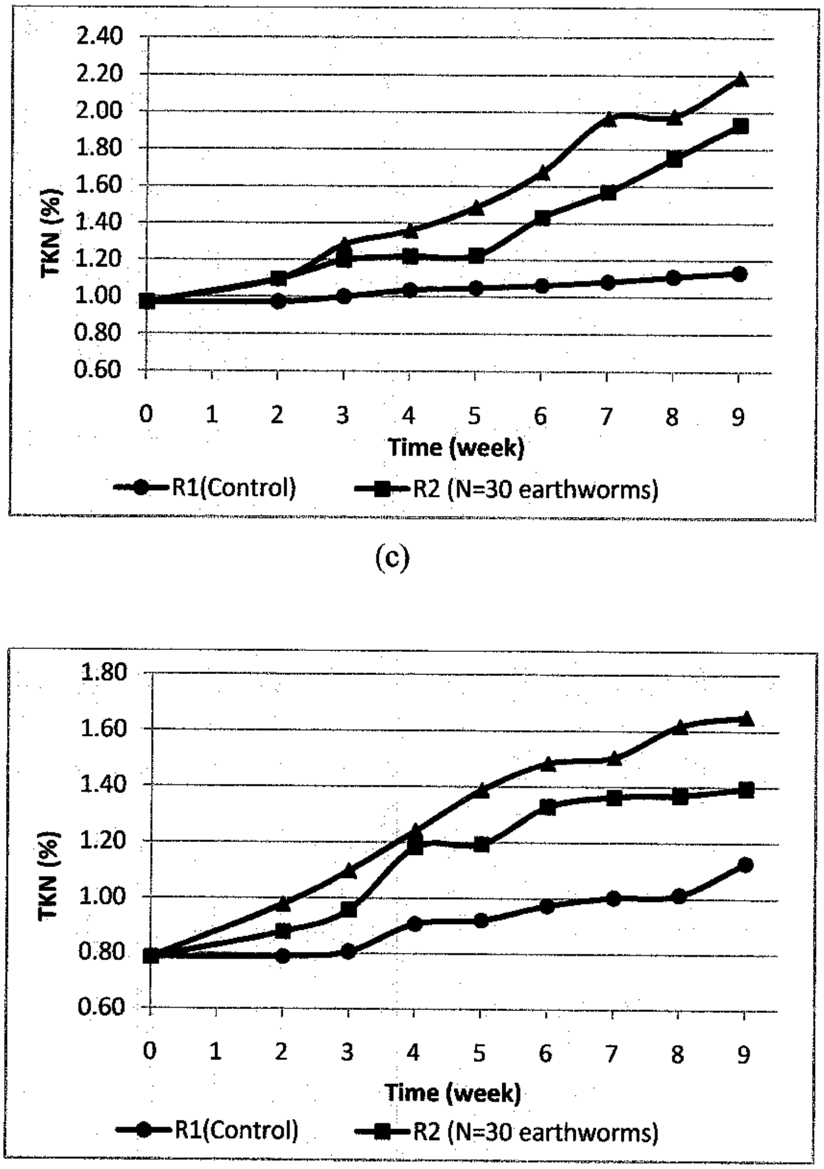
Total Kjeldahl Nitrogen was determined based on ASTM for Soil and Peat (D 2973-71) method. Based on results, it proved that there is an increment in TKN for all reactors every week. The increased TKN in reactors with the presence of earthworms are higher compared to control.



(a)

(b)

Figure 23 (a) and (b): Total Kjeldahl Nitrogen (% TKN) vs Vermicomposting period (week) of C/N ratio 20 and 25.



(c)

(d)

Figure 23 (c) and (d): Total Kjeldahl Nitrogen (% TKN) vs Vermicomposting period (week) of C/N ratio 30 and 35.

From Figure 23 (a) it showed that there is no significant difference at 5% level of significance of TKN between R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 20. However, there is a significant difference of TKN between R1 (no earthworms) and R2 (N=30 earthworms). Higher increment of 184.8% of TKN is observed in R3 (N=40 earthworms) followed by R2 (N=30 earthworms) with 147.2% and R1 (no earthworms) with 11.3%.

For C/N ratio 25, Figure 23 (b) also proved there is a significant difference of TKN between R1 (no earthworms) and R2 (N=30 earthworms) but there is no significant difference of TKN between R2 (N=30 earthworms) and R3 (N=40 earthworms) at 5% level of significance. The highest reduction of TKN is in R3 (N=40 earthworms) with 168.7% followed by R2 (N=30 earthworms) with 123.0% and R1 (no earthworms) with 9.5%.

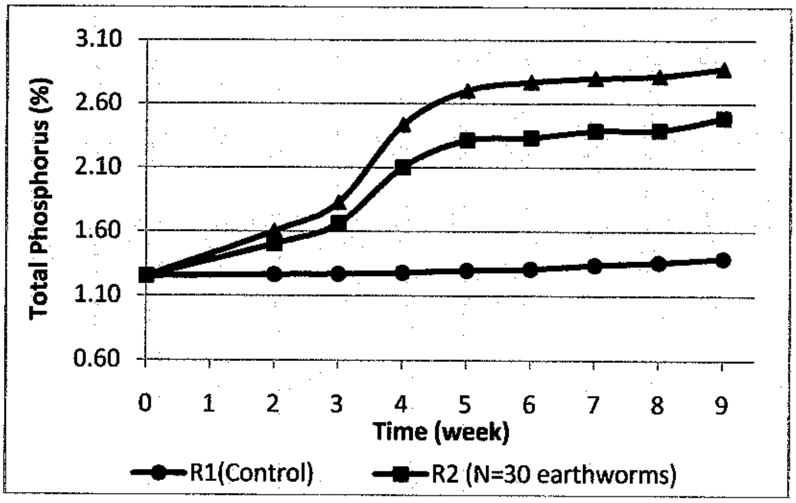
Figure 23 (c) showed that there is significant difference of TKN at 5% level of significance between R1 (no earthworms) and R2 (N=30 earthworms) for C/N ratio 30. However, there is no big difference in reduction of TKN between R2 (N=30 earthworms) and R3 (N=40 earthworms). The highest increment of TKN is in R3 (N=40 earthworms) with 126.0% followed by R2 (N=30 earthworms) with 99.5% and R1 (no earthworms) with 17.2%.

From Figure 23 (d), there is significant difference of TKN between R1 (no earthworms) and R2 (N=30 earthworms) but there is no significant difference of TKN between R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 35. The highest increment of TKN is in R3 (N=40 earthworms) with 110.0% followed by R2 (N=30 earthworms) with 77.5% and R1 (no earthworms) with 43.6%.

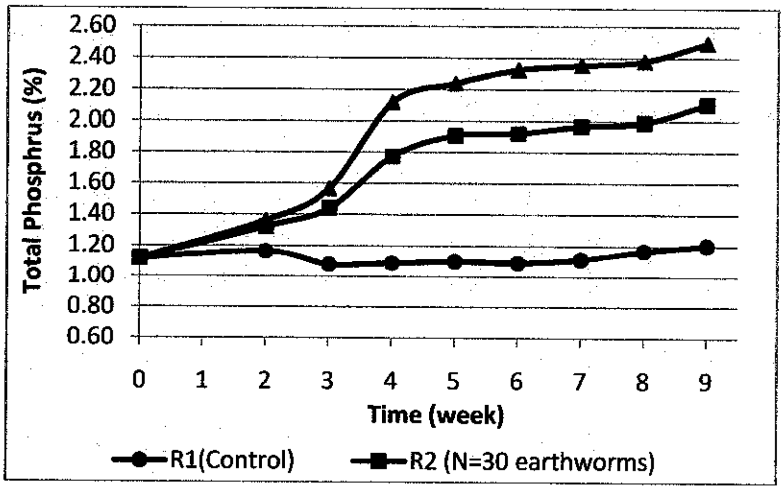
The results from Figure 23 proved that decomposition of STP sludge cause increment of TKN. The presence of earthworms promotes the faster increment because TKN of STP sludge increased significantly in R2 (N=30 earthworms) and R3 (N=40 earthworms) compared to control. It is probably because of mineralization of organic matter by earthworms [Renuka and Garg, 2007]. Casting excreted by earthworms as product decomposition content nitrogenous compounds, carbon dioxide and water [Aaron, 1996].

4.4.3 Total Phosphorus (TP) Results

Total Phosphorus was determined based on Modified Standard Methods for the Examination of Water and Wastewater (4500-P B).

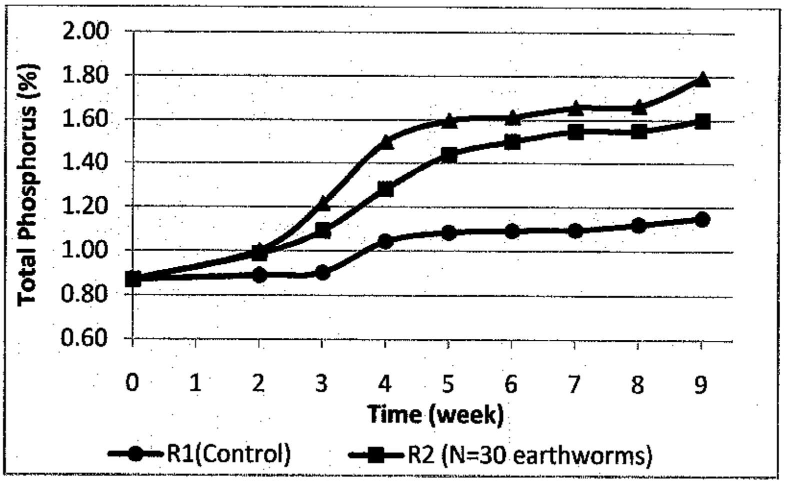


(a)

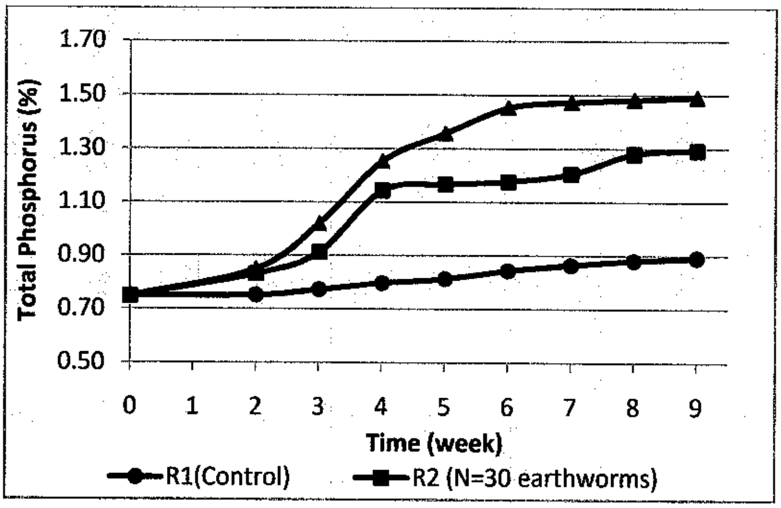


(b)

Figure 24 (a) and (b): Total Phosphorus (% TP) vs Vermicomposting period (week) of C/N ratio 20 and 25.



(c)



(d)

Figure 24 (c) and (d): Total Phosphorus (% TP) vs Vermicomposting period (week) of C/N ratio 30 and 35.

Based on statistical analysis, Figure 24 (a) showed that there is significant difference of TP at 5% level of significance between R1 (no earthworms) and R2 (N=30 earthworms) for C/N ratio 20. However, there is no big difference in of TP between R2 (N=30 earthworms) and R3 (N=40 earthworms). The highest increment of TP is in R3 (N=40 earthworms) with 130.1% followed by R2 (N=30 earthworms) with 99.1% and R1 (no earthworms) with 11.1%.

From Figure 24 (b), there is significant difference of TP between R1 (no earthworms) and R2 (N=30 earthworms) but there is no significant difference of TP between R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 25. The highest increment of TP is in R3 (N=40 earthworms) with 122.5% followed by R2 (N=30 earthworms) with 88.0% and R1 (no earthworms) with 7.5%.

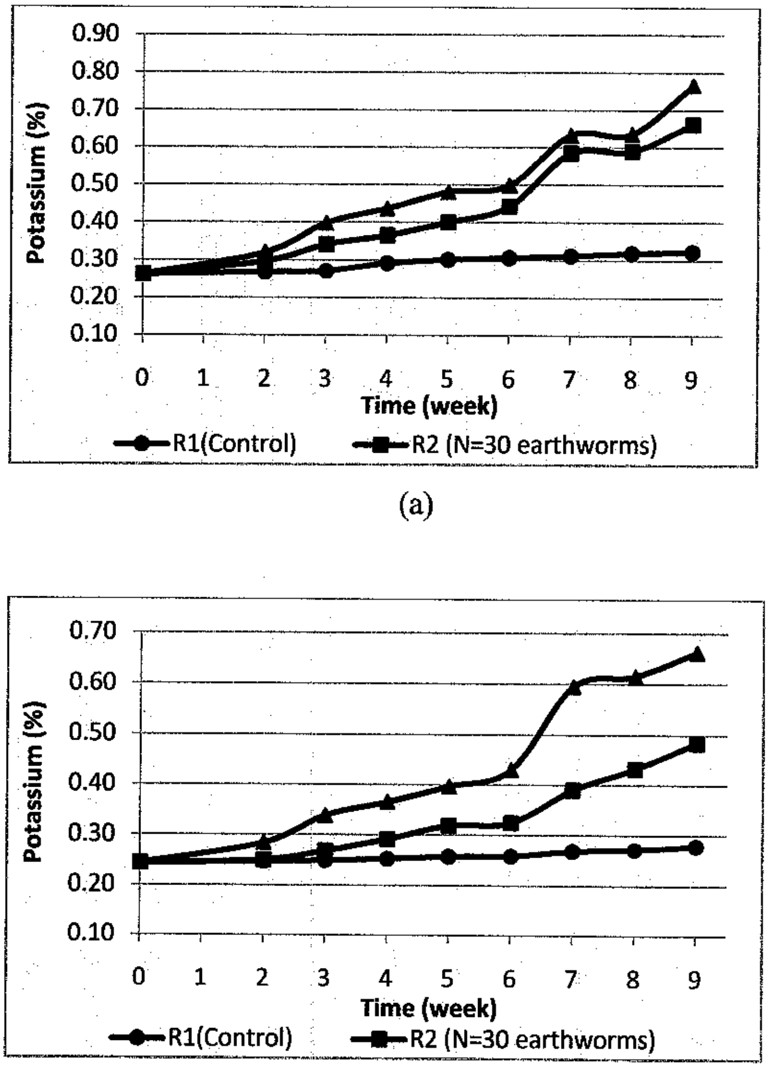
Figure 24 (c) showed that for C/N ratio 30 there is no significant difference of TP between R2 (N=30 earthworms) and R3 (N=40 earthworms) and there is significant difference in TP between R1 (no earthworms) and R2 (N=30 earthworms) at 5% level of significance. The highest increment of TP is in R3 (N=40 earthworms) with 106.0% followed by R2 (N=30 earthworms) with 83.9% and R1 (no earthworms) with 32.3%.

Figure 24 (d) also showed that for C/N ratio 35 there is no significant difference of TP between R2 (N=30 earthworms) and R3 (N=40 earthworms) and there is significant difference in TP between R1 (no earthworms) and R2 (N=30 earthworms) at 5% level of significance. The highest increment of TP is in R3 (N=40 earthworms) with 99.3% followed by R2 (N=30 earthworms) with 72.6% and R1 (no earthworms) with 19.0%.

Results reveals that available phosphorus increased significantly in all reactors with the presence of earthworms compared to control for all C/N ratio. The highest available phosphorus increased between in R3 (N=40 earthworms) for all C/N ratio between 130%-99%. However, based on statistical analysis, there is no significant difference in available phosphorus in R3 (N=30 earthworms) and R3 (N=40 earthworms). Payal in 2006 found that the increased in available phosphorus is due to physical breakdown of the organic material by earthworms. As organic waste passed through the earthworm gut, nutrients such as phosphorus transformed to more readily available to plants such as nitrate, ammonium biologically. For example, as organic matter passes through earthworm gut, nitrogen and sulfur containing compounds further decompose, yielding simple inorganic ions such as ammonium (NH_4^+) and nitrate (NO3-) that become available for uptake by plant and microorganisms.

