Evaluation of organic strength in Municipal Solid Wastes through leaching column study

By
A. A. D. T. Prasangani
02/AS/047

A research report submitted in partial fulfilment of the requirements for the degree of Bachelor of Science in
Food science and
Technology
Faculty of Applied Sciences
Sabaragamuwa University of Sri Lanka
Buttala.
October 2007

Declaration

The research work described in this thesis was carried out by me at the University of Peradeniya, Faculty of Applied Sciences and the University of Sabaragamuwa under the supervision of Prof. B. F .A. Basnayake and Dr. S. K. Gunathilake. A report on this has not been submitted to any other university for another degree.

.... 03/12/2007 ....

Signature Date

(A. A. D. T. Prasangani)

Certified by:

Internal supervisor

Dr. S. K. Gunathilake,
Senior lecturer,
Department of Natural Resources,
Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka,
Buttala.

....20/02/2008....

Signature Date

External Supervisors

Prof. B. F. A. Basnayake,
Department of Agriculture Engeenering,
Faculty of Agriculture,
Peradeniya University of Sri Lanka,
Peradeniya

....03/12/2007....

Signature Date

Head of Department

Dr. K. B. Palipane,
Head of the Department,
Department of Food Science and Technology,
Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka.
Buttala.

....06/12/2007.

Signature Date

Head/Dept. of Food Sciences & Technology
Faculty of Applied Sciences
Sabaragamuwa University of Sri Lanka
BUTTALA

DEDICATED TO MY PARENTS AND ALL MY TEACHERS

Acknowledgements

I wish to express my deepest gratitude to my external supervisors Prof B.F.A. Basnayake, Department of Agriculture Engineering, Faculty of Agriculture, University of Peradeniya for providing opportunity, guidance, advices, all encouragement, spending lot of valuable time and endless help for success of this project.

My special word of thanks to Dr. S.K. Gunathilake, senior lecturer, Department of Natural Resources, Faculty of Applied Sciences, Buttala for the assistance and encouragement through this study for success of the research.

I would like express my sincere thanks Ms. S.N.M. Menikpura, senior research assistant. Solid Waste Management Research (SWMRU) Unit, Department of Agriculture Engineering, Faculty of Agriculture, University of Peradeniya and all the staff members of AIT SIDA project for encouraging, guiding, advising and helping me through the research for success of this study. I would like to thank especially endless help during designing and fabrication of leaching column.

I would like to thank academic and non academic staff of the Department of Agriculture Engineering, Faculty of Agriculture, University of Peradeniya for providing me opportunity, laboratory facilities other necessary facilities during the research period.

Finally, I would like to thank all the members of the academic staff of Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka for their encouragement and also I would like to thank all people who were willing to give there support and assistance to me through out my project.

Abstract

Disposal of untreated Municipal Solid Waste has been a great environment issue which leads to generation of leachate and odoures gasses. Organic solid waste accumulation rate is higher as organic waste collect form household level to industrial level. Identification of efficient protocol to digestion of solid waste efficiently would be a good solution highly concerning on organic wastes. Comprehensive study on each waste type and characterization of each waste type would be a good method to identify proper efficient treating method. Leaching column method is a good technique to study on waste characteristics.

Preliminary study on leaching columns was done for mixed waste at two Liquid to Solid (L/S) ratios of 20:1 and 5:1. Total Dissolved Solids (TDS), conductivity, salinity, pH, Total Soluble Solids (TSS), Volatile Suspended Solids (VSS), Total Solids (TS) and Volatile Solids (VS) were taken as waste characteristic parameter. L/S ratio of 20:1 was identified better to application of leaching column comparatively to 5:1. It was selected for further application.

Leaching column was developed using PVC pipes and hand pump was used for recirculation. Cost effective better leaching column could be designed.

Fresh waste samples of each waste type had high organic content and highest organic content was possessed by the garden wastes. Leachate analysis of each waste type in leaching columns could observed that the all the waste types' degradation was occurred rapidly. Degradation rate of fish and meat was higher comparatively to other four types. Volatile Solids (VS) variation of all types was increased in logarithmic pattern. Logarithmic pattern was followed by five types of wastes during waste degradation. Rapid reduction of organic content can be achieved through leaching column application.

Contents

List of Figures

List of Tables

CHAPTER 01

INTRODUCTION AND OBJECTIVES

Background

Municipal Solid Waste (MSW) is a major environment issue which leads to generation of leachate and odoures gases. Leachate is potentially polluting as it can cause oxygen depletion in water which leads to many health problems. Landfilling of leachate or making any connection the leachate with ground leads to contaminate the ground water with toxic compounds. So that several researches have done to remove the toxic materials before exposing the leachate to the environment and it has been studied leachability of each component to the ground through leaching column study. An efficient technique to treat this MSW is very important to eliminate such problem arise due to accumulation of bulk amount of waste. The available treating methods like composting, anaerobic digestion, landfilling and pulverizing are not efficient up to that extend of generation of waste. So that it is important to identify quick method of treating solid waste based on waste composition.

Data on characteristics of MSW can be used to develop quick efficient method of treating MSW. Here availability of high amount of organic fraction in the MSW leads to number of problems during treatment phase. This high organic loading leads to biological clogging. So that, there is a growing trend to reduce the organic content in landfills and reduction of amount of biodegradable organic fraction being directly landfilled. Organic strength of the waste varies according to the waste types. Here food wastes and fish and meat wastes have very high organic loading comparing to coir wastes. Garden wastes organic loading differs according to location. As well as mixed waste organic strength and composition variation is specific to the proportion of each waste type. Through comprehensive knowledge on each waste type, can identify efficient waste treatment method while linking to available time consuming methods.

Leaching column study has been used for many researches like study the leaching behavior of heavy metals and chemicals. But this is a good technique to comprehensively study the waste digestion in anaerobic condition. Leaching column study can be applied to the characterization of different types of waste very efficiently. During this anaerobic digestion of waste mainly production of leachate and CO_2 are occurred. Other odoures gasses are produced in smaller amounts. Leaching column study, comprehensively study the anaerobic microbial action on each waste types and there digestion, stabilization period of each waste type. Here it's prediction done through analytical approach produced by Monod kinetic model. Development of protocol to reduce the organic loading of waste can be identified through this leaching column study. Introducing of new protocol while linking with available time consuming method would be a good approach to eliminate arise environment and health problems due to accumulation of waste.

Justification and problem identification

Accumulation of, bulk amount of waste to the environment have been a big issue as it leads to many health and environment problems. The available waste treating methods have been face to the problem of reduction of organic content in the waste. So that it is better to study on development protocol to achieve the quick reduction of organic loading in the waste.

The main waste types can be seen depending on generation rate are food waste, fish and meat waste, garden waste, mixed waste and coir waste. Through leaching column study the,

- Biodegradability of each waste type
- Waste characterization
- Comprehensive study of digestion of each waste type in anaerobic condition
- Organic strength variation during anaerobic treatment in each waste type
- Stabilization period taken to each waste type
- Development of protocol to reduce the organic loading in waste quickly

So that it is better to do a leaching column study to develop a protocol to eliminate organic loading problem in the available methods. Identification of best method of treating the each waste type can be identified through the waste characterization. As well as by linking the developed protocol with existing waste treating techniques efficient use of them can be achieved. This will be a quick method to determine the biodegradability of different waste types.

Objectives :

To establish a protocol based on leaching columns for determining organic solid waste characteristics.

Specific objectives:

1. To identify best water ratio with waste to addition of leaching column.
2. Designing of leaching column.
3. To determine the stabilization period of each waste type.
4. Evaluation of leachate parameters to predict the organic content and its impact on environment.

CHAPTER 02

LITRETURE REVIEW

2.1 Waste

The term wastes (recently given the equalent term residuals) refer to the materials which are discarded by community activities to the environment and include solid, liquid and gases (Barton, 1979). The waste can be categorized as solid waste, liquid waste, dust or particular matter and gaseous waste.

2.1.1 Solid wastes

The term solid waste encompasses all of those wastes which are neither waste water discharges nor atmospheric emission. Solid waste may therefore be a semi solid, solid or even a liquid. According to the degradation pattern solid waste can be categorized to biodegradable solid waste and non- biodegradable solid waste.

Depending on source of waste generation it can be again classified in to three groups such as

- Municipal solid wastes (e.g. Household wastes)
- Hazardous solid wastes (e.g. Industrial wastes)
- Infectious wastes (e.g. hospital waste, biomedical wastes) (www.edugreen.teri.res.in, 2007)

2.2 Municipal solid wastes (MSW)

The garbage generated mainly from residential and commercial complexes defined as municipal solid wastes. MSW consist of household wastes, demolition debris, sanitation residue, and wastes from streets. The amount of the MSW has been increasing as well as composition of MSW changing rapidly due to day today development, increasing population and unplanned urbanization. Waste generation rate of urban areas of Asia in 2000 was about 760,000 tones per day and it has been estimated that in 2005 the waste generation rate will be 1.8 million tones per day. Expenditure for the solid waste management in 2000 would be double in 2005 as a result of this high waste generation rate (Fossberg, 1999). Waste generation rate per day is around 6400 tonnes in Sri Lanka (UNEP, 2001),. it produces 4100 tonnes of biodegradable wastes per day in Sri Lanka since 65% out of total amount of wastes comprise of this biodegradable wastes. Therefore treatment of this biodegradable waste is important component to solid waste management to reduce toxicity and volume of the MSW (Paramsothy, 2004). As well as high fraction of MSW more than 50% is organic waste with high moisture (Juanga, 2007).

Municipal governments are usually the responsible agency for the solid waste collection and disposal. But the high amounts of solid waste have been problematic to manage the solid waste their selves and it has urge the corporation of other levels of government, business and general community. Generally management of residential solid waste which is about 30% of overall MSW has been empersized much higher than other types of MSW. But the waste component Asia needs priority attention is organics and paper (Fossberg, 1999).

2.3 Waste characterization

MSW treatment technologies are essential to managing the environment from this burden. However before applying such technologies, awareness is necessary about the MSW. Thus as a main step of solving MSW problem waste characterization studies must be done. Waste characterization is the process by which the composition of different waste streams analyzed (Wikepedia, 2007). Here solid waste streams should be characterized by their sources, by the types of wastes produced, by the generation rates, as well as composition (Fossberg, 1999). Waste characterization plays an important part in any treatment method of waste which may applied. Developers of waste technologies consider on the exact waste stream in order to fully treat the waste. Knowledge of source and type of waste in an area is required in order to design and operate appropriate solid waste management system (Fossbrg, 1999).

Mainly waste can be categorized as biodegradable waste and non- biodegradable waste (Wikepedia, 2007). However each kind of waste has included different type of waste. Therefore these all kind of waste properties has to be taken in to account for finding appropriate treatment methods.

2.3.1. Waste types

There are eight major classifications of solid waste generators: residential, industrial, commercial, institutional, construction and demolition, municipal services, processes and agricultural (figure 01). MSW included wastes generated from residential, commercial, industrial, institutional, construction, demolition, processes, and municipal services. But the MSW definition varies greatly among waste studies and commonly excludes the waste generated from construction, demolition, municipal services and industrial. Often residential wastes referred as MSW and it comprises of 25%-35% of overall solid wastes in high income countries (Fossberg, 1999)

Source and types of Solid Wastes		
Source	Typical waste generators	Types of solid wastes
Residential	Single and multi family dwelling	Food wastes, paper, cardboard, plastics, textiles, yard wastes, leather, wood, glass, metal, ashes, special wastes (e.g. bulky items, consumer electronics, batteries, oils, tires), and house hold hazardous wastes
Industrial	Light and heavy manufacturing, fabrications, constructions sites, power, and chemical plants	House keeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes and special wastes
Commercial	Stores, hotels, restaurants, markets, office buildings etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	School, hospitals, prisons, government centers	Same as commercial
Construction and demolition	New construction sites, road repairs, renovation sites, demolition building	Wood, steel, concrete, dirt etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas and water and waste water treatment plants	Street sweeping, landscape and tree trimming; general wastes from parks, beaches, and other recreational areas sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, slag, tailings
Agriculture	Crops, vineyards, orchards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g. pesticides)

(Fossberg, 1999)

Table 2.1 Sources and types of Solid Wastes

Considering on this all waste types and sources, bulk amount of municipal solid waste consist with the following 5 types of waste.

- Food waste

  Food waste is any form of biodegradable waste that was originally intended to consumption. It typically consists of vegetable droppings, meat scraps and other discard from the kitchen.

- Garden waste (Green wastes)

  These are biodegradable waste comprised with garden or park waste such as grass, flower cutting, hedge trimming.

- Fish and meat waste

  Fish and meat waste is biodegradable waste consist of any animal body parts cut off in the preparation of carcass for use as food. This waste generates from several sources including slaughter houses, restaurants and farms.

- Coir waste

  Coir waste is lignin waste consisting of mainly fiber of coconut, ropes and other fiber wastes. These are biodegradable waste and it can be degraded readily by *Psedomonas Sp*.

- Mixed waste

  Mixed wastes can be referred as mixture of waste types. Here according to the mixing ratios mixed waste properties are changed (Wikepedia, 2007).

2.3.2. Waste composition

Waste composition is influenced by external factors such as geographical location, the population's standard of living, energy source and weather.

Generally low and middle income countries have high percentage of combustible organic matters in the urban waste streams, ranging from 40-85 percent of the total. But China and India diverts from this general trend as they use coal as traditional household fuel source. Combustible organic fraction of waste in high income countries which ranges between 25 – 45 percent is lower than low and middle income countries. With the degree of population's wealth and urbanization, increase of consumer packaging wastes can be observed. The presence of paper, plastic, glass and metal become more prevalent in the waste streams of middle and high income countries (Fossberg, 1999).

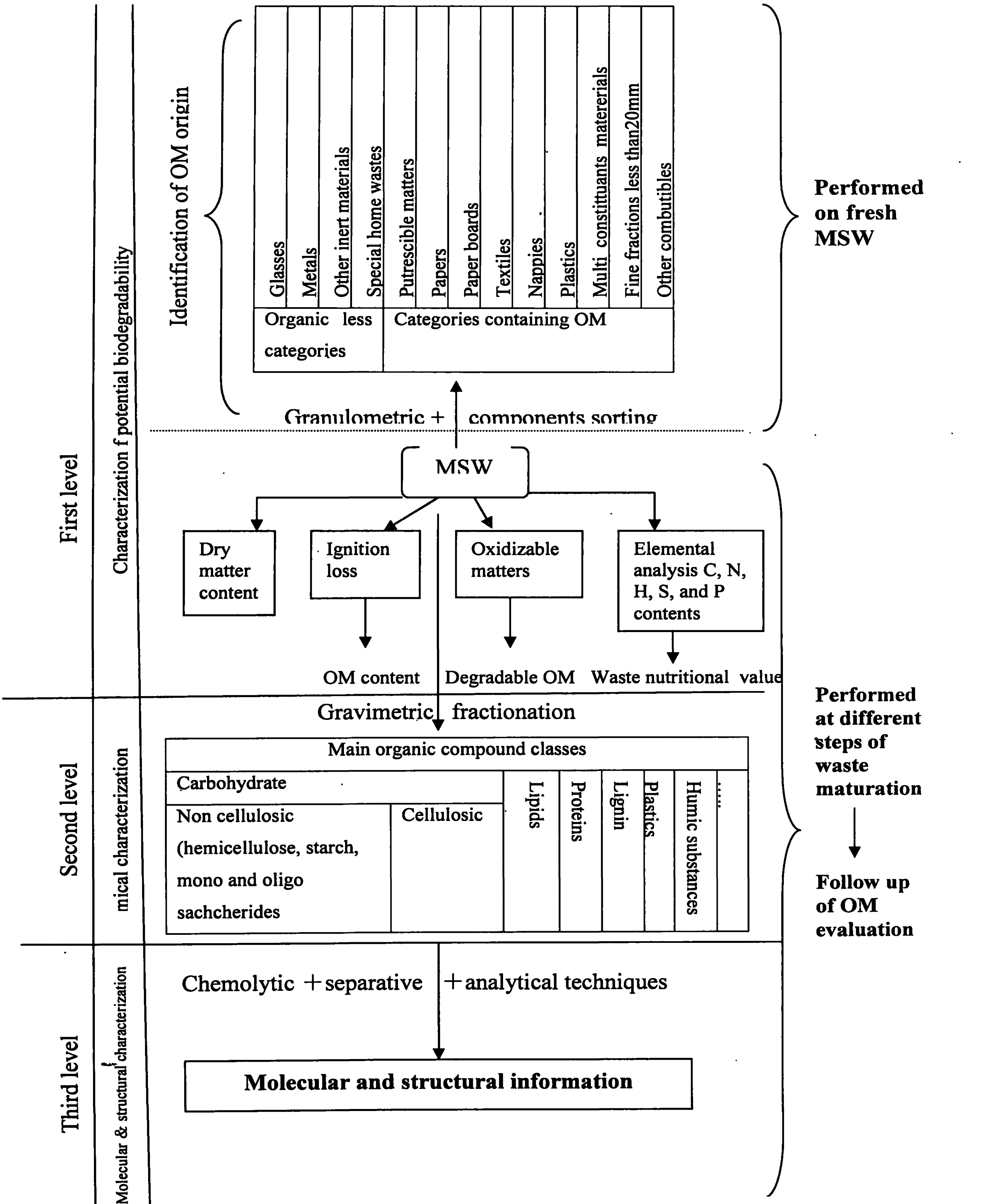
2.4 Importance of waste characterization

Complete waste characterization leads to; recognize the proper waste treatment methods. Since mis- characterization waste could be lead to happen many errors like inaccurate modeling outputs, erroneous decision making, redundant testing of waste and wrong land application or liner selection

2.5 Waste characterization strategies

The analysis of MSW organic matter composition can be done at different levels such as (figure 2),

- Global characterization
- Chemical characterization
- Structural and molecular characterization



(Brauer et.al, 2005)

Table 2.2 The waste characterization strategies

2.5.1. Global characterization

Global characterization is a one way of characterizing OM of MSW. Here it categorizes to the sizes and sort the landfill entering waste in to several categorize according o the nature of the each component. It is important to have a precious data on the weight percentages of organic materials such as putrescible fraction which consist of food and garden wastes, paper, textiles, nappies, plastics for the prediction of further behaving during maturation and treatment efficiency. The MODECOM™ procedure developed by the French environmental protection agency ADEME (ADEME, 1993) can be used to categorize in such manner. Here it separates wastes in to 4 mineral categories and 9 fractionation categories containing more or less biodegradable matters (Baurer, 2005). A classic approach of potential biodegradability of raw waste materials is provided by basic chemical analysis (Achour, 2004). The gravimetric procedures are performed on solid samples which represents whole wastes to quantify Dry Matter, Total Organic Carbon, oxidative organic matter, Ignition loss, Total Inorganic Carbon, Plastic materials, soluble fraction, Inert materials. During the elemental analysis, waste nutrition value is measured from C, H, N and P. It also possible to predict the biodegradability of waste, by microorganisms through these analyzing parameters. Potential biogas production can lead to evaluate the degree of aromaticity of the wastes and to access the maturity level from its elemental composition (Brauer, 2005).

2.5.2. Chemical characterization

OM of MSW again can be categorize into the major chemical compound classes such as carbohydrate (hemicellulose, starch, mono and oligosaccherides), cellulose, protein, lipids, lignin, humic substances and plastics. There are different gravimetric fractionation methods developed to separate and quantify these chemical compound classes (Van Soest and Wine, 1967; cheftz et.al 1998, Pichler and Kogel-Knabner, 2000). These fractionations are based on solubility and hydrolyzability properties of each kind of compounds and these are not really specific. Though such disadvantage there, chemical indicators cellulose lignin ratios, lipids and protein index (Archour, 2004), humic stability index [humic acid]/[flavic acid] (Sanchez-Monedeoro, 1999, Francou, 2003, Castaldi et.al, 2005) have been identified and successfully used to evolution of OM during stabilization (Brauer et.al, 2005).

Chemical characterization of MSW is difficult as many factors interfere during fractionation. The results strongly depend on experimental condition. These analytical problems partially can be overcome by calculating relatively OM composition. However the establishing the chemical parameter to measure the stability achieved by organic matter at different stages of waste maturation is not yet perfectly solved (Bauer et.al, 2005).