4.4.4 Potassium Results

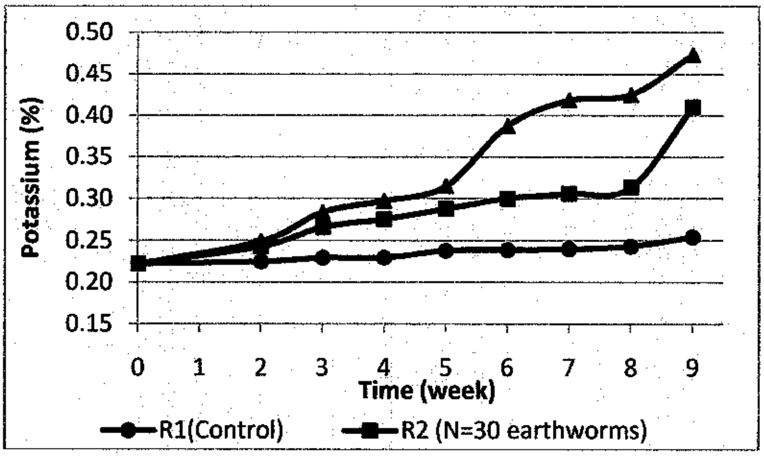
Potassium was determined based on Modified Standard Methods for the Examination of Water and Wastewater (4500-P B). Based on results, it proved that available potassium increased every week for 9 weeks of vermicomposting periods.



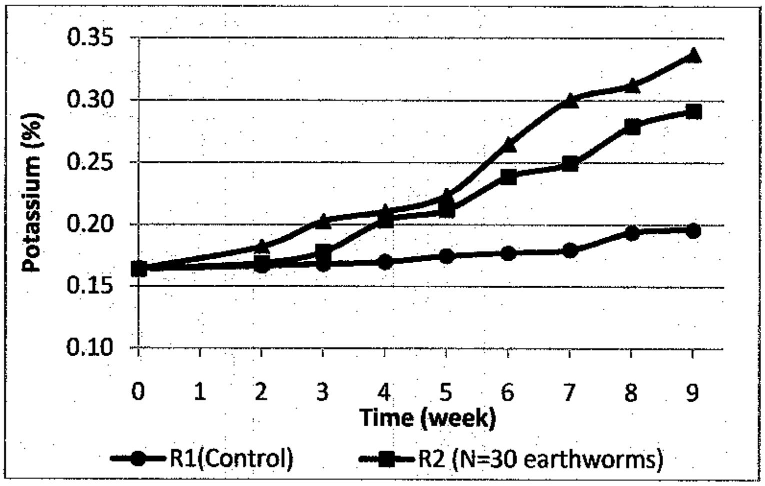
(a)

(b)

Figure 25 (a) and (b): Potassium (%) vs. Vermicomposting period (week) of C/N ratio 20 and 25.



(c)



(d)

Figure 25 (c) and (d): Potassium (%) vs Vermicomposting period (week) of C/N ratio 30 and 35.

Based on statistical analysis, Figure 25 (a) showed for C/N ratio 20 that there is significant difference between R1 (no earthworms) and R2 (N=30 earthworms) and there is no significant difference between R2 (N=30 earthworms) and R3 (N=40 earthworms) at 5% level of significant. The highest increment of Potassium is in R3 (N=40 earthworms) with 192.7% followed by R2 (N=30 earthworms) with 152.6% and R1 (no earthworms) with 23.5%.

Figure 25 (b) showed that for C/N ratio 25 there is no significant difference of Potassium between R2 (N=30 earthworms) and R3 (N=40 earthworms) and there is significant difference in Potassium between R1 (no earthworms) and R2 (N=30 earthworms) at 5% level of significance. The highest increment of Potassium is in R3 (N=40 earthworms) with 172.7% followed by R2 (N=30 earthworms) with 99.2% and R1 (no earthworms) with 14.8%.

Figure 25 (c) showed that for C/N ratio 30 there is no significant difference of Potassium between R2 (N=30 earthworms) and R3 (N=40 earthworms) and there is significant difference in Potassium between R1 (no earthworms) and R2 (N=30 earthworms) at 5% level of significance. The highest increment of Potassium is in R3 (N=40 earthworms) with 113.0% followed by R2 (N=30 earthworms) with 85.0% and R1 (no earthworms) with 14.5%.

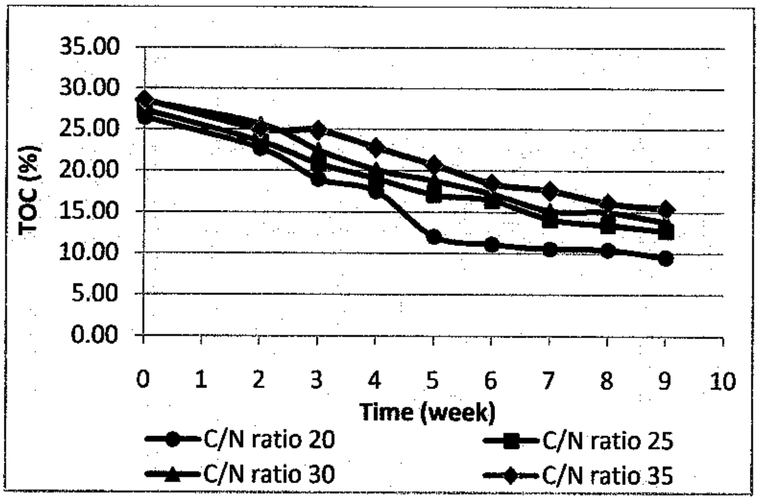
Figure 25 (d) also showed that for C/N ratio 35 there is no significant difference of Potassium between R2 (N=30 earthworms) and R3 (N=40 earthworms) and there is significant difference in Potassium between R1 (no earthworms) and R2 (N=30 earthworms) at 5% level of significance. The highest increment of TP is in R3 (N=40 earthworms) with 105.6% followed by R2 (N=30 earthworms) with 78.1% and R1 (no earthworms) with 19.7%.

Based on the results for potassium, it showed that available potassium also increased in final product for all C/N ratios. It proved that as the organic matter decomposed nutrients such as potassium are released and recycled in various chemical forms through microorganisms and earthworms that make up the compost food web [Nancy, 1998]. The significant increased of potassium is observed in reactors with the presence of earthworms compared to control. This showed that the earthworms help in accelerating rate of decomposition of organic matter by microorganisms. Microorganisms use mucus in earthworm's gut as substrate to decompose complex organic compounds into simpler substances that are digestible by the earthworms [Payal 2006].

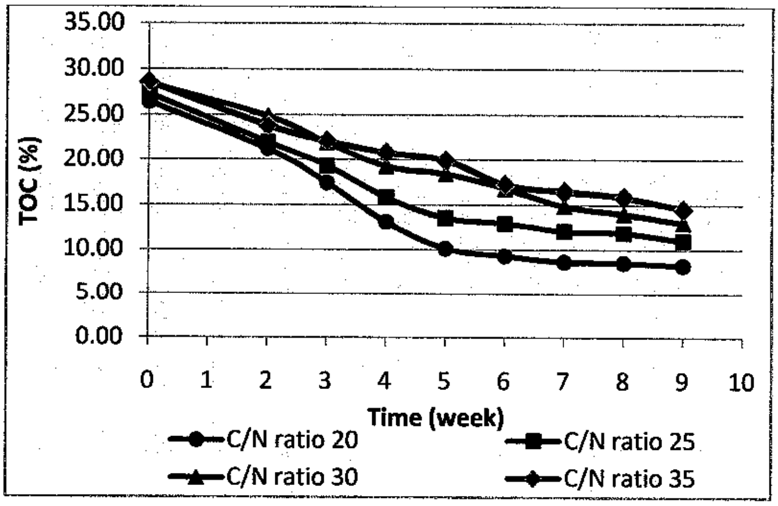
4.5 Effect of Initial C/N Ratio with Fixed Initial Number of Earthworms

Two initial number of earthworms which is N=30 earthworms and N=40 earthworms were tested for difference C/N ratio. The initial C/N ratio tested were C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35. Then the decomposition at differences C/N ratios were evaluated with fixed number of earthworms.

4.5.1 Total Organic Carbon Results



(a) R2(N=30 earthworms)



(b) R3(N=40 earthworms)

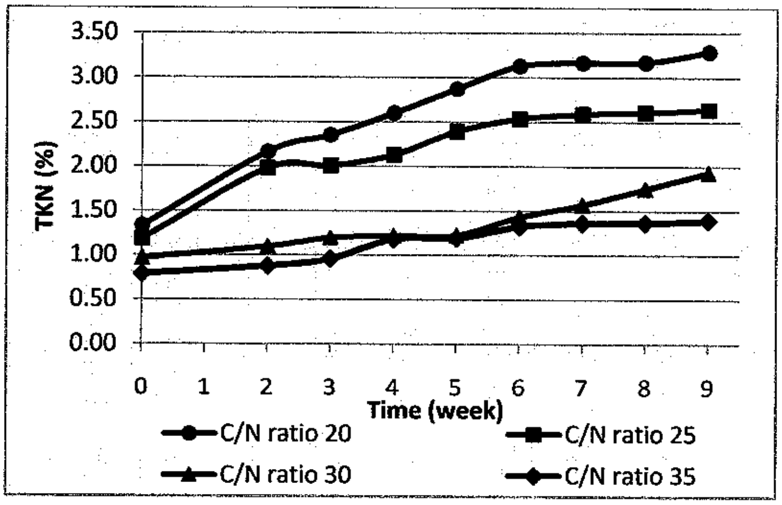
Figure 26 (a) and (b): Total Organic Carbon (TOC %) vs Vermicomposting period (week) of R2 (N=30 earthworms) and R3 (N=40 earthworms).

Based on statistical analysis, Figure 26 (a) showed for TOC of R2 (N=30 earthworms) there is significant difference between C/N ratio 20 and C/N ratio 35. However, there is no significant difference of TOC between C/N ratio 20, C/N ratio 25 and C/N ratio 35 at 5% level of difference.

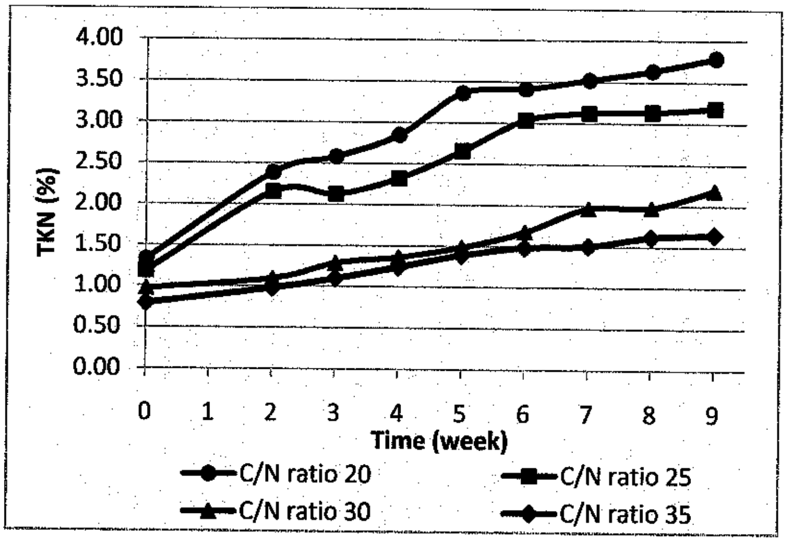
Figure 26 (b) showed that there is no significant difference of TOC for R3 (N=40 earthworms) between C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 at 5 % level of difference.

Results showed that there is no significant variance in reduction of TOC between C/N ratio 20 and C/N ratio 35. The TOC reduction is almost same for all C/N ratios in the optimum range. This showed that the variance between C/N ratios to investigate the change in TOC in too small. However, for both R2 (N=30 earthworms) and R3 (N=40 earthworms), C/N ratio 20 showed there highest reduction followed by C/N ratio 25, 30 and 35.

4.5.2 Total Kjeldahl Nitrogen Results



(a) R2 (N=30 earthworms)



(b) R3 (N=40 earthworms)

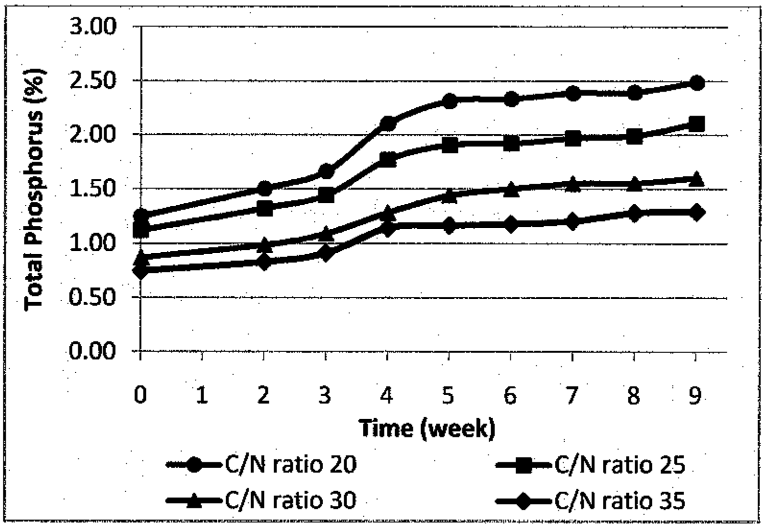
Figure 27 (a) and (b): Total Kjeldahl Nitrogen (TKN %) vs Vermicomposting period (week) of R2 (N=30 earthworms) and R3 (N=40 earthworms).

Figure 27 (a) showed that for R2 (N=30 earthworms) there is a significant difference of TKN for between C/N ratio 20 and C/N ratio 30, C/N ratio 20 and 35 C/N ratio 25 and C/N ratio 30 as well as C/N ratio 25 and C/N ratio 35. However, there is no significant difference of TKN between C/N ratio 20 and C/N ratio 25 as well as C/N ratio 30 and C/N ratio 35.

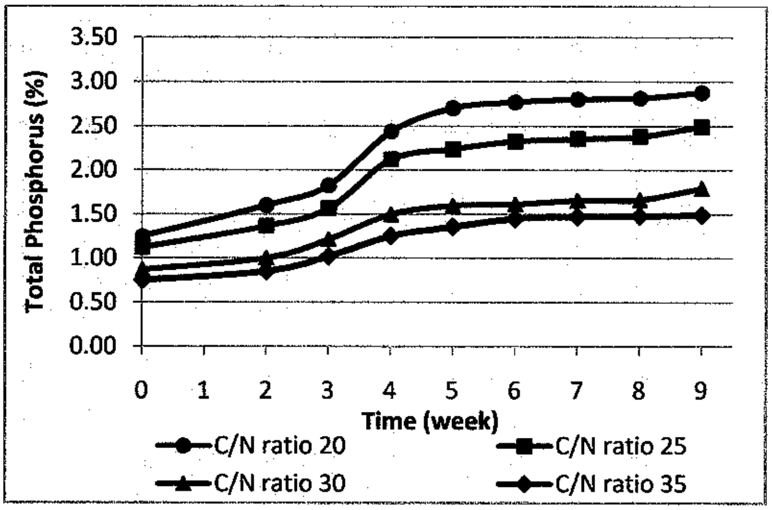
From Figure 27 (b), for R3 (N=40 earthworms), there is no significant difference of TKN between C/ N ratio 20 and C/ ratio 30, C/N ratio 20 and C/N ratio 35, C/N ratio 25 and C/N ratio 30 as well as C/N ratio 25 and C/N ratio 35. But there is no significant difference of TKN between C/N ratio 20 and C/N ratio 25 as well as C/N ratio 30 and C/N ratio 35.

Based on those results of TKN, it proved that the increment of TKN is fastest. The variance between C/N ratios tested is significant to evaluate the change in TKN. For both R2 (N=30 earthworms) and R3 (N=40 earthworms), C/N ratio 20 showed there highest increment followed by C/N ratio 25, 30 and 35.

4.5.3 Total Phosphorus Results



(a) R2 (N=30 earthworms)



(b) R3(N=40 earthworms)

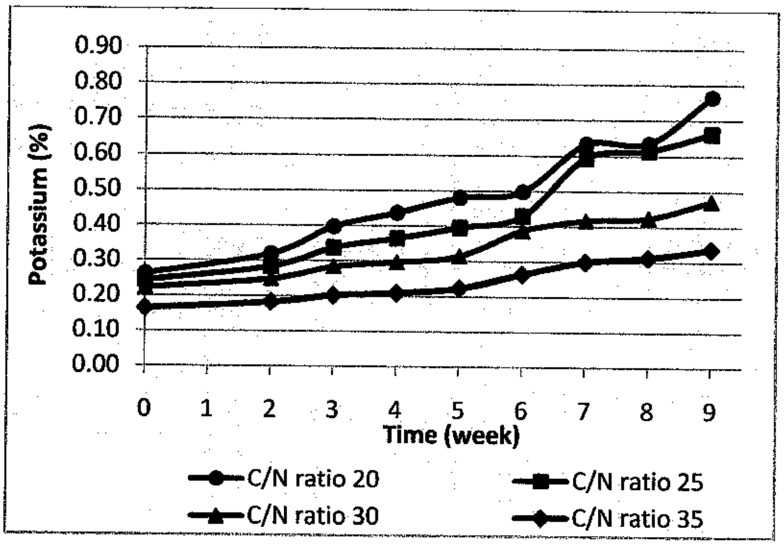
Figure 28 (a) and (b): Total Phosphorus (TP %) vs Vermicomposting period (week) of R2 (N=30 earthworms) and R3 (N=40 earthworms).