2.5.3. Molecular and structural stabilization

Macromolecular structures posses by most of the organic matters in MSW. So that degradative step such as thermolytic or chemolytic technique is needed to study the fine structural information at molecular level (Kogel-Knabner, 2000). Chromatography technique is applied to separate these fragments and analyzing done by mass spectrometry or other spectroscopic method. There is a disadvantage of secondary reaction with these fragments so those conclusions on the original structure of macromolecules have to drawn with caution.

Molecular or structural characterization can be also achieved by applying non-destructive spectroscopic method. This method is better suited to identify gross composition of chemicals but hardly identify the specific compounds. UV visible absorption spectroscopy, fluorescence, FTIR, and thermal analysis such as thermogravimetry, Differential scanning calorimetry (Melis and Castaldi, 2004) have been used for OM evolution. These studies have led to gather information on aromaticity and complexicity of OM (Brauer et.al, 2005).

2.6 Waste Characterization Methods

Waste characterization is important to maximize the knowledge that is necessary to make important decision on waste treatment. It is necessary for gauging what risks a waste might pose to surface water, ground water and air. Also it drives waste management unit design and operation decision.

This waste characterization can be achieved using two ways, such as process knowledge and leachate testing (Schaefer, 2006). Some times combination of these two methods is applied to get sound knowledge on waste as process knowledge alone might not be sufficiently yields reliable results. Leachate testing will likely give more precise assessment waste constituent concentration than process knowledge (Jennifer and Steven., 2006).

2.6.1 Process knowledge

Process knowledge refers to detailed information on process that generates wastes. It can be used to partly or in many cases, completely characterize waste to ensure proper management. For proper characterization of waste, enough information on process will be needed. Here by reviewing process flow diagram or plans, determining all inputs and outputs and by familiarizing with physical state of the waste, volume of waste produced, and general composition of waste.

Process knowledge includes,

- Existing published or documented waste analysis data or studies conducted on waste generated by processes similar to that which generated the waste.
- Waste analysis data obtained from other facilities in the same industry.
- Facility's records of previously performed analyses (Schaefer, 2006).

A material balance exercise using process knowledge can be useful in understanding where waste are generated within a process and in estimating concentrations of waste constituents particularly analytical test data are limited. This process knowledge method is cost saving method, which is economical (Jennifer and Steven, 2006).

2.7 Leachate Testing

Leaching is method to remove soluble components from solid matrix. Describing the leaching by very simple equation:

Material (leachate) + Leachant $\rightarrow$ Leachate (Kim, 2005)

A survey of literature has identified over 100 leaching methods (Hesbach and Lamey, 2001). The purpose of the research will determine the selection of the leachant and the conditions of the test.

Leaching tests are mainly performed by professionals who are involved in management or regulations of solid wastes as a mean of assessing the risk of the solid wastes to human health or environment (Kim, 2005). Leaching tests data used to help assess the ability of a pollutant to partition from waste into surrounding liquid medium.

Many batch leaching test protocols have been developed to simulate the leaching processes of waste materials in landfill or other disposal scenarios to evaluate potential risks to human or ground water. The results of batch test should be evaluate carefully before been used for regulatory or design purposes.

Main purpose of leaching test can be identified as,

To obtain aqueous phase concentration(s) of constituent(s) which are released from solids when placed in a land disposal unit(s) (Ishwar, 2003).

When analyze the main objectives of performing leaching test, it can be listed as,

- Classify waste as a hazardous or non hazardous for regulatory application
- Evaluate leaching potential of pollutants resulting from a waste under specified environmental conditions
- Simulate waste or site specific leaching conditions to evaluate leaching potential
- Provide an extract that is representative of the actual leachate produced in the field
- Measure treatment effectiveness of the waste
- Identify the appropriate waste management scenario or waste disposal environment
- Determine partition and kinetic parameters for the purpose of contaminant transport modeling (Timothy, 2003)

Leaching tests performed to achieve above mentioned objectives, can be categorized as,

- Batch test
- Field test
- Column test

Parameters	Batch test	Column test
Testing period	Short term (hours to days)	Long term (days to month)
Operation	Easy to operate	Difficult to operate (channeling due to non uniform packing of waste or clogging of column)
Cost	Relatively low	Relatively high
Application of results	Depending on the type of batch test	More specific scenario
L/S ratio	Relatively high (to estimate the maximum amounts of pollutants to be leached)	Relatively low (close to field condition)
pH control	Easy to control pH with appropriate chemical	Materials dictates its own chemical environment

(Timothy et.al, 2003)

Table 2.3 Differentiation on batch tests and column tests

2.7.1 Batch Test

Common batch tests include,

- Extraction Procedure Toxicity (EP-Tox; US EPA method 1310, 2001)
- Toxicity Characteristics Leaching Procedure (TCLP; US EPA method 1311, 2001)
- Synthetic Precipitation Leaching Procedure (SPLP; US EPA method 1312, 2001)
- Waste Extraction Test (WET; California Code of Regulations, 1985)
- American society for testing and materials extraction test (ASTM D 3987-85, 2001)
- Multiple Extraction Procedure (MEP; USA EPA Method 1320) (Timothey et.al, 2003)

2.7.2 Field Test

Mainly a field scale leaching test performed to stimulate leaching processes of waste by constructing and operating simulated waste cells under actual field conditions. This test provides considerably valuable information regarding the leaching behavior of waste. But this field scale leaching test (e.g. test cell experiment) has limitations due to high time consuming, extremely expensive and labor intensive. As a result, very limited leaching data of field studies are available. (Timothy et al., 2003)

2.8 Column Test

A column test or lysimeter test is used to study the leaching process from waste materials. This test involves placement of waste material in a lysimeter or column and addition of leaching solution to the material to produce leachate. Here continuous flow of leaching solution occurs through the waste materials placed in the column (Figure 2.1). Therefore due to this continuous flux it is called as dynamic test and may be more representative of field conditions. Controlling experimental condition for this test is not easy as well as reproducibility of the column test is difficult to extend. This problem may be due to the flow channeling, clogging and biological activity (Timothy et al., 2003)

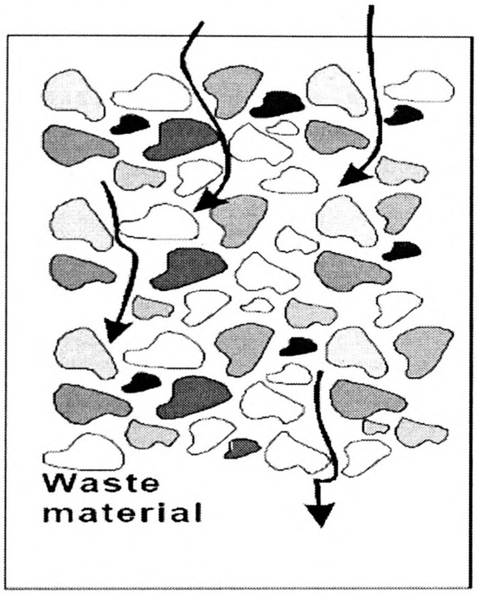


Figure 2.1 A simple schematic diagram of column test

In order to identify the appropriate waste management scenario leaching column test is important. Column test stimulate to a grater degree the leaching condition at an actual site (Hjemlar, 1990). Unlike batch tests, column tests take into accounts the neutralizing effect of the CO_2 and address the low L/S ratios that are not attainable under the batch test conditions.

A typical leaching column or lysimeter consist of stainless steel leaching columns. The lysimeter constructed of 6" diameter Type 316 stainless steel, Teflon O-rings, and Type 316 Stainless Steel filter screens. The overall length of typical column is 4 feet and the entire column apperature is shown in figure 2.2. Deionized water solution is pumped from a 16-gallon stainless steel reservoir, using peristaltic pump at a flow rate of 225ml/day. There is currently no standard methodology for column study but according to the needs of the testing these procedures are followed (Timothy, 1998).

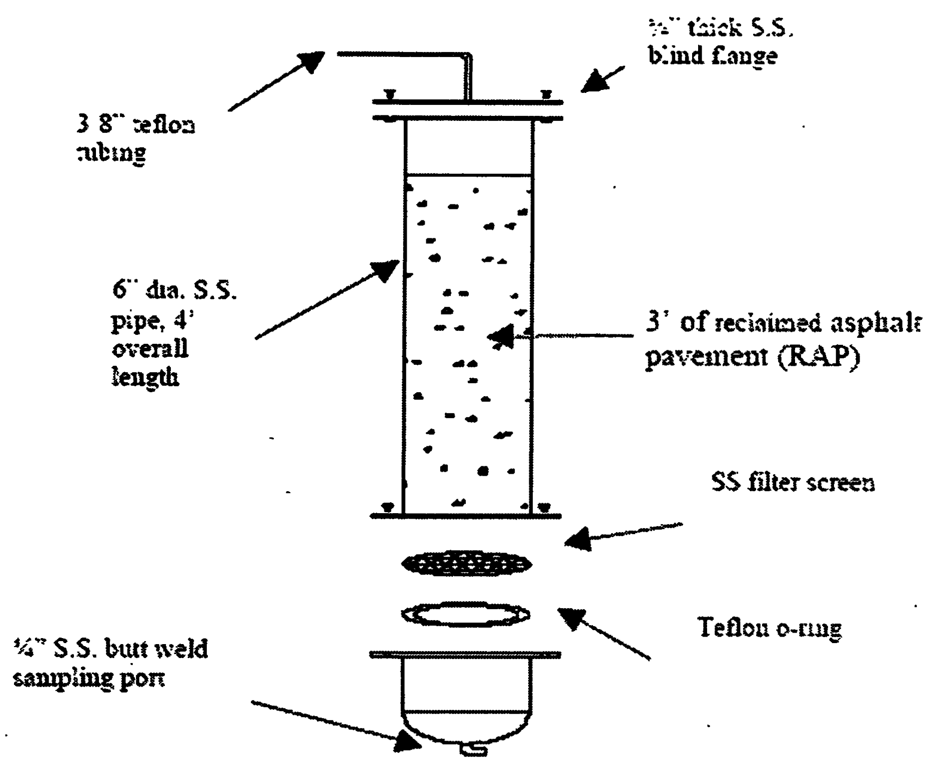


Figure 2.2 Typical leaching column lysimeter (Timothy, 1998).