Figure 28 (a) showed that for R2 (N=30 earthworms) there is a significant difference of TP for between C/N ratio 20 and C/N ratio 30, C/N ratio 20 and 35 C/N ratio 25 and C/N ratio 30 as well as C/N ratio 25 and C/N ratio 35. However, there is no significant difference of TP between C/N ratio 20 and C/N ratio 25 as well as C/N ratio 30 and C/N ratio 35.

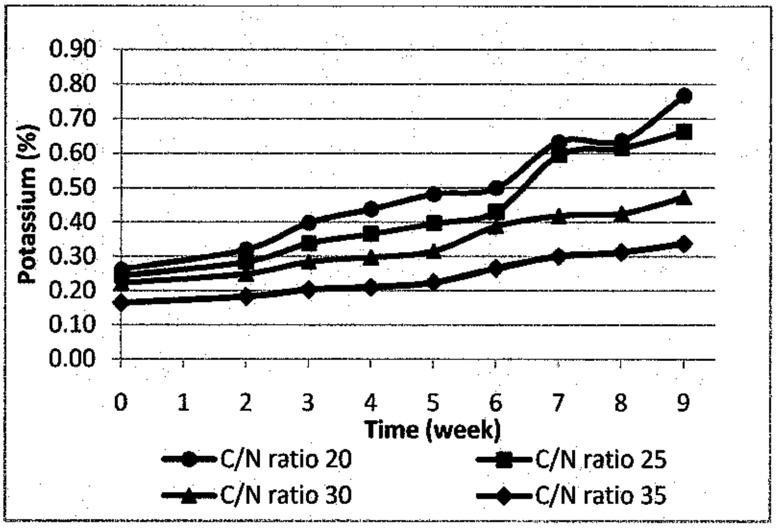
From Figure 28 (b), for R3 (N=40 earthworms), there is no significant difference of TP between C/N ratio 20 and C/N ratio 30, C/N ratio 20 and C/N ratio 35, C/N ratio 25 and C/N ratio 30 as well as C/N ratio 25 and C/N ratio 35. But there is no significant difference of TP between C/N ratio 20 and C/N ratio 25 as well as C/N ratio 30 and C/N ratio 35.

Based on those results of TP, it proved that the increment of TP is fastest. The variance between C/N ratios tested is significant to evaluate the change in TP. For both R2 (N=30 earthworms) and R3 (N=40 earthworms), C/N ratio 20 showed there highest increment followed by C/N ratio 25, 30 and 35.

4.5.4 Potassium Results



(a) R2(N=30 earthworms)



(b) R3(N=40 earthworms)

Figure 29 (a) and (b): Potassium (%) vs Vermicomposting period (week) of R2 (N=30 earthworms) and R3 (N=40 earthworms).

Figure 29 (a) showed that for R2 (N=30 earthworms) there is a significant difference of Potassium for between C/N ratio 20 and C/N ratio 30, C/N ratio 20 and 35 C/N ratio 25 and C/N ratio 35 as well as C/N ratio 30 and C/N ratio 35. However, there is no significant difference of Potassium between C/N ratio 20 and C/N ratio 25 as well as C/N ratio 25 and C/N ratio 30.

From Figure 29 (b), for R3 (N=40 earthworms), there is no significant difference of Potassium for between C/N ratio 20 and C/N ratio 30, C/N ratio 20 and 35 C/N ratio 25 and C/N ratio 35 as well as C/N ratio 30 and C/N ratio 35. However, there is no significant difference of Potassium between C/N ratio 20 and C/N ratio 25 as well as C/N ratio 25 and C/N ratio 30.

Based on those results of Potassium, it proved that the increment of Potassium is fastest. The variance between C/N ratios tested is significant to evaluate the change in Potassium. For both R2 (N=30 earthworms) and R3 (N=40 earthworms), C/N ratio 20 showed there highest increment followed by C/N ratio 25, 30 and 35.

4.6 Changes in Carbon to Nitrogen Ratio

Carbon to nitrogen ratio plays an important role in determining degree of decomposition and quality of vermicompost. Since there are changes in Total Organic Carbon and Total Kjeldahl Nitrogen, the initial C/N ratio also changes. As vermicomposting proceed, the C/N ratio decreased. Table 8 showed the changes of C/N ratio for all reactors at different C/N ratio. Based on those results, the highest reduction of C/N ratio is at initial C/N ratio 20 for both R2 (N=30 earthworms) and R3 (N=40 earthworms). It is showed that the decomposition proceeded best at C/N ratio 20 in vermicomposting of STP sludge and shredded paper. Hou in 2005 also found the same results for vermicomposting of municipal solid waste. However, the difference of reduction of C/N ratio between C/N ratios 20 is not much differing from other C/N ratio.

Table 8: Change in C/N ratio after nine (9) weeks of vermicomposting period.

C/N ratio	Reactor	Observed C/N ratio (week=0)			Final C/N ratio (week=9)			Percentage of difference (%)
		TOC (%)	TKN (%)	C/N ratio	TOC (%)	TKN (%)	C/N ratio	
20	R1(Control)	26.44	1.33	19.87	20.44	1.48	13.81	30.51
	R2 (N=30 earthworms)	26.44	1.33	19.87	9.51	3.29	2.89	85.46
	R3(N=40 earthworms)	26.44	1.33	19.87	8.23	3.79	2.17	89.07
25	R1(Control)	27.31	1.18	23.05	21.41	1.30	16.50	28.43
	R2 (N=30 earthworms)	27.31	1.18	23.05	12.74	2.64	4.82	79.08
	R3(N=40 earthworms)	27.31	1.18	23.05	11.01	3.18	3.46	85.00
30	R1(Control)	28.44	0.97	29.39	24.56	1.13	21.65	26.34
	R2 (N=30 earthworms)	28.44	0.97	29.39	13.85	1.93	7.17	75.60
	R3(N=40 earthworms)	28.44	0.97	29.39	13.02	2.19	5.95	79.75
35	R1(Control)	28.58	0.79	36.35	25.76	1.13	22.82	37.22
	R2 (N=30 earthworms)	28.58	0.79	36.35	15.46	1.40	11.08	69.52
	R3(N=40 earthworms)	28.58	0.79	36.35	14.56	1.65	8.82	75.74

4.7 Growth of *Eisenia foetida*

Based on Table 9, it is observed that there are changes in the number of earthworms after eight (8) weeks of vermicomposting period. The cocoons in Figure 34 (b) were found in all reactors with the presence of earthworms in week four (4) of vermicomposting period. The number of earthworms at C/N ratio 20 for both R2 (N=30 earthworms) and R3 (N=40 earthworms) is higher compared to other C/N ratio. It showed that earthworms grow better at C/N ratio 20. The increment in number of earthworms proved the ability of *Eisenia foetida* to decompose STP sludge blended with shredded paper.

Table 9: Change in number of earthworms after eight (8) weeks of vermicomposting period.

C/N ratio	Number of earthworms			
	R2 (N=30 earthworms)		R3 (N=40 earthworms)	
	Week =0	Week=8	Week =0	Week=8
20	30	56	40	58
25	30	48	40	51
30	30	50	40	53
35	30	42	40	48


(a) (b)

Figure 30: (a) *Eisenia foetida* before vermicomposting (b) *Eisenia foetida* after 8 weeks of vermicomposting period.

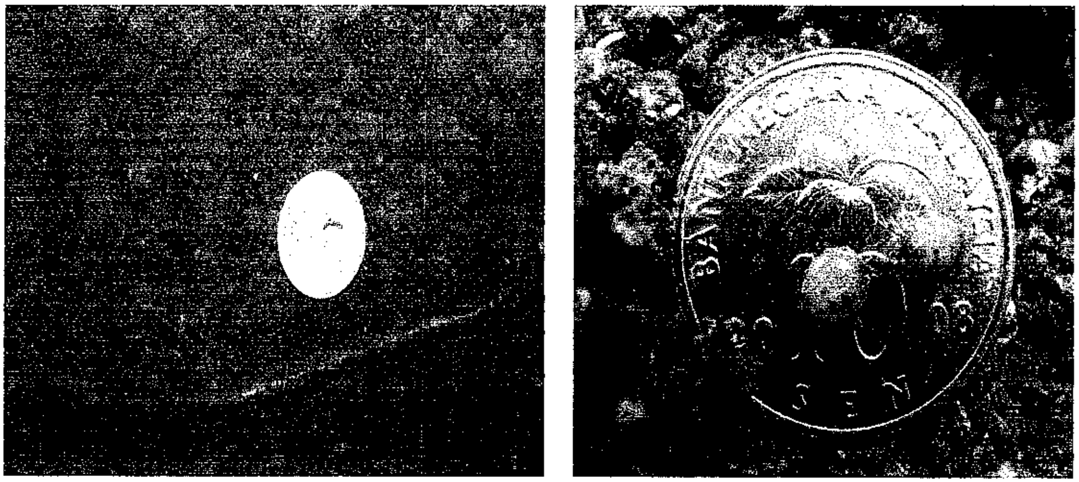

(a) (b)

Figure 31: (a) The longest *Eisenia foetida* in R2 (N=30 earthworms) for C/N ratio 20 (b) Cocoons of *Eisenia foetida* produced after 4 weeks of vermicomposting period.

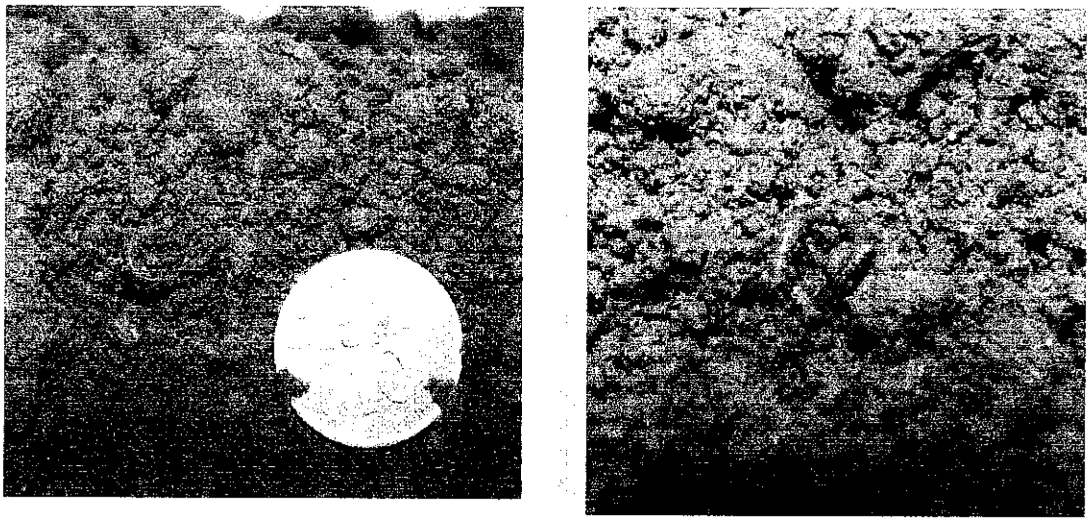


Figure 32: Babies of *Eisenia foetida*

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this project, research was done for nine (9) weeks to evaluate the ability of *Eisenia foetida* to decompose sludge from Sewage Treatment Plant of UTP. From the results obtained, it proved the ability of the earthworms to decompose the sludge due to changes in physical and chemical characteristics of the sludge.

Results proved that Total Organic Carbon (TOC) reduced in all reactors after 9 weeks of vermicomposting period. The highest reduction of TOC was found at C/N ratio 20 for R3 (N= 40 earthworms) which is 68.87%. The reductions of TOC in reactors with the presence of earthworms were significantly high compared to control.

For Total Kjeldahl Nitrogen (TKN), the results showed that there were increments in TKN in all reactors. However the increment of TKN in reactors with the presence of earthworms is significantly high compared to control. The highest increment of TKN was found at C/N ratio 20 for R3 (N=40 earthworms) which is 147.2%.

Total Phosphorus results also showed that there were increments in all reactors. The highest increment was found at C/N ratio 20 which is 130.1% after 9 weeks of vermicomposting periods. The increments of TP in reactors with the presence of earthworms are significantly high compared to control.

The same results were found for Potassium. The increment of Potassium in reactors with the presence of earthworms were significantly high compared to control and the highest increment was found in reactor at C/N ratio 20 for R3 (N=40 earthworms) which is 192.7%.

There were also changes in pH after 9 weeks of vermicomposting periods. The pHs were reduced from alkaline to acidic. The faster reductions of pH were found in reactors with the presence of earthworms for all C/N ratios. However, the final pHs were still within the optimum range.

From the results, it is observed that vermicomposting of STP sludge proceed faster with the presence of earthworms compared to control. Therefore, it can be concluded that vermicomposting can be an applicable technology for decomposition of municipal sludge.

5.2 Recommendations

From the results, it is recommended that vermicomposting can be applied to decompose sludge from Sewage Treatment Plant of UTP to replace landfill method since it is economically viable because it can produce beneficial end product.

For further study, it is recommended to prolong the vermicomposting period because a minimum of 100 days is required for the production of stable vermicompost [Aaron, 1996]. Instead of that, it is also recommended that detail study need to be done to evaluate chemical characteristics of vermicompost produced from decomposition of the sludge to compare the quality of vermicompost with the conventional compost used in Malaysia.

REFERENCES

[1] Aaron Mahimainathan 1996. "A study on the vermicomposting of dewatered dairy waste". Environmental Science and Forestry.

[2] A.H.Molla, A.Fakhru'l-Razi and M.Z. Alam 2006."Solid State Bioconversion: An Effective Process for Safe Disposal and Recycling of Domestice Wastewater Sludge as Compost". Journal of the Agricultural Engineering Society 9:57-71.

[3] A Parvaresh, H Movahedian and L Hamidian 2004. " Vermistabilazation of Municipal Sludge with *Eisenia fetida*". *Iranian J Environment Health Science Engineering* 1:43-50.

[4] DOE, 2004. Environmental Quality Report, Department of Environment, Ministry of Science, Technology and Environment, Kuala Lumpur, Malaysia.

[5] Fuad Hadinata Yaakoob 2007. "Cacing Rakan Karib Mustafa", Harian Metro pp 15-16.

[6] Gautam Bhattacharjee and PS Chaudhuri 2002. "Cocoon production, morphology, hatching pattern and fecundity in seven tropical earthworm species". *Bioresource Technology* 27: 283-294.

[7] George Tchobanoglous 1993, Integrated Solid Waste Management, 1th edition, McGraw-Hill

[8] George W.Dickerson 2003. "Vermicomposting", College of Agriculture and Home Economics.

[9] Hou Jicong et al. 2005. "The Influence of Temperature, pH and C/N ratio on the Growth and Survival of Earthwormsin Municipal Solid Waste". Agricultural Engineering International 7: 1-6.

[10] Indah Water Konsortium Sdn. Bhd., (2008) < http://www.iwk.com.my/f-links.htm>.

[11] Mansfield 2003, "*Pilot Study Initial Results for Vermicomposting Yard Waste with Biosolids*", 1st Edition, Gannett Fleming.

[12] Manuel Aira, Fernando Monroy, Jorge Domínguez and Salustiano Mato 2004, "How earthworm density affects microbial biomas and activity in pig manure", *Bioresource Technology* 38: 7-10.

[13] Metcalf & Eddy 2004, Wastewater Engineering-Treatment & Reuse, 4th edition, McGraw-Hill.

[14] Nancy M. Trautmann and Marianne E. Krasny (1998), "Composting in the classroom"; pp 116.

[15] Payal Garga, Asha Guptaa and Santosh Satyab 2006. "Vermicomposting of different types of waste using Eisenia foetida". Bioresource Technology 97:391-395.

[16] Renuka Gupta and V.K. Garg 2008. "Stabilization of primary sewage sludge during vermicomposting" Journal of Hazardous Materials 153: 1023-1030.

[17] Renuka Gupta et al. 2007. "Development of a water hyacinth based vermireactor using an epigeic earthworm Eisenia foetida" . Journal of Hazardous Materials 98: 2605-2610.