Here it shows the method of sample loading and collection to the leaching column lysimeter, basically on the objective of chemical analysis. The columns were pre cleaned with deionized water and then rinsed with dilute nitric acid solution. The columns were rinsed again with deionized water and pre rinsed with leaching solution. The loading process began by placing the stainless steel filter screen at the bottom of the column. Approximately 6 inch of gravels was placed on the top of the screen and then another stainless steel filter screen was placed on top of the gravels. The gravel and screens were cleaned and rinsed with nitric acid, and heated in an oven at 110°C over night. The addition of gravel allowed for unsaturated leachate sample to remain separated from Reclaimed Asphalt Pavement (RAP) after draining to the bottom of the lysimeter the stainless steel filter screen protected against infiltration of particles into the lechate samples. The RAP samples were loaded into the columns with approximately 3 feet of RAP material placed into the column. Three inches of fine sands were placed on the top of the RAP to help the distribution of the leaching solution evenly through the column. The sands were pre cleaned in the same manner as the gravels (Timothy, 1998)

2.9 Factors Controlling Leaching

The factors influencing the chemical leaching from waste materials can be categorized as,

- Physical factors
- Chemical factors
- Biological factors

Physical factors	Chemical-biological factors
Particle size, contact time, homogeneity, liquid to solid ratio, porosity, sorption, partitioning, temperature, type of flow	pH, redox, complexation, precipitation, organic carbon content, alkalinity, common ion effect

Table 2.4 Categorization of physical and chemical factors

2.9.1 pH

pH is significant factor controlling the release of waste materials. The pH in leaching experiments controlled by number of reactions such as dissolution of atmospheric CO_2, production of CO_2 as a results of biological activity, dissolution of minerals in waste materials. Many metals are widely known to have the tendency to leach more at extreme pH values (Goumans et al., 1991; Van Der Sloot et al., 1997; Jang et al., 2002).

2.9.2 Particle size

Surface area exposed to the leaching solution is determined by particle size of the waste materials. Where a larger surface area is expose to leaching solution, resulting in more chance of leach contaminants from the materials to the solution. Hence many leaching tests are carried out on size reduced materials.

2.9.3 Complexation

When ligands or number of molecules are attached covalent bonds to ion, complex formation occurs. A common example of such complexation is metal/organic acid complexes.

2.9.4 Oxidation Reduction Condition

This may play a significant role in chemical leaching from the waste. Here oxidation reduction potential (ORP) is measured to determine the oxidation reduction condition in a given chemical system. ORP indicates the intensity of oxidation or reduction in the chemical system. For some heavy metals, this ORP changes the oxidation state of the metals consequently determine their mobility in the environment.

For example arsenic is commonly known to exist as As^{+3} and As^{+5}. The As^{+3} is believed to be more mobile and toxic then the As^{+5}. As a result arsenic will leach from waste at higher rate under reduced conditions.

Biologically active environment such as MSW landfill can create reducing condition typically less than -200mv of ORP, resulting in heavy metals being substantially immobilized within the waste through precipitation with sulfides and complexation with organic acids. Currently leaching behavior of waste materials under reducing condition has not been well addressed by commonly used batch leaching tests.

2.9.5 Liquid –to-Solid (L/S) Ratio

The L/S ratio is defined as the amount of leaching solution in contact with the amount of waste material tested. In batch tests, L/S ratio typically ranges from 20 to 10, while low L/S ratio is used in column or field tests.

2.9.6 Contact Time

Quantity of contaminants leached may be influenced by the amount of the tome which the leaching solution is contact with the waste material unless the equilibrium condition are established. In extraction batch test, contact time is equal to the duration of the test. Due to this contact time should be run until the equilibrium conditions are reached for the contaminants interest (Timothy et al, 2003).

2.10 Factors effecting to the leaching depending on leaching compound

Compounds leaching through column can be mainly categorized as,

- Organic compounds
- Inorganic compounds

2.10.1 Factors effecting to the leaching of organic compounds

For most organic chemicals the controlling factors for leaching can be listed as below,

- Solubility
- Partitioning
- Presence of organic carbon
- Solid to liquid ratio for extraction
- Non-Aqueous phase liquid

2.10.2 Factors effecting to the leaching of inorganic compounds

Most inorganic chemicals leachability is controlled by following factors,

- pH
- Redox condition
- Solid to liquid ratio for extraction
- Solubility
- Solid phase compounds (Ishwar, 2003)

2.11 Anaerobic Digestion Process

Waste of the leaching column is mainly subjected to anaerobic digestion as anaerobic condition is developed in the system. Anaerobic biodegradation of organic materials proceeds in the absence of oxygen and the presence of anaerobic microorganisms (Karen, 2005). Anaerobic digestion is the consequence of a series of metabolic interactions among various groups of microorganisms. It occurs in three stages;

- Hydrolysis or liquefaction
- Acidogenisis
- Methonogenisis
-

2.11.1 Hydrolysis or liquifacation

This is the first stage of hydrolysis or liquefaction and during this stage insoluble complex organic matters such as cellulose are converted to simple organic compounds such as sugars, fatty acids and amino acids. Fermentative microbes such as *Sachchoromyces sp.* are activated in this stage. The complex polymeric matters is hydrolyzed to monomers, e.g., cellulose to sugar or alcohols, proteins to peptides or amino acids by hydrolytic enzymes like lipase, amylase, protease secreted by microbes. Hydrolytic activity is significant importance in high organic waste and this stage may be a rate limiting factor of digestion. By application of chemical reagent hydrolysis of organic waste can be enhance and digestion period can be result the shorter and produce high methane yield. Some industries apply the chemical reagents to make the digestion period short.

Hydrolysis or Liquefaction Reactions

Lipids $\longrightarrow$ Fatty acids

Polysaccharides $\longrightarrow$ Monosaccharides

Proteins $\longrightarrow$ Amino acids

Nucleic acids $\longrightarrow$ Purines and Pyrmidines

2.11.2 Acetogenisis

Acetogenic bacteria are activated in this second stage and they are called as acid formers even. It converts first phase products to simple organic acids, hydrogen and carbon dioxide. The principal acids formed during acetogenisis are acetic acids (CH_3COOH), butyric acids (CH3CH2CH2COOH), and ethanol (C2H5OH).

Some of microbes that are contributing to acetogenisis reaction are *syntrophobacter wolinii*, a propionate decomposer and *sytrophomonas wolfei*, a butyrate decomposer. Other acid formers are *clostridium spp.*, *peptococus anaerobes*, *lactobacillus*, and *actinomyces*. An example for acetogenic reaction shown in below;

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

2.11.3 Methonogenisis

This is the third and final stage, here methonogenic bacterial reaction is taken place. These bacteria are called as methane formers. This reaction processed in two ways;

- By means of cleavage of acetic acid molecules to generate carbon dioxide with hydrogen.
- By reduction of carbon dioxide with hydrogen

Methnogenic bacteria include *methonobacterium*, *methonobacillus*, *methonococus*, and *methonosarcina*. Methonogens again can be divided as acitates and H_2/CO_2 consumers. Methonosarcina spp., methonothrix spp. (also, methonosaeta) are considered to be important as it activates in both ways of acitates and H_2/CO_2 consumers. Reaction taken place during this methonogenic stage can be expressed as;

- CH3COOH → CH4 + CO2 (eg. *Methonosarcina Barkeri*)
  (acetic acid) (methane) (carbon dioxide)

- 2C2H5OH + CO2 → CH4 + 2CH3COOH
  (ethanol)

- CO2 + 4H2 → CH4 + 2H2O (eg. *Methonobacterium Bryantii*)
  (hydrogen) (water)

(www.anaerobic digestion.com, 2007)

Methane production is higher from reduction of carbon dioxide but limited hydrogen concentration in digesters results in that the acetates reaction is the primary producers of methane (Verma, 2002).

2.12 Important analyzing parameters in leaching column process

Microbial growth is a paramount process in the degradation of solid waste in a leaching column. Here gravel act as a good surface for microbial growth. The operating parameters can be control the degradation of waste by enhancing microbial activity and thus increasing the anaerobic degradation efficiency of the system. Some of these parameters are,

2.12.1 Total solids content (TS)

A total solid is the term uses to define material residues remain in a vessel after evaporation of sample and its subsequent drying in an oven at a constant temperature (103°C or 180°C). TS includes Total Suspended Solids, the portion of solids remain after filtration, Total Dissolved Solids, the portion of Solids passes through a 2.0μm(or smaller) nominal pore size filter (Yonge, 2006). TS is a better measure of the actual kinetics of the microbial population and substrate, respectively in biochemical transformation (Basnayake, 2007). Low solids in the system contains less than 10% TS, medium solids (MS) about 15%-20% and high solids (HS) processes range from 20%-40%. It has been identified that increase TS in the reactor leads to increase in the reactor volume (Raman, 2002).

2.12.2 Total Dissolved Solids

TDS is portion of solids in liquid that can pass through 2 micron filter. The more minerals dissolves in the liquid it increases the TDS in the liquid (www.bfhe.wa.gov, 2007). TDS of a liquid consist of both organic as well as inorganic components (Bosnic et.al, 2000). In many cases persistent of this organic and inorganic dissolved compound leads to cumulative toxic effect (Genschow et.al, 1996). The major components of inorganic dissolved solids include the ions of calcium, magnesium, sodium, potassium, bicarbonates, chlorides, sulphites etc. An amount of 2100mg/l is the permissible TDS limits in water as per EPA standards. Maximum TDS level for drinking water have set up in 500mg/l by EPA standards (Kumar et al, 2005).

2.12.2 Volatile Solids (VS)

The volatile solids (VS) in organic wastes are measured as total solids minus the ash content as obtained by the complete combustion of feed waste or leachate. The volatile solids comprise the biodegradable volatile solids (BVS) fraction and the refractory volatile solids (RVS). It has been showed that the knowledge of the BVS fraction of MSW helps in better estimate the biodegradability of wastes, biogas generation, organic loading rate and C/N ratio (Raman, 2002).

Biodegradable VS can be considered as substrate in leaching column where the reaction is taking place in the solid-liquid phase. Since biodegradable VS is proportional to the BOD_{ult} under anaerobic conditions (Basnayake et al., 2006) or a product of a former reaction that can once again become a substrate for subsequent reactions until solids are mineralized (Basnayake et al.,2007).

Lignin is a complex organic material that is not easily degrade by the anaerobic microbes and constitutes the refractory volatile solids (RVS) in organic MSW. Wastes can be characterized as high VS, low non-biodegradable matter or RVS and this characterization best suit to anaerobic digestion (Raman, 2002).

2.12.4 Total Suspended Solids (TSS) and Volatile Suspended Solids (VSS)

Total Suspended Solids are the portion of total solids remained in the filter after filtration. The separation of suspended solids from the dissolved solids is controlled by the type of filter holder, porosity, pore size, thickness like principle factors of filter as well as physical nature, particle size and amount of materials deposited in the filter effect to the TSS amount (Yonge, 2006). TSS is better measure of actual kinetics of microbial population and substrate , respectively in biochemical transformation (Basnayake, 2007). As well as VSS is a indirect measure of microbial population has been well documented (Loehr, 1984; Scheneider et.al., 2007)

2.12.5 pH level

Anaerobic bacteria, especially methonogens, are sensitive to the acid concentration with in the column and the methonogens growth can be inhibited by high acidic conditions. The acid concentration in aqueous system is expressed by the pH value. At neutral condition, water contains the 10^{-7} of hydrogen ions and has a pH of 7. Acidity indicates pH value lower than 7 and alkalinity is showed by increasing the pH value higher than 7. It has been identified that optimum pH value for anaerobic digestion lies between 5.5 and 8.5. During digestion of waste, two processes methonogenisis and acidogenisis needs different pH levels for optimum process control.

The acidogenisis can leads to accumulation of large amounts of organic acids resulting in pH below 5. Excessive generation of acids can inhibit the action of methonogens, due to their high sensitivity to the acidic condition.

As digestion reaches to the methonogenisis stage, the concentration of ammonia increases and the ph value can increase to above 8. When methane production is stabilized, ph lies between 7.2 to 8.2.

CHAPTER 03

MATERIALS AND METHODOLOGY

3.1 Preliminary study on leaching column and identify the best water waste ratio to add the leaching column.

3.1.1. Experimental site

The experiment was carried out at Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya.

3.1.2. Materials:

2 bottles of 5 L

Gravels of 5m^3 volume

¼ flexible transparent horse 0.5m

½ valve socket

½ forest sockets

½ endcaps

Grinder

Plastic tray

1 L measuring cylinder

Weight balance

Polythine gauge 0.5m

3.1.3 Procedure:

3.1.3.1. Preliminary study for finding optimum waste to water ratio.

As showed in the Figure 3.1, five liter plastic bottles were used as the experiment set up. Cleaned gravels were layered in the bottom of the bottle up to 5cm height as a surface for the microbial growth and development. Gas collecting point was connected to the 300 gauge polythene bags to measure the gas volume. Finally the set up was checked for leakages. Mixed waste was used as the substrate.

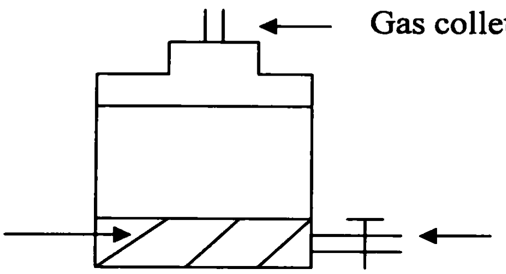


Figure: 3.1 Basic structure of preliminary study.

3.1.3.2. Preparation and feeding of the waste to the experiment unit.

Mostly disposal five types of municipal solid wastes were used for the experiment. Food wastes and coir waste were collected from restaurant of Peradeniya in market premises. Fish and meat were collected from Peradeniya market premises. Garden wastes were collected from Peradeniya university premises. Then mixed wastes were prepared by mixing same proportions of above waste types which were collected from different places.

Then mixed waste particle size was reduced to 5mm size by passing through shredding machine. 100g of shredded mixed waste was weighed and added with 2 L of water to obtain 20:1 water to waste ratio. Same procedure was followed to the other experiment set up but in second experiment set up 400g of shredded waste was used with 2L of water to get 5:1 water to waste ratio. After feeding the waste to the experimental set up, it was sealed by applying the grease to avoid leakages and to maintain the anaerobic condition for achieving optimum reaction.

Sampling was done daily basis from both leaching columns. 100 ml volume of leachate was taken from the leaching columns at each sampling time and leachate quality parameters were tested. In addition to that experiment set up weights and gas volume also measured in daily basis. As mention above quality parameters were tested daily basis such as Total Dissolved Solids (TDS), Conductivity, Salinity, pH, Total Solids (TS), Volatile Solids (VS), Total Suspended Solids (TSS) and Volatile Suspended Solids (VSS). Experiment was carried out 12 days and data were analyzed to find the best water to waste ratio.

3.2 DESIGNING OF LEACHING COLUMN

3.2.1. EXPERIMENTAL SITE

The experiment was carried out at Meewatura University farm, Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya.

3.2.1. MATERIALS

6" diameter PVC pipe 1.5m

½" flexible transparent horse 150m

½" forest sockets

½" valve sockets

½" L bend

½" T bend

¼" L angle iron

6" endcaps

PVC glue

No leak compound

5 cans of 20 L

3.2.2. APPARATUS:

Iron bending machine

Lathe machine

Spanners

Welding machine

Aczo blade

3.2.3 PROCEDURE:

According to the Figure 3.2 and 3.3 designing of leaching columns were done. Leaching columns were prepared by using four feet height and six inch diameter PVC pipe. Cleaned and washed gravels were layered till 15 cm thickness as a surface for microbial growth and development, and as a filter media. Gas measuring and pressure balancing orifices were made at the head end cap (see Figure 3.4). Sampling port was attached to bottom end cap (see Figure 3.5).