[18] Rola M.Atiyeh 2000. "Mechanism by which Earthworm-Processed Organic Waste Influence Plant Growth". The Ohio State University for Environmental Science. Report No. 9971509. Report 147 pp.

[19] S.Gajalakshimi, P.Sankar Ganesh, S.A.Abbasi 2005."A highly cost-effective simplification in the design of fast-paced vermireactors based on epigeic earthworms". Bioresource Technology 22: 111-116.

APPENDICES

APPENDIX A

TP at C/N ratio 25 and TP at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 25	C/N ratio = 35
1.121	0.749
1.364	0.851
1.567	1.020
2.119	1.254
2.240	1.357
2.326	1.454
2.354	1.474
2.381	1.483
2.494	1.493

	Variable 1	*Variable 2*
Mean	1.9963904	1.2371631
Variance	0.2572257	0.0848539
Observations	9	9
Pooled Variance	0.1710398	
Hypothesized Mean Difference	0	
df	16	
t Stat	3.8943007	
P(T<=t) one-tail	0.0006446	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0012892	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TP at C/N ratio 30 and TP at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 30	C/N ratio = 35
0.871	0.749
1.003	0.851
1.217	1.020
1.499	1.254
1.598	1.357
1.615	1.454
1.658	1.474
1.666	1.483
1.794	1.493

	Variable 1	*Variable 2*
Mean	1.4357082	1.2371631
Variance	0.1058857	0.0848539
Observations	9	9
Pooled Variance	0.0953698	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.3638293	
P(T<=t) one-tail	0.095751	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.191502	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

APPENDIX –A11: Potassium at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R2 (N=30 earthworms)

Potassium at C/N ratio 20 and Potassium at C/N ratio 25 for R2 (N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 20	C/N ratio = 25
0.262	0.243
0.298	0.250
0.342	0.268
0.365	0.291
0.401	0.319
0.443	0.325
0.585	0.390
0.590	0.432
0.662	0.484

	Variable 1	*Variable 2*
Mean	0.4385845	0.3336049
Variance	0.0201896	0.0071351
Observations	9	9
Pooled Variance	0.0136624	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.9052324	
P(T<=t) one-tail	0.0374416	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0748831	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

Potassium at C/N ratio 20 and Potassium at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 20	C/N ratio = 30
0.262	0.222
0.298	0.243
0.342	0.266
0.365	0.275
0.401	0.288
0.443	0.300
0.585	0.306
0.590	0.313
0.662	0.411

	Variable 1	*Variable 2*
Mean	0.4385845	0.2916628
Variance	0.0201896	0.0028824
Observations	9	9
Pooled Variance	0.011536	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.9017826	
P(T<=t) one-tail	0.0052012	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0104024	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

Potassium at C/N ratio 20 and Potassium at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 20	C/N ratio = 35
0.262	0.164
0.298	0.169
0.342	0.178
0.365	0.203
0.401	0.212
0.443	0.239
0.585	0.249
0.590	0.279
0.662	0.292

	Variable 1	*Variable 2*
Mean	0.4385845	0.220659
Variance	0.0201896	0.0022265
Observations	9	9
Pooled Variance	0.011208	
Hypothesized Mean Difference	0	
df	16	
t Stat	4.3666597	
P(T<=t) one-tail	0.0002397	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0004793	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

Potassium at C/N ratio 25 and Potassium at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 25	C/N ratio = 30
0.243	0.222
0.250	0.243
0.268	0.266
0.291	0.275
0.319	0.288
0.325	0.300
0.390	0.306
0.432	0.313
0.484	0.411

	Variable 1	*Variable 2*
Mean	0.3336049	0.2916628
Variance	0.0071351	0.0028824
Observations	9	9
Pooled Variance	0.0050088	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.2571646	
P(T<=t) one-tail	0.1133681	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.2267363	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

Potassium at C/N ratio 25 and Potassium at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 25	C/N ratio = 35
0.243	0.164
0.250	0.169
0.268	0.178
0.291	0.203
0.319	0.212
0.325	0.239
0.390	0.249
0.432	0.279
0.484	0.292

	Variable 1	*Variable 2*
Mean	0.3336049	0.220659
Variance	0.0071351	0.0022265
Observations	9	9
Pooled Variance	0.0046808	
Hypothesized Mean Difference	0	
df	16	
t Stat	3.5020017	
P(T<=t) one-tail	0.0014755	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.002951	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

Potassium at C/N ratio 30 and Potassium at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 30	C/N ratio = 35
0.222	0.164
0.243	0.169
0.266	0.178
0.275	0.203
0.288	0.212
0.300	0.239
0.306	0.249
0.313	0.279
0.411	0.292

	Variable 1	*Variable 2*
Mean	0.2916628	0.220659
Variance	0.0028824	0.0022265
Observations	9	9
Pooled Variance	0.0025544	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.9801731	
P(T<=t) one-tail	0.0044187	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0088374	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

APPENDIX –A12: Potassium at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R3 (N=40 earthworms)

Potassium at C/N ratio 20 and Potassium at C/N ratio 25 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 20	C/N ratio = 25
0.262	0.243
0.321	0.284
0.398	0.338
0.438	0.366
0.481	0.397
0.499	0.430
0.634	0.595
0.636	0.615
0.767	0.663

	Variable 1	*Variable 2*
Mean	0.4928042	0.4367413
Variance	0.0263102	0.0231632
Observations	9	9
Pooled Variance	0.0247367	
Hypothesized Mean Difference	0	
df	16	
t Stat	0.7561551	
P(T<=t) one-tail	0.2302726	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.4605453	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

Potassium at C/N ratio 20 and Potassium at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 20	C/N ratio = 30
0.262	0.222
0.321	0.249
0.398	0.284
0.438	0.297
0.481	0.315
0.499	0.388
0.634	0.418
0.636	0.425
0.767	0.473

	Variable 1	*Variable 2*
Mean	0.4928042	0.3413135
Variance	0.0263102	0.0076401
Observations	9	9
Pooled Variance	0.0169751	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.4665253	
P(T<=t) one-tail	0.0126603	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0253206	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

Potassium at C/N ratio 20 and Potassium at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 20	C/N ratio = 35
0.262	0.164
0.321	0.182
0.398	0.203
0.438	0.210
0.481	0.224
0.499	0.265
0.634	0.301
0.636	0.313
0.767	0.337

	Variable 1	*Variable 2*
Mean	0.4928042	0.2443545
Variance	0.0263102	0.0038085
Observations	9	9
Pooled Variance	0.0150593	
Hypothesized Mean Difference	0	
df	16	
t Stat	4.2947895	
P(T<=t) one-tail	0.0002783	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0005567	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

Potassium at C/N ratio 25 and Potassium at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 25	C/N ratio = 30
0.243	0.222
0.284	0.249
0.338	0.284
0.366	0.297
0.397	0.315
0.430	0.388
0.595	0.418
0.615	0.425
0.663	0.473

	Variable 1	*Variable 2*
Mean	0.4367413	0.3413135
Variance	0.0231632	0.0076401
Observations	9	9
Pooled Variance	0.0154016	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.6311646	
P(T<=t) one-tail	0.0611898	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.1223795	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

Potassium at C/N ratio 25 and Potassium at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 25	C/N ratio = 35
0.243	0.164
0.284	0.182
0.338	0.203
0.366	0.210
0.397	0.224
0.430	0.265
0.595	0.301
0.615	0.313
0.663	0.337

	Variable 1	*Variable 2*
Mean	0.4367413	0.2443545
Variance	0.0231632	0.0038085
Observations	9	9
Pooled Variance	0.0134858	
Hypothesized Mean Difference	0	
df	16	
t Stat	3.5143314	
P(T<=t) one-tail	0.0014376	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0028752	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

Potassium at C/N ratio 30 and Potassium at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

Potassium (%)	
C/N ratio = 30	C/N ratio = 35
0.222	0.164
0.249	0.182
0.284	0.203
0.297	0.210
0.315	0.224
0.388	0.265
0.418	0.301
0.425	0.313
0.473	0.337

	Variable 1	*Variable 2*
Mean	0.3413135	0.2443545
Variance	0.0076401	0.0038085
Observations	9	9
Pooled Variance	0.0057243	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.7185264	
P(T<=t) one-tail	0.0075922	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0151844	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

APPENDIX B

APPENDIX-B

APPENDIX-B1: Summary Results of Total Organic Carbon (TOC) for 9 Weeks of vermicomposting periods.

C/N Ratio	Reactor	TOC (%)								
		Week								
		0	2	3	4	5	6	7	8	9
20	R1(Control)	26.44	25.02	24.99	24.78	23.55	23.42	21.54	20.89	20.44
	R2 (N=30 earthworms)	26.44	22.72	19.03	17.54	12.05	11.12	10.54	10.44	9.51
	R3(N=40 earthworms)	26.44	21.21	17.44	13.11	10.15	9.32	8.65	8.55	8.23
25	R1(Control)	27.31	26.87	26.68	26.02	25.78	25.41	24.55	23.64	21.41
	R2 (N=30 earthworms)	27.31	23.54	20.88	19.08	17.12	16.43	14.17	13.45	12.74
	R3(N=40 earthworms)	27.31	21.98	19.33	15.84	13.56	12.97	12.08	11.88	11.01
30	R1(Control)	28.44	28.40	27.99	27.46	26.87	26.76	25.67	24.65	24.56
	R2 (N=30 earthworms)	28.44	25.64	22.51	20.16	18.84	17.24	15.22	15.02	13.85
	R3(N=40 earthworms)	28.44	24.89	21.94	19.28	18.45	16.85	14.88	14.02	13.02
35	R1(Control)	28.58	28.53	28.50	27.89	27.77	27.65	27.33	26.91	25.76
	R2 (N=30 earthworms)	28.58	25.07	24.89	22.84	20.75	18.51	17.65	16.15	15.46
	R3(N=40 earthworms)	28.58	23.84	22.12	20.83	19.94	17.26	16.51	15.88	14.56

APPENDIX-B2: Summary Results of Total Kjeldahl Nitrogen (TKN) for 9 Weeks of vermicomposting periods.

C/N Ratio	Reactor	TKN (%)								
		Week								
		0	2	3	4	5	6	7	8	9
20	R1(Control)	1.331	1.376	1.382	1.401	1.419	1.426	1.434	1.462	1.480
	R2 (N=30 earthworms)	1.331	2.165	2.356	2.600	2.874	3.130	3.168	3.172	3.291
	R3(N=40 earthworms)	1.331	2.387	2.583	2.850	3.359	3.413	3.525	3.637	3.790
25	R1(Control)	1.185	1.193	1.222	1.226	1.258	1.269	1.271	1.277	1.298
	R2 (N=30 earthworms)	1.185	1.983	2.007	2.132	2.395	2.537	2.588	2.609	2.642
	R3(N=40 earthworms)	1.185	2.155	2.131	2.322	2.660	3.034	3.122	3.134	3.184
30	R1(Control)	0.968	0.972	1.000	1.037	1.049	1.064	1.086	1.112	1.135
	R2 (N=30 earthworms)	0.968	1.098	1.199	1.221	1.226	1.434	1.572	1.752	1.932
	R3(N=40 earthworms)	0.968	1.097	1.284	1.361	1.487	1.677	1.968	1.978	2.188
35	R1(Control)	0.786	0.790	0.807	0.908	0.923	0.975	1.005	1.014	1.129
	R2 (N=30 earthworms)	0.786	0.878	0.958	1.183	1.194	1.329	1.364	1.370	1.395
	R3(N=40 earthworms)	0.786	0.978	1.098	1.242	1.388	1.484	1.507	1.619	1.651

TP at C/N ratio 20 and TP at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 20	C/N ratio = 35
1.251	0.749
1.602	0.851
1.828	1.020
2.437	1.254
2.704	1.357
2.773	1.454
2.802	1.474
2.819	1.483
2.878	1.493

	Variable 1	*Variable 2*
Mean	2.3438925	1.2371631
Variance	0.3818478	0.0848539
Observations	9	9
Pooled Variance	0.2333508	
Hypothesized Mean Difference	0	
df	16	
t Stat	4.8600758	
P(T<=t) one-tail	8.686E-05	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0001737	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TP at C/N ratio 25 and TP at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 25	C/N ratio = 30
1.121	0.871
1.364	1.003
1.567	1.217
2.119	1.499
2.240	1.598
2.326	1.615
2.354	1.658
2.381	1.666
2.494	1.794

	Variable 1	*Variable 2*
Mean	1.9963904	1.4357082
Variance	0.2572257	0.1058857
Observations	9	9
Pooled Variance	0.1815557	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.7913741	
P(T<=t) one-tail	0.0065359	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0130718	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

APPENDIX –A10: TP at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R3 (N=40 earthworms)

TP at C/N ratio 20 and TP at C/N ratio 25 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 20	C/N ratio = 25
1.251	1.121
1.602	1.364
1.828	1.567
2.437	2.119
2.704	2.240
2.773	2.326
2.802	2.354
2.819	2.381
2.878	2.494

	Variable 1	*Variable 2*
Mean	2.3438925	1.9963904
Variance	0.3818478	0.2572257
Observations	9	9
Pooled Variance	0.3195368	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.3040772	
P(T<=t) one-tail	0.1053286	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.2106572	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TP at C/N ratio 20 and TP at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 20	C/N ratio = 30
1.251	0.871
1.602	1.003
1.828	1.217
2.437	1.499
2.704	1.598
2.773	1.615
2.802	1.658
2.819	1.666
2.878	1.794

	Variable 1	*Variable 2*
Mean	2.3438925	1.4357082
Variance	0.3818478	0.1058857
Observations	9	9
Pooled Variance	0.2438668	
Hypothesized Mean Difference	0	
df	16	
t Stat	3.9012516	
P(T<=t) one-tail	0.0006352	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0012704	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

APPENDIX –A: Statistical Analysis

APPENDIX –A1: TOC in R1 (No earthworms), R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35.

TOC in R1 (No earthworms) compare with TOC in R2 (N=30 earthworms) for C/N ratio 20

TOC (%)	
R1=Control	R2=30 earthworms
26.44	26.44
25.02	22.72
24.99	19.03
24.78	17.54
23.55	12.05
23.42	11.12
21.54	10.54
20.89	10.44
20.44	9.51

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	23.4522	15.4878
Variance	4.3523	38.2007
Observations	9.0000	9.0000
Pooled Variance	21.2765	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	3.6628	
P(T<=t) one-tail	0.0011	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0021	
t Critical two-tail	2.1199	

Since t Stat >2.1199, therefore reject Ho=0, and conclude that there is significant difference between TOC in R1 (No earthworms) and TOC in R2 (N=30 earthworms) of C/N ratio 20 at 5% level of significance.

TOC in R2 (N=30 earthworms) compare with TOC in R3 (N=40 earthworms) for C/N ratio 20

TOC (%)	
R2=30 earthworms	R3=40 earthworms
26.44	26.44
22.72	21.21
19.03	17.44
17.54	13.11
12.05	10.15
11.12	9.32
10.54	8.65
10.44	8.55
9.51	8.23

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	15.4878	13.6778
Variance	38.2007	43.3465
Observations	9.0000	9.0000
Pooled Variance	40.7736	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	0.6013	
P(T<=t) one-tail	0.2780	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.5561	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TOC in R2 (N=30 earthworms) and TOC in R3 (N=40 earthworms) of C/N ratio 20 at 5% level of significance

TOC in R1 (No earthworms) compare with TOC in R2 (N=30 earthworms) for C/N ratio 25

TOC (%)	
R1=Control	R2=30 earthworms
27.31	27.31
26.87	23.54
26.68	20.88
26.02	19.08
25.78	17.12
25.41	16.43
24.55	14.17
23.64	13.45
21.41	12.74

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	25.2967	18.3022
Variance	3.4526	24.0356
Observations	9.0000	9.0000
Pooled Variance	13.7441	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	4.0022	
P(T<=t) one-tail	0.0005	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0010	
t Critical two-tail	2.1199	

Since t Stat >2.1199, therefore reject Ho=0, and conclude that there is significant difference between TOC in R1 (No earthworms) and TOC in R2 (N=30 earthworms) of C/N ratio 25 at 5% level of significance.

TOC in R2 (N=30 earthworms) compare with TOC in R3 (N=40 earthworms) for C/N ratio 25

TOC (%)	
R2=30 earthworms	R3=40 earthworms
27.31	27.31
23.54	21.98
20.88	19.33
19.08	15.84
17.12	13.56
16.43	12.97
14.17	12.08
13.45	11.88
12.74	11.01

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	18.3022	16.2178
Variance	24.0356	30.8424
Observations	9.0000	9.0000
Pooled Variance	27.4390	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	0.8441	
P(T<=t) one-tail	0.2055	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.4110	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TOC in R2 (N=30 earthworms) and TOC in R3 (N=40 earthworms) of C/N ratio 25 at 5% level of significance.