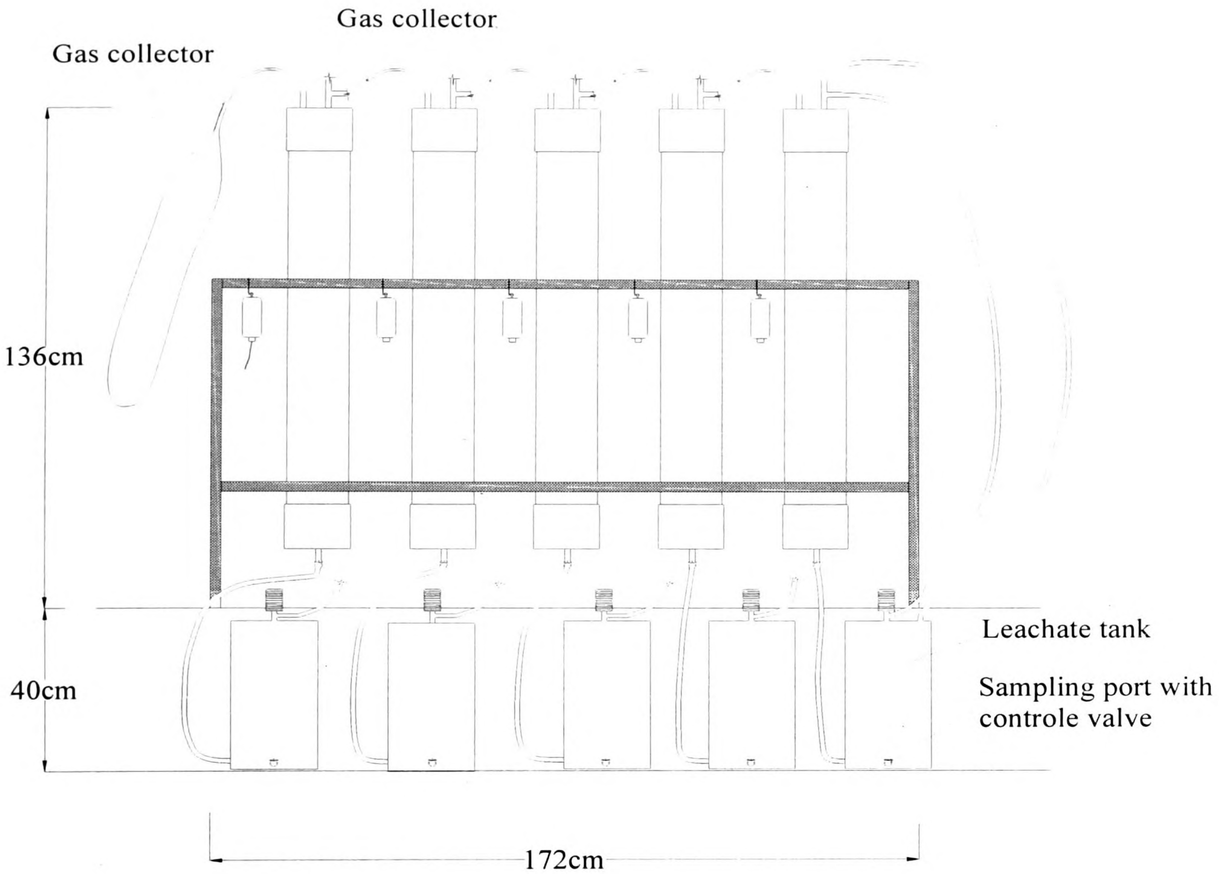


Figure 3.2 Front view of leaching columns structure

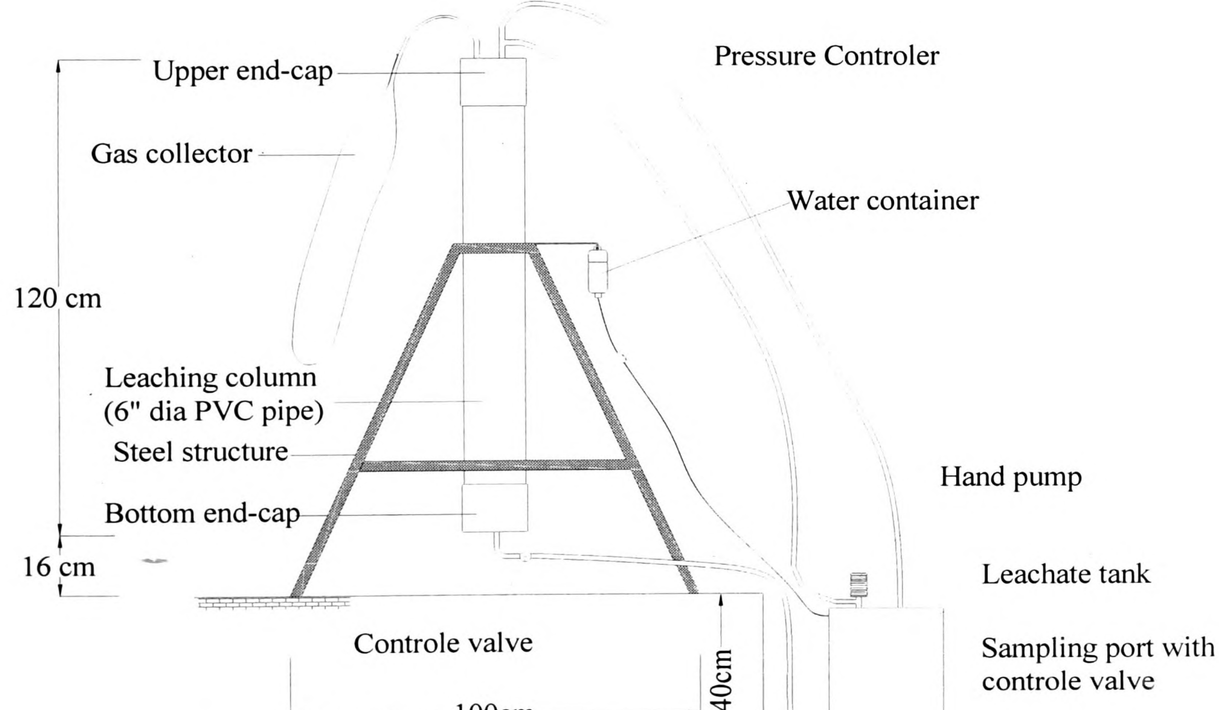


Figure 3.3 Side view of leaching columns structure

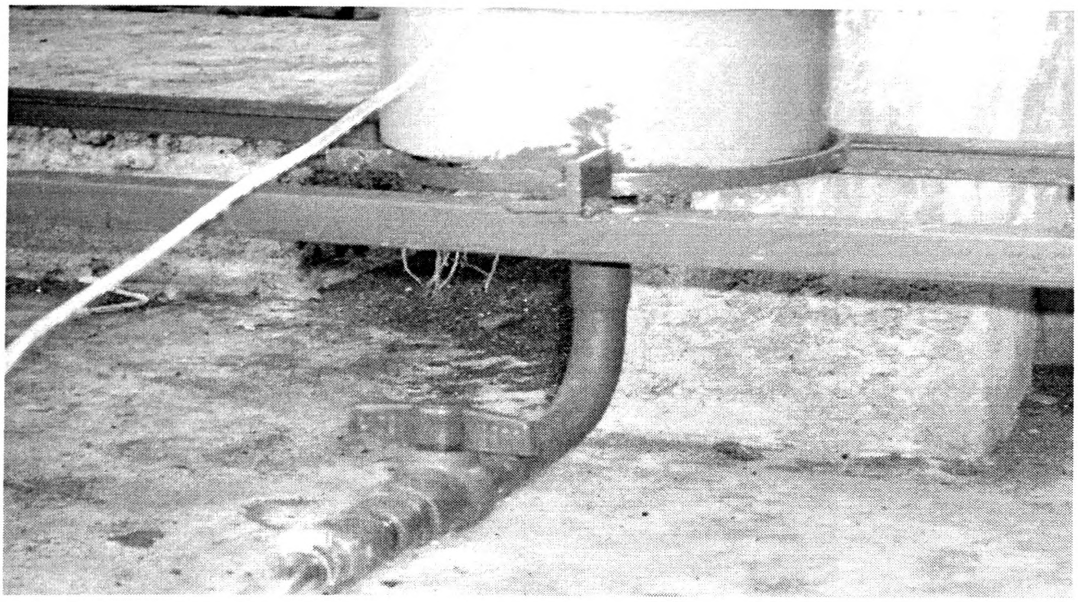


Figure 3.4 Head end cap of the leaching column

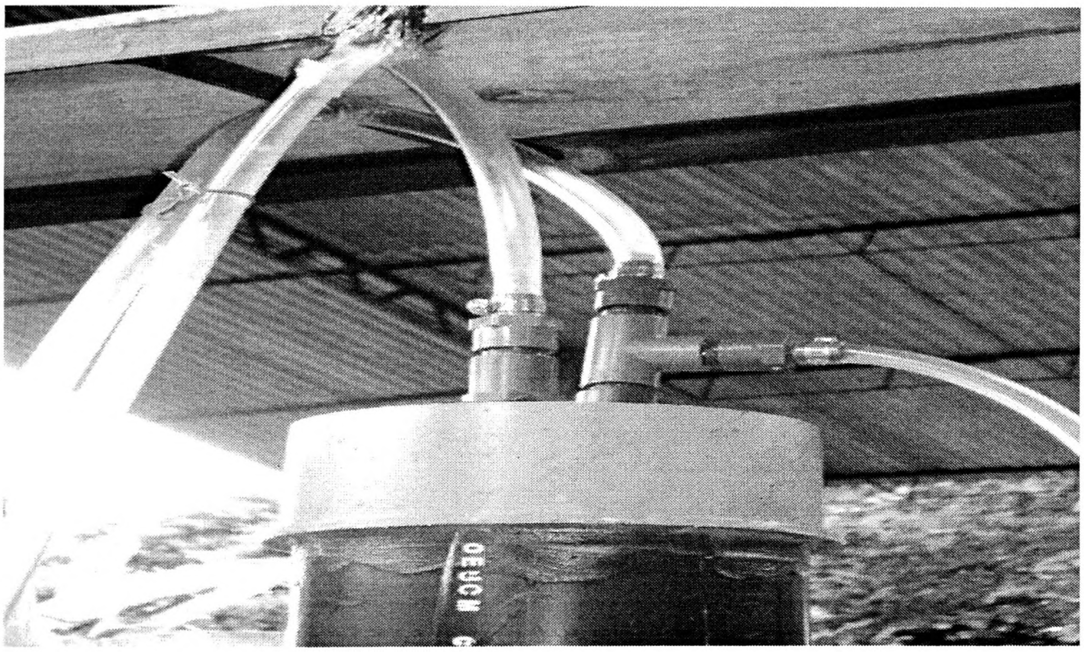


Figure 3.5 Bottom end-caps of the leaching column

Twenty liters volume cans were used as the collecting and storage tanks (Figure 3.6). Control values were fixed to the sampling points for regulating the leachate flow during sampling (see Figure 3.7). Sampling port was made at the bottom of the can to obtain the well mixed sample for representing the actual condition. Pressure controlling tube arising from the head cap was fixed to the top of the can (see Figure 3.8). Manually operating pump was fixed to the collecting tank for refilling the leachate to the leaching columns while recirculation taking place.

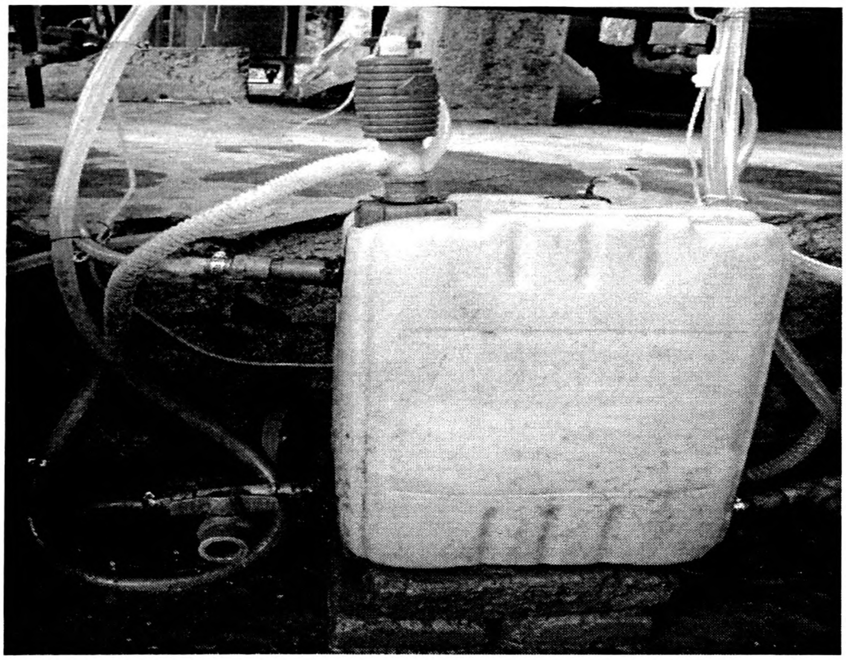


Figure 3.6 leachate collecting can

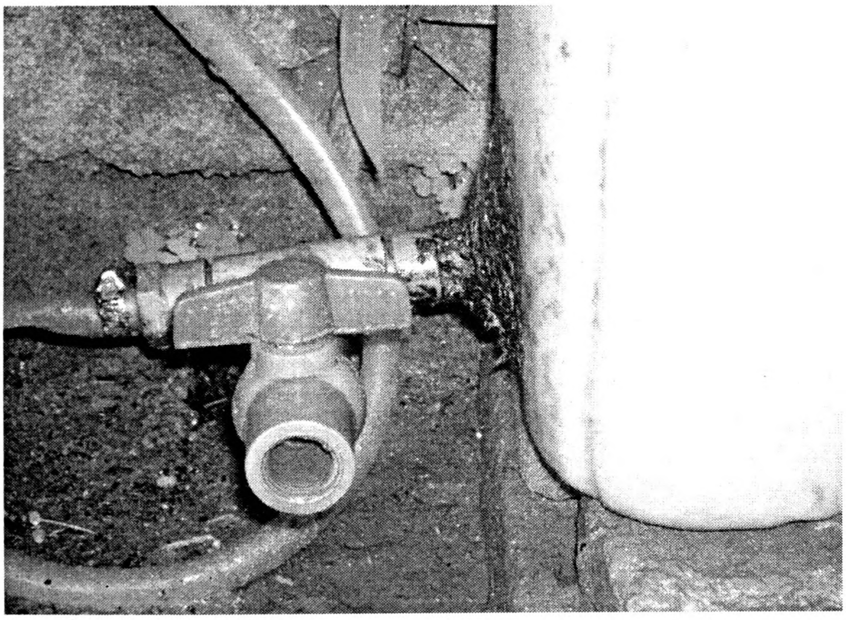


Figure 3.7 leachate sampling point

Figure 3.8 View of the experiment set up

3.3 Leaching column study

3.3.1. Sample preparation and feeding to the leaching columns.

Food waste and coir waste was collected from restaurants of Peradeniya market premises. Garden waste was collected from University of Peradeniya premises and Meewatura University Farm. Fish and meat waste was collected from Peradeniya market premises. Mixed waste was prepared by mixing food waste, fish and meat, coir and garden waste relative proportion similar to the rations of MSW. For creating optimum microbial activities, all kind of waste was shredded for reducing partial size for achieving optimum reaction rate.