TOC in R1 (No earthworms) compare with TOC in R2 (N=30 earthworms) for C/N ratio 30

TOC (%)	
R1=Control	R2=30 earthworms
28.44	28.44
28.40	25.64
27.99	22.51
27.46	20.16
26.87	18.84
26.76	17.24
25.67	15.22
24.65	15.02
24.56	13.85

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	26.7556	19.6578
Variance	2.2509	25.3437
Observations	9.0000	9.0000
Pooled Variance	13.7973	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	4.0535	
P(T<=t) one-tail	0.0005	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0009	
t Critical two-tail	2.1199	

Since t Stat >2.1199, therefore reject Ho=0, and conclude that there is significant difference between TOC in R1 (No earthworms) and TOC in R2 (N=30 earthworms) of C/N ratio 30 at 5% level of significance.

TOC in R2 (N=30 earthworms) compare with TOC in R3 (N=40 earthworms) for C/N ratio 30

TOC (%)	
R2=30 earthworms	R3=40 earthworms
28.44	28.44
25.64	24.89
22.51	21.94
20.16	19.28
18.84	18.45
17.24	16.85
15.22	14.88
15.02	14.02
13.85	13.02

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	19.6578	19.0856
Variance	25.3437	26.8653
Observations	9.0000	9.0000
Pooled Variance	26.1045	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	0.2376	
P(T<=t) one-tail	0.4076	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.8152	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TOC in R2 (N=30 earthworms) and TOC in R3 (N=40 earthworms) of C/N ratio 30 at 5% level of significance.

TOC in R1 (No earthworms) compare with TOC in R2 (N=30 earthworms) for C/N ratio 35

TOC (%)	
R1=Control	R2=30 earthworms
28.58	28.58
28.53	25.07
28.50	24.89
27.89	22.84
27.77	20.75
27.65	18.51
27.33	17.65
26.91	16.15
25.76	15.46

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	27.6578	21.1000
Variance	0.8319	20.5185
Observations	9.0000	9.0000
Pooled Variance	10.6752	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	4.2577	
P(T<=t) one-tail	0.0003	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0006	
t Critical two-tail	2.1199	

Since t Stat >2.1199, therefore reject Ho=0, and conclude that there is significant difference between TOC in R1 (No earthworms) and TOC in R2 (N=30 earthworms) of C/N ratio 35 at 5% level of significance.

TOC in R2 (N=30 earthworms) compare with TOC in R3 (N=40 earthworms) for C/N ratio 35

TOC (%)	
R2=30 earthworms	R3=40 earthworms
28.58	28.58
25.07	23.84
24.89	22.12
22.84	20.83
20.75	19.94
18.51	17.26
17.65	16.51
16.15	15.88
15.46	14.56

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	21.1000	19.9467
Variance	20.5185	19.9724
Observations	9.0000	9.0000
Pooled Variance	20.2455	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	0.5437	
P(T<=t) one-tail	0.2971	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.5941	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TOC in R2 (N=30 earthworms) and TOC in R3 (N=40 earthworms) of C/N ratio 35 at 5% level of significance.

APPENDIX –A2: TKN in R1 (No earthworms), R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35.

TKN in R1 (No earthworms) compare with TKN in R2 (N=30 earthworms) for C/N ratio 20

TKN (%)	
R1=Control	R2=30 earthworms
1.331	1.331
1.376	2.165
1.382	2.356
1.401	2.600
1.419	2.874
1.426	3.130
1.434	3.168
1.462	3.172
1.480	3.291

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.4125	2.6762
Variance	0.0021	0.4113
Observations	9.0000	9.0000
Pooled Variance	0.2067	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-5.8968	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0000	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TKN in R1 (No earthworms) and TKN in R2 (N=30 earthworms) of C/N ratio 20 at 5% level of significance.

TKN in R2 (N=30 earthworms) compare with TKN in R3 (N=40 earthworms) for C/N ratio 20

TKN (%)	
R2=30 earthworms	R3=40 earthworms
1.331	1.331
2.165	2.387
2.356	2.583
2.600	2.850
2.874	3.359
3.130	3.413
3.168	3.525
3.172	3.637
3.291	3.790

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	2.6762	2.9861
Variance	0.4113	0.6202
Observations	9.0000	9.0000
Pooled Variance	0.5157	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-0.9154	
P(T<=t) one-tail	0.1868	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.3736	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TKN in R2 (N=30 earthworms) and TKN in R3 (N=40 earthworms) of C/N ratio 20 at 5% level of significance.

TKN in R1 (No earthworms) compare with TKN in R2 (N=30 earthworms) for C/N ratio 25

TKN (%)	
R1=Control	R2=30 earthworms
1.185	1.185
1.193	1.983
1.222	2.007
1.226	2.132
1.258	2.395
1.269	2.537
1.271	2.588
1.277	2.609
1.298	2.642

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.2444	2.2309
Variance	0.0016	0.2219
Observations	9.0000	9.0000
Pooled Variance	0.1117	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-6.2601	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0000	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TKN in R1 (No earthworms) and TKN in R2 (N=30 earthworms) of C/N ratio 25 at 5% level of significance.

TKN in R2 (N=30 earthworms) compare with TKN in R3 (N=40 earthworms) for C/N ratio 25

TKN (%)	
R2=30 earthworms	R3=40 earthworms
1.185	1.185
1.983	2.155
2.007	2.131
2.132	2.322
2.395	2.660
2.537	3.034
2.588	3.122
2.609	3.134
2.642	3.184

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	2.2309	2.5474
Variance	0.2219	0.4455
Observations	9.0000	9.0000
Pooled Variance	0.3337	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.1624	
P(T<=t) one-tail	0.1311	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.2621	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TKN in R2 (N=30 earthworms) and TKN in R3 (N=40 earthworms) of C/N ratio 25 at 5% level of significance.

TKN in R1 (No earthworms) compare with TKN in R2 (N=30 earthworms) for C/N ratio 30

TKN (%)	
R1=Control	R2=30 earthworms
0.968	0.968
0.972	1.098
1.000	1.199
1.037	1.221
1.049	1.226
1.064	1.434
1.086	1.572
1.112	1.752
1.135	1.932

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.0467	1.3779
Variance	0.0035	0.1016
Observations	9.0000	9.0000
Pooled Variance	0.0526	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-3.0643	
P(T<=t) one-tail	0.0037	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0074	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TKN in R1 (No earthworms) and TKN in R2 (N=30 earthworms) of C/N ratio 30 at 5% level of significance.

TKN in R2 (N=30 earthworms) compare with TKN in R3 (N=40 earthworms) for C/N ratio 30

TKN (%)	
R2=30 earthworms	R3=40 earthworms
0.968	0.968
1.098	1.097
1.199	1.284
1.221	1.361
1.226	1.487
1.434	1.677
1.572	1.968
1.752	1.978
1.932	2.188

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.3779	1.5563
Variance	0.1016	0.1794
Observations	9.0000	9.0000
Pooled Variance	0.1405	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.0100	
P(T<=t) one-tail	0.1638	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.3275	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TKN in R2 (N=30 earthworms) and TKN in R3 (N=40 earthworms) of C/N ratio 30 at 5% level of significance.

TKN in R1 (No earthworms) compare with TKN in R2 (N=30 earthworms) for C/N ratio 35

TKN (%)	
R1=Control	R2=30 earthworms
0.786	0.786
0.790	0.878
0.807	0.958
0.908	1.183
0.923	1.194
0.975	1.329
1.005	1.364
1.014	1.370
1.129	1.395

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.9263	1.1621
Variance	0.0138	0.0539
Observations	9.0000	9.0000
Pooled Variance	0.0338	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-2.7186	
P(T<=t) one-tail	0.0076	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0152	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TKN in R1 (No earthworms) and TKN in R2 (N=30 earthworms) of C/N ratio 35 at 5% level of significance.

TKN in R2 (N=30 earthworms) compare with TKN in R3 (N=40 earthworms) for C/N ratio 35

TKN (%)	
R2=30 earthworms	R3=40 earthworms
0.786	0.786
0.878	0.978
0.958	1.098
1.183	1.242
1.194	1.388
1.329	1.484
1.364	1.507
1.370	1.619
1.395	1.651

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.1621	1.3060
Variance	0.0539	0.0901
Observations	9.0000	9.0000
Pooled Variance	0.0720	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.1375	
P(T<=t) one-tail	0.1360	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.2721	
t Critical two-tail	2.1199	

Since $-2.1199 < t$ Stat < 2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TKN in R2 (N=30 earthworms) and TKN in R3 (N=40 earthworms) of C/N ratio 35 at 5% level of significance.

APPENDIX –A3: TP in R1 (No earthworms), R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35.

TP in R1 (No earthworms) compare with TP in R2 (N=30 earthworms) for C/N ratio 20

TP(%)	
R1=Control	R2=30 earthworms
1.251	1.251
1.263	1.504
1.268	1.661
1.280	2.105
1.297	2.313
1.307	2.334
1.339	2.390
1.359	2.395
1.390	2.491

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.3060	2.0494
Variance	0.0022	0.2087
Observations	9.0000	9.0000
Pooled Variance	0.1055	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-4.8554	
P(T<=t) one-tail	0.0001	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0002	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TP in R1 (No earthworms) and TP in R2 (N=30 earthworms) of C/N ratio 20 at 5% level of significance.

TP in R2 (N=30 earthworms) compare with TP in R3 (N=40 earthworms) for C/N ratio 20

TP(%)	
R2=30 earthworms	R3=40 earthworms
1.251	1.251
1.504	1.602
1.661	1.828
2.105	2.437
2.313	2.704
2.334	2.773
2.390	2.802
2.395	2.819
2.491	2.878

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	2.0494	2.3439
Variance	0.2087	0.3818
Observations	9.0000	9.0000
Pooled Variance	0.2953	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.1496	
P(T<=t) one-tail	0.1336	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.2672	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TP in R2 (N=30 earthworms) and TP in R3 (N=40 earthworms) of C/N ratio 20 at 5% level of significance.

TP in R1 (No earthworms) compare with TP in R2 (N=30 earthworms) for C/N ratio 25

TP(%)	
R1=Control	R2=30 earthworms
1.121	1.121
1.165	1.324
1.084	1.441
1.092	1.773
1.102	1.907
1.094	1.923
1.114	1.968
1.170	1.992
1.205	2.108

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.1275	1.7285
Variance	0.0018	0.1195
Observations	9.0000	9.0000
Pooled Variance	0.0607	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-5.1759	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0001	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TP in R1 (No earthworms) and TP in R2 (N=30 earthworms) of C/N ratio 25 at 5% level of significance.

TP in R2 (N=30 earthworms) compare with TP in R3 (N=40 earthworms) for C/N ratio 25

TP(%)	
R2=30 earthworms	R3=40 earthworms
1.121	1.121
1.324	1.364
1.441	1.567
1.773	2.119
1.907	2.240
1.923	2.326
1.968	2.354
1.992	2.381
2.108	2.494

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.7285	1.9964
Variance	0.1195	0.2572
Observations	9.0000	9.0000
Pooled Variance	0.1884	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.3094	
P(T<=t) one-tail	0.1044	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.2089	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TP in R2 (N=30 earthworms) and TP in R3 (N=40 earthworms) of C/N ratio 25 at 5% level of significance.

TP in R1 (No earthworms) compare with TP in R2 (N=30 earthworms) for C/N ratio 30

TP (%)	
R1=Control	R2=30 earthworms
0.871	0.871
0.889	0.988
0.904	1.092
1.044	1.284
1.085	1.440
1.095	1.501
1.098	1.549
1.121	1.553
1.152	1.602

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.0287	1.3200
Variance	0.0120	0.0748
Observations	9.0000	9.0000
Pooled Variance	0.0434	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-2.9654	
P(T<=t) one-tail	0.0046	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0091	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TP in R1 (No earthworms) and TP in R2 (N=30 earthworms) of C/N ratio 30 at 5% level of significance.

TP in R2 (N=30 earthworms) compare with TP in R3 (N=40 earthworms) for C/N ratio 30

TP (%)	
R2=30 earthworms	R3=40 earthworms
0.871	0.871
0.988	1.003
1.092	1.217
1.284	1.499
1.440	1.598
1.501	1.615
1.549	1.658
1.553	1.666
1.602	1.794

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.3200	1.4357
Variance	0.0748	0.1059
Observations	9.0000	9.0000
Pooled Variance	0.0904	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-0.8167	
P(T<=t) one-tail	0.2130	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.4261	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TP in R2 (N=30 earthworms) and TP in R3 (N=40 earthworms) of C/N ratio 30 at 5% level of significance.

TP in R1 (No earthworms) compare with TP in R2 (N=30 earthworms) for C/N ratio 35

TP (%)	
R1=Control	R2=30 earthworms
0.749	0.749
0.752	0.833
0.773	0.913
0.798	1.143
0.814	1.166
0.845	1.178
0.866	1.206
0.882	1.280
0.891	1.293

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.8190	1.0847
Variance	0.0030	0.0401
Observations	9.0000	9.0000
Pooled Variance	0.0215	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-3.8394	
P(T<=t) one-tail	0.0007	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0014	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between TP in R1 (No earthworms) and TP in R2 (N=30 earthworms) of C/N ratio 35 at 5% level of significance.

TP in R2 (N=30 earthworms) compare with TP in R3 (N=40 earthworms) for C/N ratio 35

TP (%)	
R2=30 earthworms	R3=40 earthworms
0.749	0.749
0.833	0.851
0.913	1.020
1.143	1.254
1.166	1.357
1.178	1.454
1.206	1.474
1.280	1.483
1.293	1.493

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	1.0847	1.2372
Variance	0.0401	0.0849
Observations	9.0000	9.0000
Pooled Variance	0.0625	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.2944	
P(T<=t) one-tail	0.1070	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.2139	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between TP in R2 (N=30 earthworms) and TP in R3 (N=40 earthworms) of C/N ratio 35 at 5% level of significance.

APPENDIX –A4: Potassium in R1 (No earthworms), R2 (N=30 earthworms) and R3 (N=40 earthworms) for C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35.

Potassium in R1 (No earthworms) compare with Potassium in R2 (N=30 earthworms) for C/N ratio 20

Potassium (%)	
R1	R2
0.262	0.262
0.268	0.298
0.272	0.342
0.292	0.365
0.301	0.401
0.307	0.443
0.312	0.585
0.319	0.590
0.323	0.662

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.2952	0.4386
Variance	0.0005	0.0202
Observations	9.0000	9.0000
Pooled Variance	0.0104	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-2.9894	
P(T<=t) one-tail	0.0043	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0087	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between Potassium in R1 (No earthworms) and Potassium in R2 (N=30 earthworms) of C/N ratio 20 at 5% level of significance.

Potassium in R2 (N=30 earthworms) compare with Potassium in R3 (N=40 earthworms) for C/N ratio 20

Potassium (%)	
R2	R3
0.262	0.262
0.298	0.321
0.342	0.398
0.365	0.438
0.401	0.481
0.443	0.499
0.585	0.634
0.590	0.636
0.662	0.767

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.4386	0.4928
Variance	0.0202	0.0263
Observations	9.0000	9.0000
Pooled Variance	0.0232	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-0.7543	
P(T<=t) one-tail	0.2308	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.4616	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between Potassium in R2 (N=30 earthworms) and Potassium in R3 (N=40 earthworms) of C/N ratio 20 at 5% level of significance.

Potassium in R1 (No earthworms) compare with Potassium in R2 (N=30 earthworms) for C/N ratio 25

Potassium (%)	
R1=Control	R2=30 earthworms
0.243	0.243
0.247	0.250
0.249	0.268
0.253	0.291
0.257	0.319
0.259	0.325
0.268	0.390
0.272	0.432
0.279	0.484

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.2585	0.3336
Variance	0.0002	0.0071
Observations	9.0000	9.0000
Pooled Variance	0.0036	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-2.6399	
P(T<=t) one-tail	0.0089	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0178	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between Potassium in R1 (No earthworms) and Potassium in R2 (N=30 earthworms) of C/N ratio 25 at 5% level of significance.

Potassium in R2 (N=30 earthworms) compare with Potassium in R3 (N=40 earthworms) for C/N ratio 25

Potassium (%)	
R2=30 earthworms	R3=40 earthworms
0.243	0.243
0.250	0.284
0.268	0.338
0.291	0.366
0.319	0.397
0.325	0.430
0.390	0.595
0.432	0.615
0.484	0.663

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.3336	0.4367
Variance	0.0071	0.0232
Observations	9.0000	9.0000
Pooled Variance	0.0151	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.7776	
P(T<=t) one-tail	0.0472	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0945	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between Potassium in R2 (N=30 earthworms) and Potassium in R3 (N=40 earthworms) of C/N ratio 25 at 5% level of significance.