After the preparing samples, 1kg of food, fish and meat, coir, garden and mixed waste was added to the five columns separately. Then 20L of water was added to each column to maintain the 20:1 water to waste ratio. After that the end caps of each column were fixed tightly with application of grease for accomplishing the anaerobic environment.

3.3.2 Sample collection and data analysis

Total leachate amount was collected to the storage tank at each sampling time. And each sampling time 100 ml volume of leachate samples were taken from each can and 100 ml of distill water was added to the storage can to retain constant water to waste ratio. After that the collected leachate in the cans were re-circulated by using manually operating pumps. First three days samples were collected six hours interval and after it was performed daily basis. Finally samples were analyzed for Total Dissolve Solid (TDS), Conductivity, pH, Total Solid (TS), Volatile Solid (VS), Total Suspended Solid (TSS), and the Volatile Suspended Solid (VSS).

3.3.3 Analysis of parameters

pH

pH of the leachate was measured using pH meter of ORION RESEARCH, ionizer/ Model 407A.

Conductivity and TDS

These parameters were measured using Thermoorion conductivity meter, Model 145A.

Total Solid

Oven dry method - Samples were kept in the oven under 105°C 24 hours.

TS (mg/l) = (W1-W)/Volume of sample (ml)*1000

Where

W1- Weight after oven dry

W- Weight of the crucible

Volatile Solid

Oven dried samples were weighed and kept in muffle furnace at 550C^0 for 30 minutes.

VS (mg/l) = (W2-W1)/sample volume (ml)*1000

W2- Weight after muffle dry

W1- Weight after oven dry

Total Suspended Solid

Sample volume was filtered through the Watmen no 44 Filter paper- Remaining on the filter paper was kept in the oven under 105°C 24 hours.

TSS (mg/l) = (W2-W1 -W)/Volume of sample (ml)*1000

Where

W2- Weight after oven dry

W1- Weight of the crucible

W- Weight of the filter paper

Volatile Suspended Solid

Oven dried samples were kept in muffle furnace at 550C^0 for 30 minutes and weight was taken.

VSS (mg/l) = (W2-W3 -W)/Volume of sample (ml)*1000

Where

W2- Weight after oven dry

W3- Weight after muffle dry

W- Weight of the filter paper

CHAPTER 04
RESULTS AND DISCUSSION

4.1 Analysis of preliminary study on leaching columns for identification of best waste to liquid (water) ratio

Mixed waste was used to characterize MSW which consisted of food, garden, coir, fish and meat. All of these kinds of waste were taken in equal portions to prepare the mixed waste content. The particles of the wastes were reduced to 5 mm size for achieving quick stabilization as reported by Juang et.al (2007). According to them, particles less than 30mm size completed very quick reactions and stabilization was achieved within the mass (see Figure 4.1). However waste to liquid ratio is one of most important factors which govern degradation of organic compounds as pointed out by Ishwar (2003).Thus the variations of the parameters of two replicates under different water solid ratios were critically analyzed to evaluate the best liquid to solid ratio.

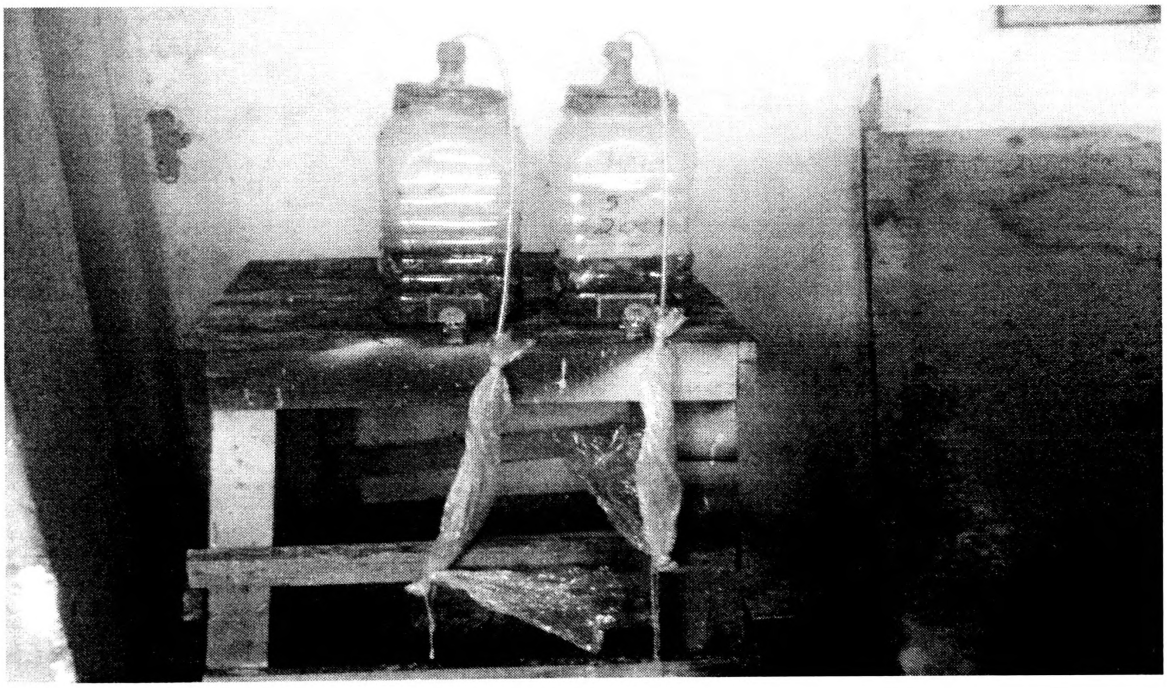


Figure 4.1 Preliminary study of leaching columns

4.1.1. TDS variation in two replicates

Atekwana et al 2004 had reported that TDS resulting from enhanced mineral weathering due to acids produced during biodegradation. Therefore TDS is the indicator to measure availability of substrate for further biological reactions. At the initial stage both replicates showed high TDS concentrations. However after 5 days, 20:1 ratio replicate showed decreasing trends of TDS since in the initial stage, there would have been rapid reductions in available substrate due to high microbial reactions (see Figure 4.2). But 5:1 ratio replicate still showed an increasing trend due to the remaining high concentration of waste. Notably, the lack of adequate water would have slowed the reaction rate, although water was also formed during decomposition reactions, resulting in an unbalance between solid and liquid (Atekwana, 2004). As mentioned earlier, TDS indicates availability of substrate and rapid TDS reduction due to the rapid substrate utilization. Therefore waste degradation rate is higher in the 20:1 ratio under the favorable solid to liquid ratio than the 5:1 ratio.

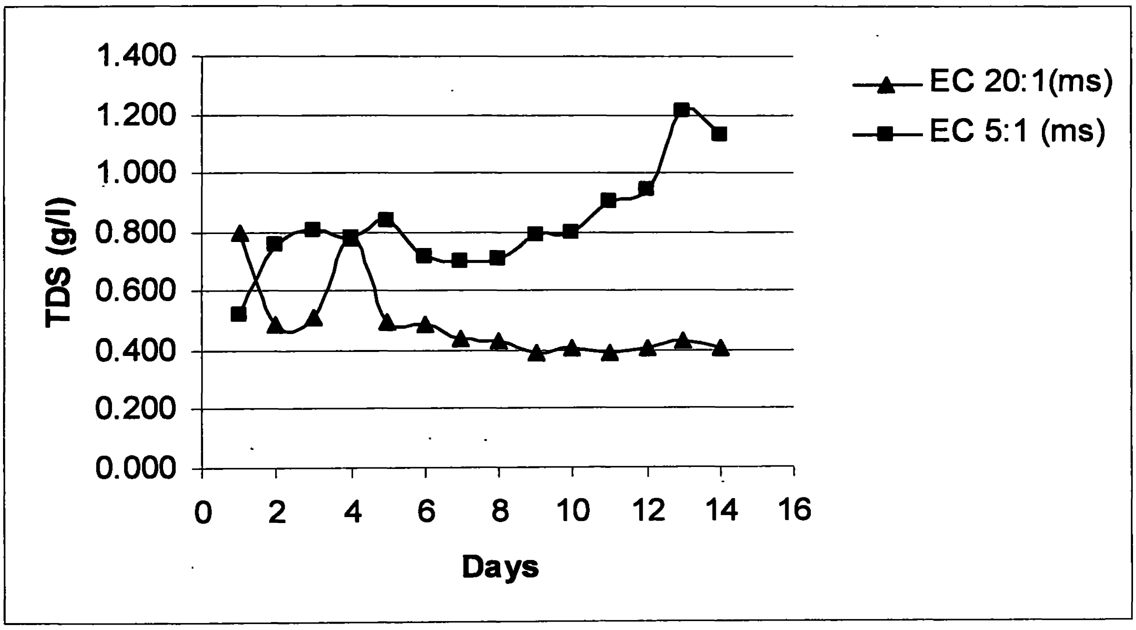


Figure 4.2 TDS variation of two replicates leaching column

4.1.2. Conductivity and salinity variations

The changes in conductivity measurements can be used to monitor the processes in wastewater treatment. In many of the treatment plants, the causes of these changes in conductivity are mainly biological removal of phosphorus and nitrogen (Atekwana, 2004). In this study, the 5:1 leaching column showed a gradual increase of conductivity, whereas, in the 20:1 leaching column, the variations of conductivity did not have a distinct pattern. However, it was observed that there was a reduction of conductivity within the period of experiment. Thus the availability of ions in the solution reduced. Whenever, there is an increase in available ions, rapid reactions of microorganisms can be predicted. However, during the reduction of substrate and stabilization of wastes, availability of ions in the solution would be reduced. So that it can be predicted for the 5:1 leaching column, since the conductivity was increasing, signifying that microorganism action was rapidly taking place, nevertheless, the substrates for the microorganisms have been reduced (Figure 4.3).