Potassium in R1 (No earthworms) compare with Potassium in R2 (N=30 earthworms) for C/N ratio 30

Potassium (%)	
R1=Control	R2=30 earthworms
0.222	0.222
0.225	0.243
0.229	0.266
0.230	0.275
0.238	0.288
0.239	0.300
0.240	0.306
0.243	0.313
0.254	0.411

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.2357	0.2917
Variance	0.0001	0.0029
Observations	9.0000	9.0000
Pooled Variance	0.0015	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-3.0750	
P(T<=t) one-tail	0.0036	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0072	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between Potassium in R1 (No earthworms) and Potassium in R2 (N=30 earthworms) of C/N ratio 30 at 5% level of significance.

Potassium in R2 (N=30 earthworms) compare with Potassium in R3 (N=40 earthworms) for C/N ratio 30

Potassium (%)	
R2=30 earthworms	R3=40 earthworms
0.222	0.222
0.243	0.249
0.266	0.284
0.275	0.297
0.288	0.315
0.300	0.388
0.306	0.418
0.313	0.425
0.411	0.473

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.2917	0.3413
Variance	0.0029	0.0076
Observations	9.0000	9.0000
Pooled Variance	0.0053	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-1.4521	
P(T<=t) one-tail	0.0829	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.1658	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between Potassium in R2 (N=30 earthworms) and Potassium in R3 (N=40 earthworms) of C/N ratio 30 at 5% level of significance.

Potassium in R1 (No earthworms) compare with Potassium in R2 (N=30 earthworms) for C/N ratio 35

Potassium (%)	
R1=Control	R2=30 earthworms
0.164	0.164
0.166	0.169
0.168	0.178
0.170	0.203
0.174	0.212
0.177	0.239
0.180	0.249
0.194	0.279
0.196	0.292

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.1766	0.2207
Variance	0.0001	0.0022
Observations	9.0000	9.0000
Pooled Variance	0.0012	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-2.7175	
P(T<=t) one-tail	0.0076	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.0152	
t Critical two-tail	2.1199	

Since t Stat < -2.1199, therefore reject Ho=0, and conclude that there is significant difference between Potassium in R1 (No earthworms) and Potassium in R2 (N=30 earthworms) of C/N ratio 35 at 5% level of significance.

Potassium in R2 (N=30 earthworms) compare with Potassium in R3 (N=40 earthworms) for C/N ratio 35

Potassium (%)	
R2=30 earthworms	R3=40 earthworms
0.164	0.164
0.169	0.182
0.178	0.203
0.203	0.210
0.212	0.224
0.239	0.265
0.249	0.301
0.279	0.313
0.292	0.337

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.2207	0.2444
Variance	0.0022	0.0038
Observations	9.0000	9.0000
Pooled Variance	0.0030	
Hypothesized Mean Difference	0.0000	
df	16.0000	
t Stat	-0.9151	
P(T<=t) one-tail	0.1869	
t Critical one-tail	1.7459	
P(T<=t) two-tail	0.3737	
t Critical two-tail	2.1199	

Since -2.1199<t Stat <2.1199, therefore accept Ho=0, and conclude that there is NO significant difference between Potassium in R2 (N=30 earthworms) and Potassium in R3 (N=40 earthworms) of C/N ratio 35 at 5% level of significance.

APPENDIX –A5: TOC at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R2 (N=30 earthworms)

TOC at C/N ratio 20 and TOC at C/N ratio 25 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 20	C/N ratio = 25
26.44	27.31
22.72	23.54
19.03	20.88
17.54	19.08
12.05	17.12
11.12	16.43
10.54	14.17
10.44	13.45
9.51	12.74

	Variable 1	*Variable 2*
Mean	15.487778	18.302222
Variance	38.200669	24.035594
Observations	9	9
Pooled Variance	31.118132	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.070267	
P(T<=t) one-tail	0.1501898	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.3003795	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 20 and TOC at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 20	C/N ratio = 30
26.44	28.44
22.72	25.64
19.03	22.51
17.54	20.16
12.05	18.84
11.12	17.24
10.54	15.22
10.44	15.02
9.51	13.85

	Variable 1	*Variable 2*
Mean	15.487778	19.657778
Variance	38.200669	25.343669
Observations	9	9
Pooled Variance	31.772169	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.569347	
P(T<=t) one-tail	0.0680651	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.1361301	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 20 and TOC at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 20	C/N ratio = 35
27.31	28.58
26.87	25.07
26.68	24.89
26.02	22.84
25.78	20.75
25.41	18.51
24.55	17.65
23.64	16.15
21.41	15.46

	Variable 1	*Variable 2*
Mean	25.296667	21.1
Variance	3.45255	20.518525
Observations	9	9
Pooled Variance	11.985538	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.571473	
P(T<=t) one-tail	0.0102465	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.020493	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TOC at C/N ratio 25 and TOC at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 25	C/N ratio = 30
27.31	28.44
23.54	25.64
20.88	22.51
19.08	20.16
17.12	18.84
16.43	17.24
14.17	15.22
13.45	15.02
12.74	13.85

	Variable 1	*Variable 2*
Mean	18.302222	19.657778
Variance	24.035594	25.343669
Observations	9	9
Pooled Variance	24.689632	
Hypothesized Mean Difference	0	
df	16	
t Stat	-0.578717	
P(T<=t) one-tail	0.2854189	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.5708377	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 25 and TOC at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 25	C/N ratio = 35
27.31	28.58
23.54	25.07
20.88	24.89
19.08	22.84
17.12	20.75
16.43	18.51
14.17	17.65
13.45	16.15
12.74	15.46

	Variable 1	*Variable 2*
Mean	18.302222	21.1
Variance	24.035594	20.518525
Observations	9	9
Pooled Variance	22.27706	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.257449	
P(T<=t) one-tail	0.1133179	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.2266358	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 30 and TOC at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 30	C/N ratio = 35
28.44	28.58
25.64	25.07
22.51	24.89
20.16	22.84
18.84	20.75
17.24	18.51
15.22	17.65
15.02	16.15
13.85	15.46

	Variable 1	*Variable 2*
Mean	19.657778	21.1
Variance	25.343669	20.518525
Observations	9	9
Pooled Variance	22.931097	
Hypothesized Mean Difference	0	
df	16	
t Stat	-0.63889	
P(T<=t) one-tail	0.2659674	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.5319348	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

APPENDIX –A6: TOC at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R3 (N=40 earthworms)

TOC at C/N ratio 20 and TOC at C/N ratio 25 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 20	C/N ratio = 25
26.44	27.31
21.21	21.98
17.44	19.33
13.11	15.84
10.15	13.56
9.32	12.97
8.65	12.08
8.55	11.88
8.23	11.01

	Variable 1	*Variable 2*
Mean	13.677778	16.217778
Variance	43.346469	30.842444
Observations	9	9
Pooled Variance	37.094457	
Hypothesized Mean Difference	0	
df	16	
t Stat	-0.884678	
P(T<=t) one-tail	0.1947157	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.3894315	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 20 and TOC at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 20	C/N ratio = 30
27.31	28.44
21.98	24.89
19.33	21.94
15.84	19.28
13.56	18.45
12.97	16.85
12.08	14.88
11.88	14.02
11.01	13.02

	Variable 1	*Variable 2*
Mean	16.217778	19.085556
Variance	30.842444	26.865253
Observations	9	9
Pooled Variance	28.853849	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.13253	
P(T<=t) one-tail	0.1370494	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.2740989	
t Critical two-tail	2.1199053	

TOC at C/N ratio 20 and TOC at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 20	C/N ratio = 35
27.31	28.58
21.98	23.84
19.33	22.12
15.84	20.83
13.56	19.94
12.97	17.26
12.08	16.51
11.88	15.88
11.01	14.56

	Variable 1	*Variable 2*
Mean	16.217778	19.946667
Variance	30.842444	19.972375
Observations	9	9
Pooled Variance	25.40741	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.569298	
P(T<=t) one-tail	0.0680707	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.1361414	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 25 and TOC at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 25	C/N ratio = 30
27.31	28.44
21.98	24.89
19.33	21.94
15.84	19.28
13.56	18.45
12.97	16.85
12.08	14.88
11.88	14.02
11.01	13.02

	Variable 1	*Variable 2*
Mean	16.217778	19.085556
Variance	30.842444	26.865253
Observations	9	9
Pooled Variance	28.853849	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.13253	
P(T<=t) one-tail	0.1370494	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.2740989	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 25 and TOC at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 25	C/N ratio = 35
27.31	28.58
21.98	23.84
19.33	22.12
15.84	20.83
13.56	19.94
12.97	17.26
12.08	16.51
11.88	15.88
11.01	14.56

	Variable 1	*Variable 2*
Mean	16.217778	19.946667
Variance	30.842444	19.972375
Observations	9	9
Pooled Variance	25.40741	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.569298	
P(T<=t) one-tail	0.0680707	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.1361414	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TOC at C/N ratio 30 and TOC at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TOC (%)	
C/N ratio = 30	C/N ratio = 35
28.44	28.58
24.89	23.84
21.94	22.12
19.28	20.83
18.45	19.94
16.85	17.26
14.88	16.51
14.02	15.88
13.02	14.56

	Variable 1	*Variable 2*
Mean	19.085556	19.946667
Variance	26.865253	19.972375
Observations	9	9
Pooled Variance	23.418814	
Hypothesized Mean Difference	0	
df	16	
t Stat	-0.37747	
P(T<=t) one-tail	0.3553921	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.7107842	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

APPENDIX –A7: TKN at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R2 (N=30 earthworms)

TKN at C/N ratio 20 and TKN at C/N ratio 25 for R2 (N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 20	C/N ratio = 25
1.331	1.185
2.165	1.983
2.356	2.007
2.600	2.132
2.874	2.395
3.130	2.537
3.168	2.588
3.172	2.609
3.291	2.642

	Variable 1	*Variable 2*
Mean	2.6762144	2.230889
Variance	0.4112526	0.2219183
Observations	9	9
Pooled Variance	0.3165855	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.6789516	
P(T<=t) one-tail	0.0562904	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.1125809	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TKN at C/N ratio 20 and TKN at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 20	C/N ratio = 30
1.331	0.968
2.165	1.098
2.356	1.199
2.600	1.221
2.874	1.226
3.130	1.434
3.168	1.572
3.172	1.752
3.291	1.932

	Variable 1	*Variable 2*
Mean	2.6762144	1.3778805
Variance	0.4112526	0.1016492
Observations	9	9
Pooled Variance	0.2564509	
Hypothesized Mean Difference	0	
df	16	
t Stat	5.4386427	
P(T<=t) one-tail	2.732E-05	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	5.465E-05	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 20 and TKN at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 20	C/N ratio = 35
1.331	0.786
2.165	0.878
2.356	0.958
2.600	1.183
2.874	1.194
3.130	1.329
3.168	1.364
3.172	1.370
3.291	1.395

	Variable 1	*Variable 2*
Mean	2.6762144	1.1620887
Variance	0.4112526	0.0539174
Observations	9	9
Pooled Variance	0.232585	
Hypothesized Mean Difference	0	
df	16	
t Stat	6.660047	
P(T<=t) one-tail	2.74E-06	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	5.48E-06	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 25 and TKN at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 25	C/N ratio = 30
1.185	0.968
1.983	1.098
2.007	1.199
2.132	1.221
2.395	1.226
2.537	1.434
2.588	1.572
2.609	1.752
2.642	1.932

	Variable 1	*Variable 2*
Mean	2.230889	1.3778805
Variance	0.2219183	0.1016492
Observations	9	9
Pooled Variance	0.1617838	
Hypothesized Mean Difference	0	
df	16	
t Stat	4.4987531	
P(T<=t) one-tail	0.0001822	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0003645	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 25 and TKN at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 25	C/N ratio = 35
1.185	0.786
1.983	0.878
2.007	0.958
2.132	1.183
2.395	1.194
2.537	1.329
2.588	1.364
2.609	1.370
2.642	1.395

	Variable 1	*Variable 2*
Mean	2.230889	1.1620887
Variance	0.2219183	0.0539174
Observations	9	9
Pooled Variance	0.1379179	
Hypothesized Mean Difference	0	
df	16	
t Stat	6.1050964	
P(T<=t) one-tail	7.598E-06	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	1.52E-05	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 30 and TKN at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 30	C/N ratio = 35
0.968	0.786
1.098	0.878
1.199	0.958
1.221	1.183
1.226	1.194
1.434	1.329
1.572	1.364
1.752	1.370
1.932	1.395

	Variable 1	*Variable 2*
Mean	1.3778805	1.132915
Variance	0.1016492	0.0528657
Observations	9	8
Pooled Variance	0.0788835	
Hypothesized Mean Difference	0	
df	15	
t Stat	1.7949552	
P(T<=t) one-tail	0.0464168	
t Critical one-tail	1.7530503	
P(T<=t) two-tail	0.0928335	
t Critical two-tail	2.1314495	

No significant difference at 5% level of difference

APPENDIX –A8: TKN at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R3 (N=40 earthworms)

TKN at C/N ratio 20 and TKN at C/N ratio 25 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 20	C/N ratio = 25
1.331	1.185
2.387	2.155
2.583	2.131
2.850	2.322
3.359	2.660
3.413	3.034
3.525	3.122
3.637	3.134
3.790	3.184

	Variable 1	*Variable 2*
Mean	2.9861039	2.5474434
Variance	0.6201825	0.4455069
Observations	9	9
Pooled Variance	0.5328447	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.2747776	
P(T<=t) one-tail	0.1102951	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.2205902	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TKN at C/N ratio 20 and TKN at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 20	C/N ratio = 30
1.331	0.968
2.387	1.097
2.583	1.284
2.850	1.361
3.359	1.487
3.413	1.677
3.525	1.968
3.637	1.978
3.790	2.188

	Variable 1	*Variable 2*
Mean	2.9861039	1.556348
Variance	0.6201825	0.1793545
Observations	9	9
Pooled Variance	0.3997685	
Hypothesized Mean Difference	0	
df	16	
t Stat	4.7969351	
P(T<=t) one-tail	9.878E-05	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0001976	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 20 and TKN at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 20	C/N ratio = 35
1.331	0.786
2.387	0.978
2.583	1.098
2.850	1.242
3.359	1.388
3.413	1.484
3.525	1.507
3.637	1.619
3.790	1.651

	Variable 1	*Variable 2*
Mean	2.9861039	1.3059694
Variance	0.6201825	0.0900696
Observations	9	9
Pooled Variance	0.3551261	
Hypothesized Mean Difference	0	
df	16	
t Stat	5.9807965	
P(T<=t) one-tail	9.604E-06	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	1.921E-05	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 25 and TKN at C/N ratio 30 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 25	C/N ratio = 30
1.185	0.968
2.155	1.097
2.131	1.284
2.322	1.361
2.660	1.487
3.034	1.677
3.122	1.968
3.134	1.978
3.184	2.188

	Variable 1	*Variable 2*
Mean	2.5474434	1.556348
Variance	0.4455069	0.1793545
Observations	9	9
Pooled Variance	0.3124307	
Hypothesized Mean Difference	0	
df	16	
t Stat	3.7613594	
P(T<=t) one-tail	0.0008532	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0017064	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 25 and TKN at C/N ratio 35 for R3(N=40 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 25	C/N ratio = 35
1.185	0.786
2.155	0.978
2.131	1.098
2.322	1.242
2.660	1.388
3.034	1.484
3.122	1.507
3.134	1.619
3.184	1.651

	Variable 1	*Variable 2*
Mean	2.5474434	1.3059694
Variance	0.4455069	0.0900696
Observations	9	9
Pooled Variance	0.2677883	
Hypothesized Mean Difference	0	
df	16	
t Stat	5.0891836	
P(T<=t) one-tail	5.469E-05	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0001094	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TKN at C/N ratio 30 and TKN at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TKN (%)	
C/N ratio = 30	C/N ratio = 35
0.968	0.786
1.097	0.978
1.284	1.098
1.361	1.242
1.487	1.388
1.677	1.484
1.968	1.507
1.978	1.619
2.188	1.651

	Variable 1	*Variable 2*
Mean	1.556348	1.3059694
Variance	0.1793545	0.0900696
Observations	9	9
Pooled Variance	0.1347121	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.447106	
P(T<=t) one-tail	0.0835879	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.1671757	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

APPENDIX –A9: TP at C/N ratio 20, C/N ratio 25, C/N ratio 30 and C/N ratio 35 for R2 (N=30 earthworms)

TP at C/N ratio 20 and TP at C/N ratio 25 for R2 (N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 20	C/N ratio = 25
1.251	1.121
1.504	1.324
1.661	1.441
2.105	1.773
2.313	1.907
2.334	1.923
2.390	1.968
2.395	1.992
2.491	2.108

	Variable 1	*Variable 2*
Mean	2.0493998	1.7284683
Variance	0.208734	0.1195494
Observations	9	9
Pooled Variance	0.1641417	
Hypothesized Mean Difference	0	
df	16	
t Stat	1.6803867	
P(T<=t) one-tail	0.0561487	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.1122974	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

TP at C/N ratio 20 and TP at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 20	C/N ratio = 30
1.251	0.871
1.504	0.988
1.661	1.092
2.105	1.284
2.313	1.440
2.334	1.501
2.390	1.549
2.395	1.553
2.491	1.602

	Variable 1	*Variable 2*
Mean	2.0493998	1.3199852
Variance	0.208734	0.0748144
Observations	9	9
Pooled Variance	0.1417742	
Hypothesized Mean Difference	0	
df	16	
t Stat	4.1094351	
P(T<=t) one-tail	0.0004101	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0008202	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TP at C/N ratio 20 and TP at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 20	C/N ratio = 35
1.251	0.749
1.504	0.833
1.661	0.913
2.105	1.143
2.313	1.166
2.334	1.178
2.390	1.206
2.395	1.280
2.491	1.293

	Variable 1	*Variable 2*
Mean	2.0493998	1.0846603
Variance	0.208734	0.0400766
Observations	9	9
Pooled Variance	0.1244053	
Hypothesized Mean Difference	0	
df	16	
t Stat	5.8022569	
P(T<=t) one-tail	1.349E-05	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	2.699E-05	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TP at C/N ratio 25 and TP at C/N ratio 30 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 25	C/N ratio = 30
1.121	0.871
1.324	0.988
1.441	1.092
1.773	1.284
1.907	1.440
1.923	1.501
1.968	1.549
1.992	1.553
2.108	1.602

	Variable 1	*Variable 2*
Mean	1.7284683	1.3199852
Variance	0.1195494	0.0748144
Observations	9	9
Pooled Variance	0.0971819	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.7796339	
P(T<=t) one-tail	0.006696	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.013392	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TP at C/N ratio 25 and TP at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 25	C/N ratio = 35
1.121	0.749
1.324	0.833
1.441	0.913
1.773	1.143
1.907	1.166
1.923	1.178
1.968	1.206
1.992	1.280
2.108	1.293

	Variable 1	*Variable 2*
Mean	1.7284683	1.0846603
Variance	0.1195494	0.0400766
Observations	9	9
Pooled Variance	0.079813	
Hypothesized Mean Difference	0	
df	16	
t Stat	4.8342138	
P(T<=t) one-tail	9.156E-05	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0001831	
t Critical two-tail	2.1199053	

Significant difference at 5% level of difference

TP at C/N ratio 30 and TP at C/N ratio 35 for R2(N=30 earthworms)

t-Test: Two-Sample Assuming Equal Variances

TP (%)	
C/N ratio = 30	C/N ratio = 35
0.871	0.749
0.988	0.833
1.092	0.913
1.284	1.143
1.440	1.166
1.501	1.178
1.549	1.206
1.553	1.280
1.602	1.293

	Variable 1	*Variable 2*
Mean	1.3199852	1.0846603
Variance	0.0748144	0.0400766
Observations	9	9
Pooled Variance	0.0574455	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.0827931	
P(T<=t) one-tail	0.0268367	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0536734	
t Critical two-tail	2.1199053	

No significant difference at 5% level of difference

APPENDIX-B3: Volume titrated for every week

week 0

C/N	Reactor	weight of sample (g)	volume titrated (mL)	[illegible]	TKN (%)
20	R1(Control)	0.3003	15.030	0.759	1.331
	R2 (N=30 worms)				
	R3(N=40worms)				
25	R1(Control)	0.3007	13.485	0.759	1.185
	R2 (N=30 worms)				
	R3(N=40worms)				
30	R1(Control)	0.3026	11.217	0.759	0.968
	R2 (N=30 worms)				
	R3(N=40worms)				
35	R1(Control)	0.3001	9.186	0.759	0.786
	R2 (N=30 worms)				
	R3(N=40worms)				

week 2

C/N	Reactor	weight of sample (g)	volume titrated (mL)	Molarity (M)	TKN (%)
20	R1(Control)	0.5919	29.850	0.759	1.376
	R2 (N=30 worms)	0.5287	41.641	0.759	2.165
	R3(N=40worms)	0.4998	43.375	0.759	2.387
25	R1(Control)	0.5588	24.564	0.759	1.193
	R2 (N=30 worms)	0.5053	36.543	0.759	1.983
	R3(N=40worms)	0.5921	46.334	0.759	2.155
30	R1(Control)	0.5446	19.657	0.759	0.972
	R2 (N=30 worms)	0.5584	22.654	0.759	1.098
	R3(N=40worms)	0.5790	23.451	0.759	1.097
35	R1(Control)	0.5475	16.201	0.759	0.790
	R2 (N=30 worms)	0.5463	17.887	0.759	0.878
	R3(N=40worms)	0.5695	20.654	0.759	0.978

week 3

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5651	28.652	0.759	1.382
	R2 (N=30 worms)	0.5335	45.651	0.759	2.356
	R3(N=40worms)	0.5346	50.078	0.759	2.583
25	R1(Control)	0.5347	24.103	0.759	1.222
	R2 (N=30 worms)	0.5342	39.054	0.759	2.007
	R3(N=40worms)	0.5423	42.029	0.759	2.131
30	R1(Control)	0.5637	20.894	0.759	1.000
	R2 (N=30 worms)	0.5768	25.465	0.759	1.199
	R3(N=40worms)	0.5581	26.345	0.759	1.284
35	R1(Control)	0.5524	16.678	0.759	0.807
	R2 (N=30 worms)	0.5519	19.651	0.759	0.958
	R3(N=40worms)	0.5121	20.845	0.759	1.098

week 4

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5844	29.998	0.759	1.401
	R2 (N=30 worms)	0.5599	52.741	0.759	2.600
	R3(N=40worms)	0.5481	56.547	0.759	2.850
25	R1(Control)	0.5687	25.659	0.759	1.226
	R2 (N=30 worms)	0.5491	42.569	0.759	2.132
	R3(N=40worms)	0.5534	46.648	0.759	2.322
30	R1(Control)	0.5889	22.564	0.759	1.037
	R2 (N=30 worms)	0.5359	24.128	0.759	1.221
	R3(N=40worms)	0.5738	28.654	0.759	1.361
35	R1(Control)	0.5821	19.645	0.759	0.908
	R2 (N=30 worms)	0.5652	24.642	0.759	1.183
	R3(N=40worms)	0.5768	26.345	0.759	1.242

week 5

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5268	27.461	0.759	1.419
	R2 (N=30 worms)	0.5568	57.915	0.759	2.874
	R3(N=40worms)	0.5684	68.942	0.759	3.359
25	R1(Control)	0.5324	24.687	0.759	1.258
	R2 (N=30 worms)	0.5764	50.064	0.759	2.395
	R3(N=40worms)	0.5612	54.064	0.759	2.660
30	R1(Control)	0.5432	21.102	0.759	1.049
	R2 (N=30 worms)	0.5462	24.678	0.759	1.226
	R3(N=40worms)	0.5589	30.443	0.759	1.487
35	R1(Control)	0.5384	18.502	0.759	0.923
	R2 (N=30 worms)	0.5581	24.567	0.759	1.194
	R3(N=40worms)	0.5694	28.987	0.759	1.388

week 6

C/N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5346	27.994	0.759	1.426
	R2 (N=30 worms)	0.5231	59.230	0.759	3.130
	R3(N=40worms)	0.5563	68.564	0.759	3.413
25	R1(Control)	0.5347	24.987	0.759	1.269
	R2 (N=30 worms)	0.5461	50.236	0.759	2.537
	R3(N=40worms)	0.5489	60.230	0.759	3.034
30	R1(Control)	0.5564	21.894	0.759	1.064
	R2 (N=30 worms)	0.5234	27.564	0.759	1.434
	R3(N=40worms)	0.5132	31.487	0.759	1.677
35	R1(Control)	0.5234	18.984	0.759	0.975
	R2 (N=30 worms)	0.5346	26.127	0.759	1.329
	R3(N=40worms)	0.5412	29.451	0.759	1.484

week 7

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5624	29.564	0.759	1.434
	R2 (N=30 worms)	0.5512	63.120	0.759	3.168
	R3(N=40worms)	0.5416	68.940	0.759	3.525
25	R1(Control)	0.5264	24.658	0.759	1.271
	R2 (N=30 worms)	0.5614	52.650	0.759	2.588
	R3(N=40worms)	0.5423	61.230	0.759	3.122
30	R1(Control)	0.5215	20.981	0.759	1.086
	R2 (N=30 worms)	0.5647	32.457	0.759	1.572
	R3(N=40worms)	0.5234	37.541	0.759	1.968
35	R1(Control)	0.5641	21.003	0.759	1.005
	R2 (N=30 worms)	0.5247	26.324	0.759	1.364
	R3(N=40worms)	0.5469	30.187	0.759	1.507

week 8

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5791	31.000	0.759	1.462
	R2 (N=30 worms)	0.5641	64.661	0.759	3.172
	R3(N=40worms)	0.5612	73.651	0.759	3.637
25	R1(Control)	0.5123	24.132	0.759	1.277
	R2 (N=30 worms)	0.5314	50.265	0.759	2.609
	R3(N=40worms)	0.5432	61.564	0.759	3.134
30	R1(Control)	0.5321	21.885	0.759	1.112
	R2 (N=30 worms)	0.5364	34.314	0.759	1.752
	R3(N=40worms)	0.5589	40.237	0.759	1.978
35	R1(Control)	0.5617	21.102	0.759	1.014
	R2 (N=30 worms)	0.5631	28.314	0.759	1.370
	R3(N=40worms)	0.5418	32.084	0.759	1.619

week 9

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5641	30.584	0.759	1.480
	R2 (N=30 worms)	0.5423	64.494	0.759	3.291
	R3(N=40worms)	0.5842	79.845	0.759	3.790
25	R1(Control)	0.5136	24.567	0.759	1.298
	R2 (N=30 worms)	0.5746	54.985	0.759	2.642
	R3(N=40worms)	0.5416	62.354	0.759	3.184
30	R1(Control)	0.5541	23.210	0.759	1.135
	R2 (N=30 worms)	0.5638	39.654	0.759	1.932
	R3(N=40worms)	0.5861	46.561	0.759	2.188
35	R1(Control)	0.5356	22.354	0.759	1.129
	R2 (N=30 worms)	0.5264	26.994	0.759	1.395
	R3(N=40worms)	0.5496	33.165	0.759	1.651

APPENDIX-B4: Summary Results of Total Phosphorus (TP) for 9 Weeks of vermicomposting periods

C/N Ratio	Reactor	TP (%)								
		Week								
		0	2	3	4	5	6	7	8	9
20	R1(Control)	1.251	1.263	1.268	1.280	1.297	1.307	1.339	1.359	1.390
	R2 (N=30 earthworms)	1.251	1.504	1.661	2.105	2.313	2.334	2.390	2.395	2.491
	R3(N=40 earthworms)	1.251	1.602	1.828	2.437	2.704	2.773	2.802	2.819	2.878
25	R1(Control)	1.121	1.165	1.084	1.092	1.102	1.094	1.114	1.170	1.205
	R2 (N=30 earthworms)	1.121	1.324	1.441	1.773	1.907	1.923	1.968	1.992	2.108
	R3(N=40 earthworms)	1.121	1.364	1.567	2.119	2.240	2.326	2.354	2.381	2.494
30	R1(Control)	0.871	0.889	0.904	1.044	1.085	1.095	1.098	1.121	1.152
	R2 (N=30 earthworms)	0.871	0.988	1.092	1.284	1.440	1.501	1.549	1.553	1.602
	R3(N=40 earthworms)	0.871	1.003	1.217	1.499	1.598	1.615	1.658	1.666	1.794
35	R1(Control)	0.749	0.752	0.773	0.798	0.814	0.845	0.866	0.882	0.891
	R2 (N=30 earthworms)	0.749	0.833	0.913	1.143	1.166	1.178	1.206	1.280	1.293
	R3(N=40 earthworms)	0.749	0.851	1.020	1.254	1.357	1.454	1.474	1.483	1.493

APPENDIX-B5: Total Phosphorus recorded in mg/L from Spectrophotometer

week 0

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.3003	2.684	1.251
	R1 (N=30 worms)			
	R2(N=40worms)			
25	Control	0.3007	2.408	1.121
	R1 (N=30 worms)			
	R2(N=40worms)			
30	Control	0.3026	1.882	0.871
	R1 (N=30 worms)			
	R2(N=40worms)			
35	Control	0.3001	1.606	0.749
	R1 (N=30 worms)			
	R2(N=40worms)			

week 2

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5919	5.341	1.263
	R1 (N=30 worms)	0.5287	5.680	1.504
	R2(N=40worms)	0.4998	5.720	1.602
25	Control	0.5588	4.650	1.165
	R1 (N=30 worms)	0.5053	4.780	1.324
	R2(N=40worms)	0.5921	5.770	1.364
30	Control	0.5446	3.460	0.889
	R1 (N=30 worms)	0.5584	3.940	0.988
	R2(N=40worms)	0.5790	4.150	1.003
35	Control	0.5475	2.941	0.752
	R1 (N=30 worms)	0.5463	3.250	0.833
	R2(N=40worms)	0.5695	3.460	0.851

week 3

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5651	5.120	1.268
	R1 (N=30 worms)	0.5335	6.330	1.661
	R2(N=40worms)	0.5346	6.980	1.828
25	Control	0.5347	4.140	1.084
	R1 (N=30 worms)	0.5342	5.500	1.441
	R2(N=40worms)	0.5423	6.070	1.567
30	Control	0.5637	3.640	0.904
	R1 (N=30 worms)	0.5768	4.500	1.092
	R2(N=40worms)	0.5581	4.850	1.217
35	Control	0.5524	3.050	0.773
	R1 (N=30 worms)	0.5519	3.600	0.913
	R2(N=40worms)	0.5121	3.730	1.020

week 4

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5919	5.410	1.280
	R1 (N=30 worms)	0.5287	7.950	2.105
	R2(N=40worms)	0.4998	8.700	2.437
25	Control	0.5588	4.360	1.092
	R1 (N=30 worms)	0.5053	6.400	1.773
	R2(N=40worms)	0.5921	8.960	2.119
30	Control	0.5446	4.060	1.044
	R1 (N=30 worms)	0.5584	5.120	1.284
	R2(N=40worms)	0.5790	6.200	1.499
35	Control	0.5475	3.120	0.798
	R1 (N=30 worms)	0.5463	4.460	1.143
	R2(N=40worms)	0.5695	5.100	1.254

week 5

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5268	4.880	1.297
	R1 (N=30 worms)	0.5568	9.200	2.313
	R2(N=40worms)	0.5684	10.980	2.704
25	Control	0.5324	4.190	1.102
	R1 (N=30 worms)	0.5764	7.850	1.907
	R2(N=40worms)	0.5612	8.980	2.240
30	Control	0.5432	4.210	1.085
	R1 (N=30 worms)	0.5462	5.620	1.440
	R2(N=40worms)	0.5589	6.380	1.598
35	Control	0.5384	3.130	0.814
	R1 (N=30 worms)	0.5581	4.650	1.166
	R2(N=40worms)	0.5694	5.520	1.357

week 6

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5346	4.990	1.307
	R1 (N=30 worms)	0.5231	8.720	2.334
	R2(N=40worms)	0.5563	11.020	2.773
25	Control	0.5347	4.180	1.094
	R1 (N=30 worms)	0.5461	7.500	1.923
	R2(N=40worms)	0.5489	9.120	2.326
30	Control	0.5564	4.350	1.095
	R1 (N=30 worms)	0.5234	5.610	1.501
	R2(N=40worms)	0.5132	5.920	1.615
35	Control	0.5234	3.160	0.845
	R1 (N=30 worms)	0.5346	4.500	1.178
	R2(N=40worms)	0.5412	5.620	1.454

week 7

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5624	5.380	1.339
	R1 (N=30 worms)	0.5512	9.410	2.390
	R2(N=40worms)	0.5416	10.840	2.802
25	Control	0.5264	4.190	1.114
	R1 (N=30 worms)	0.5614	7.890	1.968
	R2(N=40worms)	0.5423	9.120	2.354
30	Control	0.5215	4.090	1.098
	R1 (N=30 worms)	0.5647	6.250	1.549
	R2(N=40worms)	0.5234	6.200	1.658
35	Control	0.5641	3.490	0.866
	R1 (N=30 worms)	0.5247	4.520	1.206
	R2(N=40worms)	0.5469	5.760	1.474

week 8

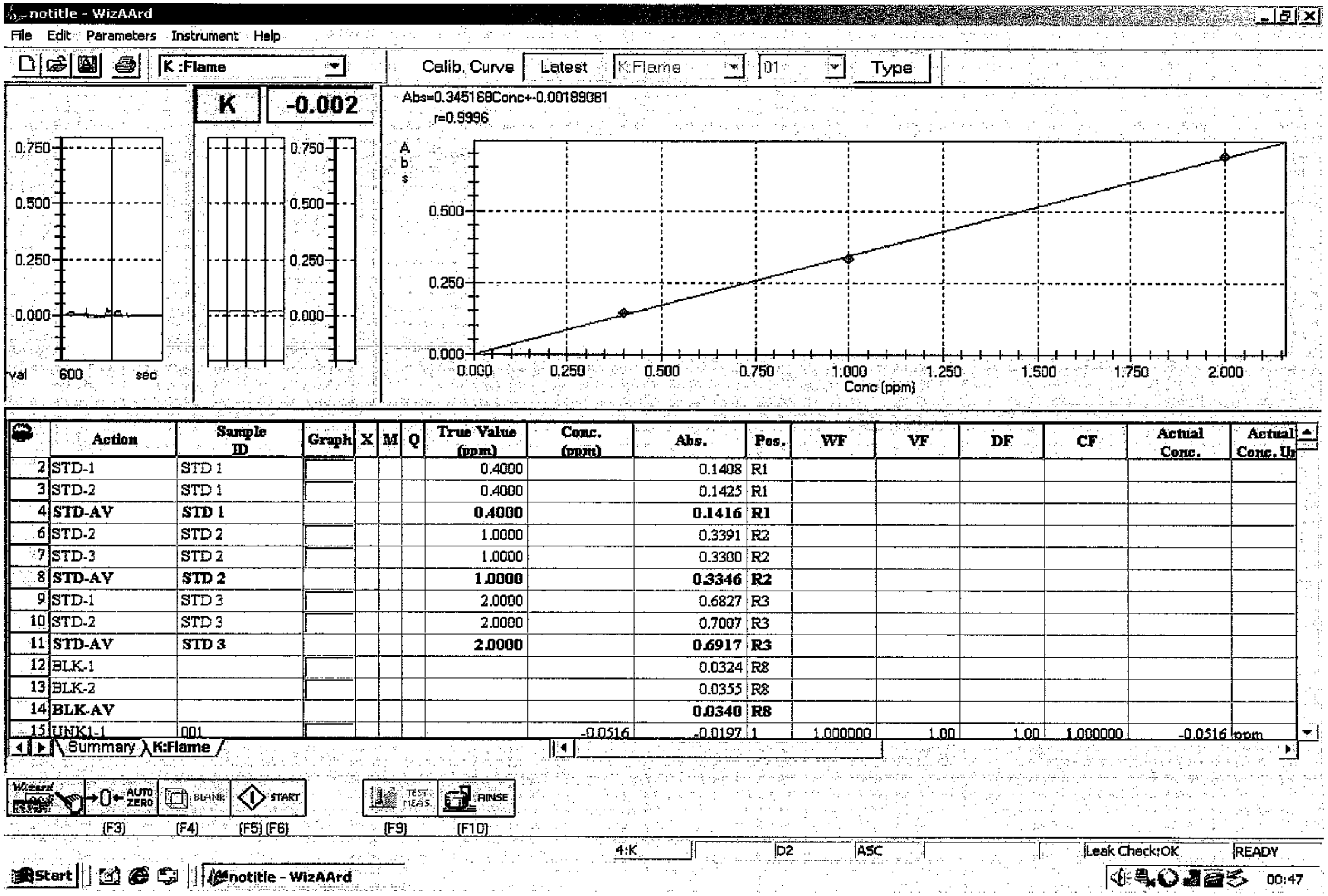
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5791	5.620	1.359
	R1 (N=30 worms)	0.5641	9.650	2.395
	R2(N=40worms)	0.5612	11.300	2.819
25	Control	0.5123	4.280	1.170
	R1 (N=30 worms)	0.5314	7.560	1.992
	R2(N=40worms)	0.5432	9.240	2.381
30	Control	0.5321	4.260	1.121
	R1 (N=30 worms)	0.5364	5.950	1.553
	R2(N=40worms)	0.5589	6.650	1.666
35	Control	0.5617	3.540	0.882
	R1 (N=30 worms)	0.5631	5.150	1.280
	R2(N=40worms)	0.5418	5.740	1.483

week 9

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	Control	0.5641	5.600	1.390
	R1 (N=30 worms)	0.5423	9.650	2.491
	R2(N=40worms)	0.5842	12.010	2.878
25	Control	0.5136	4.420	1.205
	R1 (N=30 worms)	0.5746	8.650	2.108
	R2(N=40worms)	0.5416	9.650	2.494
30	Control	0.5541	4.560	1.152
	R1 (N=30 worms)	0.5638	6.450	1.602
	R2(N=40worms)	0.5861	7.510	1.794
35	Control	0.5356	3.410	0.891
	R1 (N=30 worms)	0.5264	4.860	1.293
	R2(N=40worms)	0.5496	5.860	1.493

APPENDIX-B6: Summary Results of Potassium for 9 Weeks of vermicomposting periods

C/N Ratio	Reactor	Potassium (%)								
		Week								
		0	2	3	4	5	6	7	8	9
20	R1(Control)	0.262	0.268	0.272	0.292	0.301	0.307	0.312	0.319	0.323
	R2 (N=30 earthworms)	0.262	0.298	0.342	0.365	0.401	0.443	0.585	0.590	0.662
	R3(N=40 earthworms)	0.262	0.321	0.398	0.438	0.481	0.499	0.634	0.636	0.767
25	R1(Control)	0.243	0.247	0.249	0.253	0.257	0.259	0.268	0.272	0.279
	R2 (N=30 earthworms)	0.243	0.250	0.268	0.291	0.319	0.325	0.390	0.432	0.484
	R3(N=40 earthworms)	0.243	0.284	0.338	0.366	0.397	0.430	0.595	0.615	0.663
30	R1(Control)	0.222	0.225	0.229	0.230	0.238	0.239	0.240	0.243	0.254
	R2 (N=30 earthworms)	0.222	0.243	0.266	0.275	0.288	0.300	0.306	0.313	0.411
	R3(N=40 earthworms)	0.222	0.249	0.284	0.297	0.315	0.388	0.418	0.425	0.473
35	R1(Control)	0.164	0.166	0.168	0.170	0.174	0.177	0.180	0.194	0.196
	R2 (N=30 earthworms)	0.164	0.169	0.178	0.203	0.212	0.239	0.249	0.279	0.292
	R3(N=40 earthworms)	0.164	0.182	0.203	0.210	0.224	0.265	0.301	0.313	0.337



Abs=0.345168Conc+-0.00189081
r=0.9996

	Action	Sample ID	Graph	X	M	Q	True Value (ppm)	Conc. (ppm)	Abs.	Pos.	WF	VF	DF	CF	Actual Conc.	Actual Conc. U
2	STD-1	STD 1					0.4000		0.1408	R1						
3	STD-2	STD 1					0.4000		0.1425	R1						
4	**STD-AV**	**STD 1**					**0.4000**		**0.1416**	**R1**						
6	STD-2	STD 2					1.0000		0.3391	R2						
7	STD-3	STD 2					1.0000		0.3300	R2						
8	**STD-AV**	**STD 2**					**1.0000**		**0.3346**	**R2**						
9	STD-1	STD 3					2.0000		0.6827	R3						
10	STD-2	STD 3					2.0000		0.7007	R3						
11	**STD-AV**	**STD 3**					**2.0000**		**0.6917**	**R3**						
12	BLK-1								0.0324	R8						
13	BLK-2								0.0355	R8						
14	**BLK-AV**								**0.0340**	**R8**						
15	UNK1-1	001						-0.0516	-0.0197	1	1.000000	1.00	1.00	1.000000	-0.0516	ppm

APPENDIX - B7: Potassium recorded in mg/L from Atomic Absorption Spectrophotometer

week 0

C/N	Reactor	weight of sample (g)	Potassium (mg/L)	Potassium (%)
20	R1(Control)	0.3003	0.561	0.262
	R2 (N=30 earthworms)			0.262
	R3(N=40 earthworms)			0.262
25	R1(Control)	0.3007	0.522	0.243
	R2 (N=30 earthworms)			0.243
	R3(N=40 earthworms)			0.243
30	R1(Control)	0.3026	0.481	0.222
	R2 (N=30 earthworms)			0.222
	R3(N=40 earthworms)			0.222
35	R1(Control)	0.3001	0.351	0.164
	R2 (N=30 earthworms)			0.164
	R3(N=40 earthworms)			0.164

week 2

C/N	Reactor	weight of sample (g)	Potassium (mg/L)	Potassium (%)
20	R1(Control)	0.5919	1.134	0.268
	R2 (N=30 earthworms)	0.5287	1.124	0.298
	R3(N=40 earthworms)	0.4998	1.145	0.321
25	R1(Control)	0.5588	0.984	0.247
	R2 (N=30 earthworms)	0.5053	0.902	0.250
	R3(N=40 earthworms)	0.5921	1.201	0.284
30	R1(Control)	0.5446	0.875	0.225
	R2 (N=30 earthworms)	0.5584	0.970	0.243
	R3(N=40 earthworms)	0.5790	1.030	0.249
35	R1(Control)	0.5475	0.651	0.166
	R2 (N=30 earthworms)	0.5463	0.658	0.169
	R3(N=40 earthworms)	0.5695	0.742	0.182

week 3

C/N	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5651	1.098	0.272
	R2 (N=30 earthworms)	0.5335	1.302	0.342
	R3(N=40 earthworms)	0.5346	1.520	0.398
25	R1(Control)	0.5347	0.951	0.249
	R2 (N=30 earthworms)	0.5342	1.024	0.268
	R3(N=40 earthworms)	0.5423	1.310	0.338
30	R1(Control)	0.5637	0.923	0.229
	R2 (N=30 earthworms)	0.5768	1.097	0.266
	R3(N=40 earthworms)	0.5581	1.132	0.284
35	R1(Control)	0.5524	0.664	0.168
	R2 (N=30 earthworms)	0.5519	0.702	0.178
	R3(N=40 earthworms)	0.5121	0.742	0.203

week 4

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	R1(Control)	0.5919	1.234	0.292
	R2 (N=30 earthworms)	0.5287	1.380	0.365
	R3(N=40 earthworms)	0.4998	1.562	0.438
25	R1(Control)	0.5588	1.009	0.253
	R2 (N=30 earthworms)	0.5053	1.052	0.291
	R3(N=40 earthworms)	0.5921	1.547	0.366
30	R1(Control)	0.5446	0.894	0.230
	R2 (N=30 earthworms)	0.5584	1.098	0.275
	R3(N=40 earthworms)	0.5790	1.230	0.297
35	R1(Control)	0.5475	0.664	0.170
	R2 (N=30 earthworms)	0.5463	0.794	0.203
	R3(N=40 earthworms)	0.5695	0.856	0.210

week 5

C/N	Reactor	weight of sample (g)	Phosphorus (mg/L)	Phosphorus (%)
20	R1(Control)	0.5268	1.134	0.301
	R2 (N=30 earthworms)	0.5568	1.594	0.401
	R3(N=40 earthworms)	0.5684	1.954	0.481
25	R1(Control)	0.5324	0.978	0.257
	R2 (N=30 earthworms)	0.5764	1.312	0.319
	R3(N=40 earthworms)	0.5612	1.589	0.397
30	R1(Control)	0.5432	0.924	0.238
	R2 (N=30 earthworms)	0.5462	1.123	0.288
	R3(N=40 earthworms)	0.5589	1.258	0.315
35	R1(Control)	0.5384	0.671	0.174
	R2 (N=30 earthworms)	0.5581	0.845	0.212
	R3(N=40 earthworms)	0.5694	0.910	0.224

week 6

C/N	Reactor	weight of sample (g)	Phosphorus (mg/L)	Phosphorus (%)
20	R1(Control)	0.5346	1.172	0.307
	R2 (N=30 earthworms)	0.5231	1.654	0.443
	R3(N=40 earthworms)	0.5563	1.984	0.499
25	R1(Control)	0.5347	0.988	0.259
	R2 (N=30 earthworms)	0.5461	1.267	0.325
	R3(N=40 earthworms)	0.5489	1.687	0.430
30	R1(Control)	0.5564	0.949	0.239
	R2 (N=30 earthworms)	0.5234	1.123	0.300
	R3(N=40 earthworms)	0.5132	1.421	0.388
35	R1(Control)	0.5234	0.663	0.177
	R2 (N=30 earthworms)	0.5346	0.912	0.239
	R3(N=40 earthworms)	0.5412	1.025	0.265

week 7

C/N	Reactor	weight of sample (g)	Phosphorus (mg/L)	Phosphorus (%)
20	R1(Control)	0.5624	1.254	0.312
	R2 (N=30 earthworms)	0.5512	2.304	0.585
	R3(N=40 earthworms)	0.5416	2.451	0.634
25	R1(Control)	0.5264	1.008	0.268
	R2 (N=30 earthworms)	0.5614	1.564	0.390
	R3(N=40 earthworms)	0.5423	2.305	0.595
30	R1(Control)	0.5215	0.894	0.240
	R2 (N=30 earthworms)	0.5647	1.235	0.306
	R3(N=40 earthworms)	0.5234	1.564	0.418
35	R1(Control)	0.5641	0.724	0.180
	R2 (N=30 earthworms)	0.5247	0.935	0.249
	R3(N=40 earthworms)	0.5469	1.174	0.301

week 8

C/N	Reactor	weight of sample (g)	Phosphorus (mg/L)	Phosphorus (%)
20	R1(Control)	0.5791	1.320	0.319
	R2 (N=30 earthworms)	0.5641	2.377	0.590
	R3(N=40 earthworms)	0.5612	2.549	0.636
25	R1(Control)	0.5123	0.995	0.272
	R2 (N=30 earthworms)	0.5314	1.640	0.432
	R3(N=40 earthworms)	0.5432	2.387	0.615
30	R1(Control)	0.5321	0.925	0.243
	R2 (N=30 earthworms)	0.5364	1.200	0.313
	R3(N=40 earthworms)	0.5589	1.698	0.425
35	R1(Control)	0.5617	0.778	0.194
	R2 (N=30 earthworms)	0.5631	1.124	0.279
	R3(N=40 earthworms)	0.5418	1.210	0.313

week 9

C/N	[illegible]	Weight of sample (g)	[illegible] (mg/L)	[illegible] (%)
20	R1(Control)	0.5641	1.302	0.323
	R2 (N=30 earthworms)	0.5423	2.564	0.662
	R3(N=40 earthworms)	0.5842	3.200	0.767
25	R1(Control)	0.5136	1.024	0.279
	R2 (N=30 earthworms)	0.5746	1.987	0.484
	R3(N=40 earthworms)	0.5416	2.564	0.663
30	R1(Control)	0.5541	1.007	0.254
	R2 (N=30 earthworms)	0.5638	1.654	0.411
	R3(N=40 earthworms)	0.5861	1.980	0.473
35	R1(Control)	0.5356	0.750	0.196
	R2 (N=30 earthworms)	0.5264	1.098	0.292
	R3(N=40 earthworms)	0.5496	1.324	0.337

APPENDIX C

APPENDIX-C: Calculation

APPENDIX-C1: Calculation for Total Kjeldahl Nitrogen (TKN)

$$\text{TKN}(\%) = \frac{A - B}{C} \times 280 \times 0.0001$$

where

A = volume of sample titrated (ml)
B = volume titrated for blank (ml)
C = weight of sample (g)

(Source: ASTM for Soil and Peat (D 4972 – 95a)

APPENDIX-C2: Calculation for Total Phosphorus (TP)

$$\text{TP}(\%) = \frac{1.4 \times A \times 0.1}{B}$$

A = phosphorus (mg/L)
B = weight of sample (g)

APPENDIX-C3: Calculation for Potassium

$$\text{Potassium}(\%) = \frac{1.4 \times A \times 0.1}{B}$$

A = potassium (mg/L)
B = weight of sample (g)