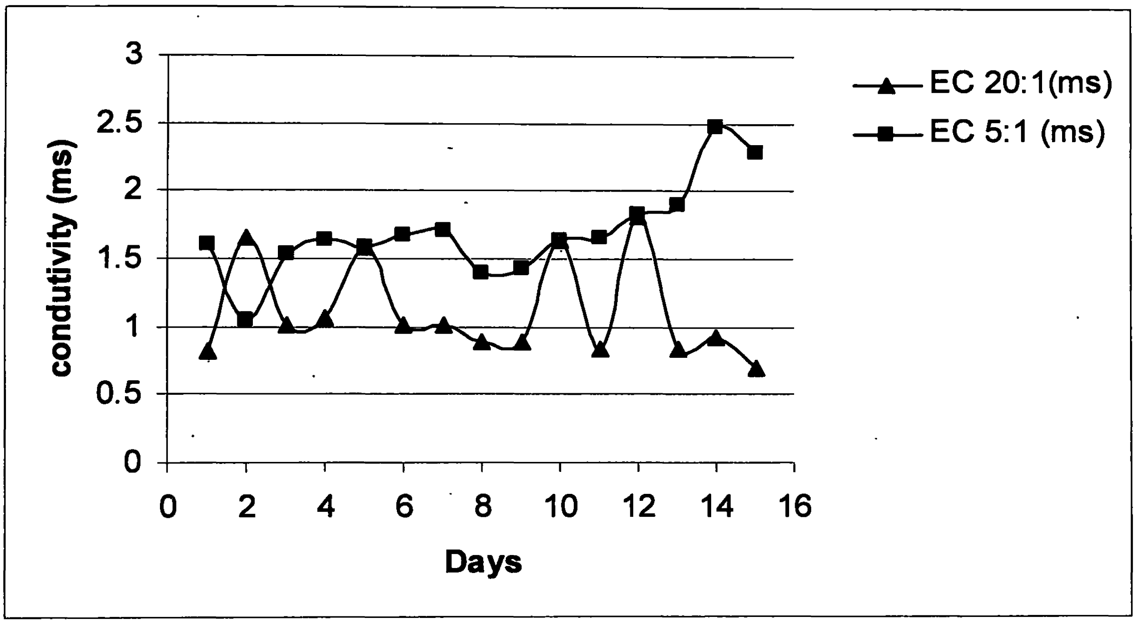


Figure 4.3 Conductivity variation of the leaching column

Initially the availability of salts, especially sodium chloride in the samples of 20:1 leaching column underwent a constant period of time. Then reduction of it could be observed and again it was constant in that reduced salinity level. The salinity variation of 5:1 leaching was different from this pattern. It observed constant salinity level for a period of time like one week then gradual increase of salts level could be observed. The pattern of salinity variation in both columns followed TDS variations of same columns with slight variations.

4.1.3. TS, VS, TSS, and VSS variations

There was a rapid increase of TS which was observed in 5:1 leaching column. The availability of high TS indicates the availability of substrate for the microbial action. Such that TSS and TS are better measures of the actual reaction kinetics of microbial population and substrate, respectively in biochemical transformations (Basnayake, 2007). So that reduction of substrate indicates the destruction of microorganisms. It could be deduced that 20:1 L/S ratio achieved better stabilization of the waste within a short period when compared to lower L/S ratios (Figure 4.4).

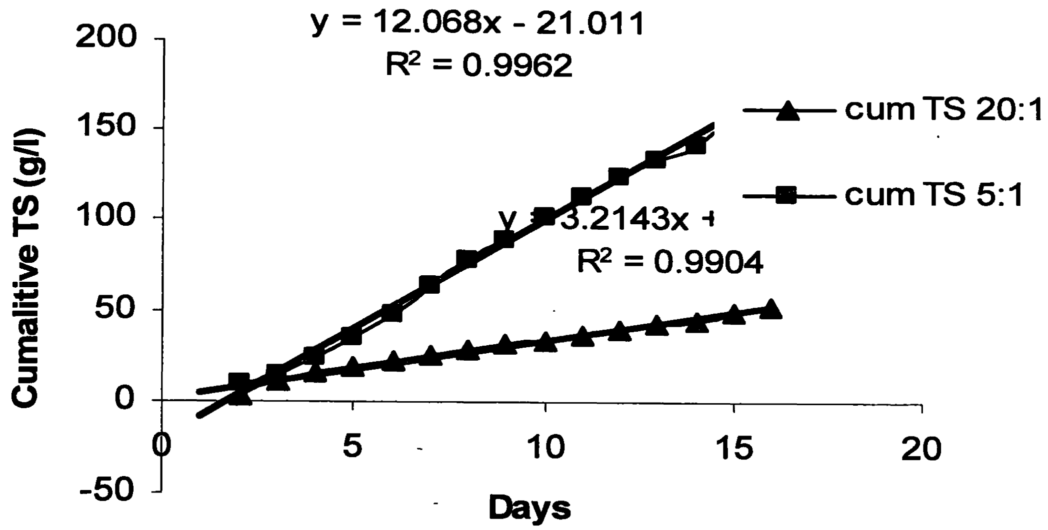


Figure 4.4 Comparison of cumulative TS variation between 20:1 leaching column and 5:1 leaching column (15 days).

4.2 Leaching column study

Similar to the earlier trial, particle reductions were done to each type of wastes with the idea of facilitating high surface area for microbial reactions. As mentioned before, Juang et.al (2007) concluded that waste stabilizations were achieved with reduced particle size < 30mm. The leachate was recirculated in designed leaching columns (see Figure 4.5) to facilitate high rate of microbial growth with the reduction of toxins being accumulated in the column. As well, recirculation leads to an even distribution of substrate in the column in same concentration. Novella *et.al* stated that leachate recirculation is stimulatory because liquid movement distributes the inoculum, minimize local shortages of nutrients and dilute potential toxins like volatile fatty acids (1997). In this study L/S was maintained at the 20:1 by ion of water by addition of water as moisture level effect to the microbial reactions. Vavlin *et.al* also stated that moisture content is a critical parameter which affects the biodegradation of MSW which can be controlled via recirculation (2002). The idea of enhancing refuse decomposition by the addition of supplemental water and/or recirculation of leachate was first proposed by Pohland (1975).

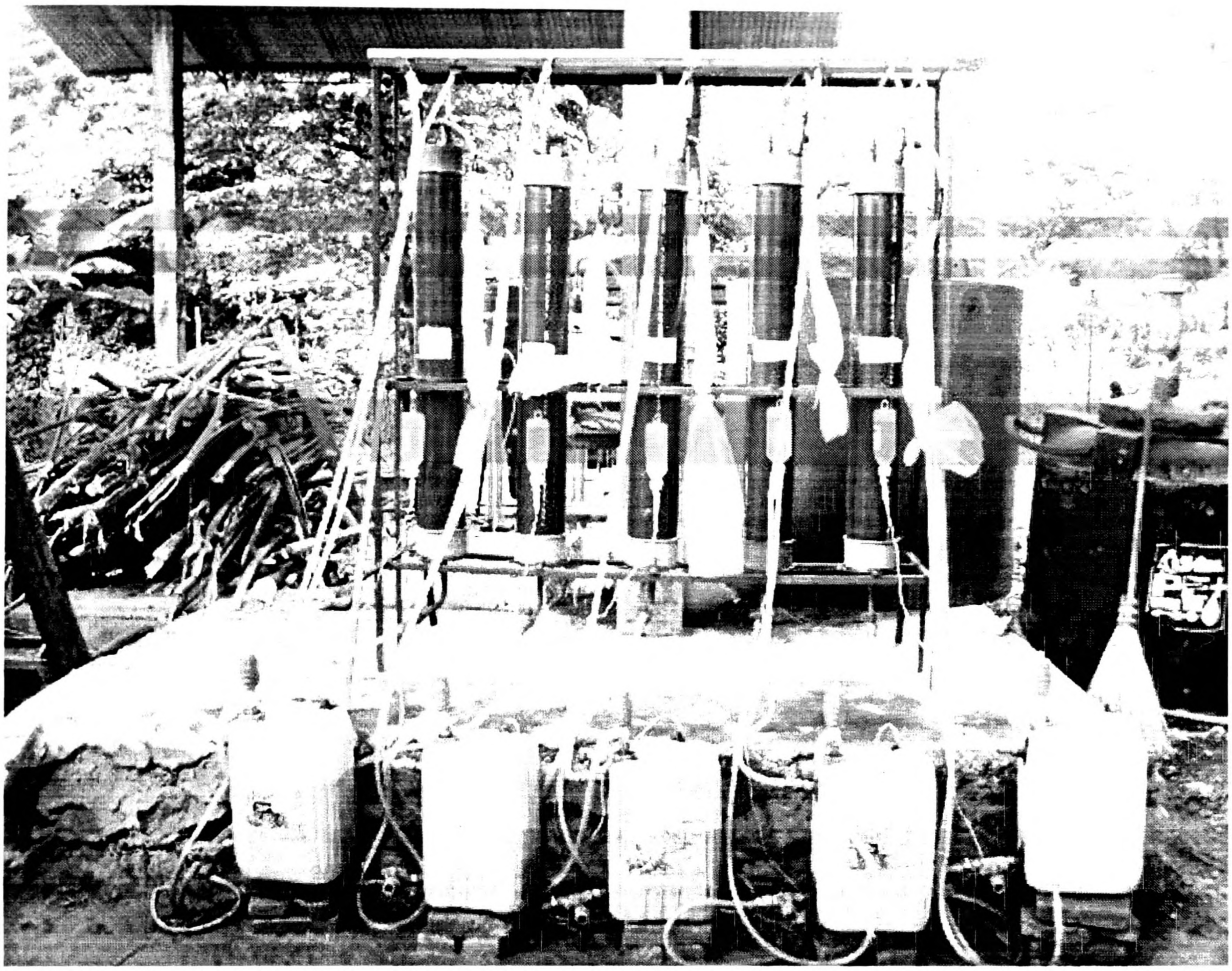


Figure 4.5 Designed leaching column structure for five types of wastes

4.2.1 Total Dissolved Solids (TDS) Analysis

Antonia stated that TDS provides an estimate of the amount of minerals available for formation of precipitates and the ionic strength of the leachate (2006). The availability of high level of TDS value indicates that an increased level of microbial populations existed. TDS is a better measure of freely available substrate for microorganisms' reactions. Thus, it could be deduced that high levels of TDS values obtained in the type 02 (Fish and meat wastes), would have resulted in high microbial populations in that column (see Figure 4.6). In fact, the TDS values were rapidly increasing in that waste type, which indicated that as yet the type 02 had sufficient organic content for degradation.

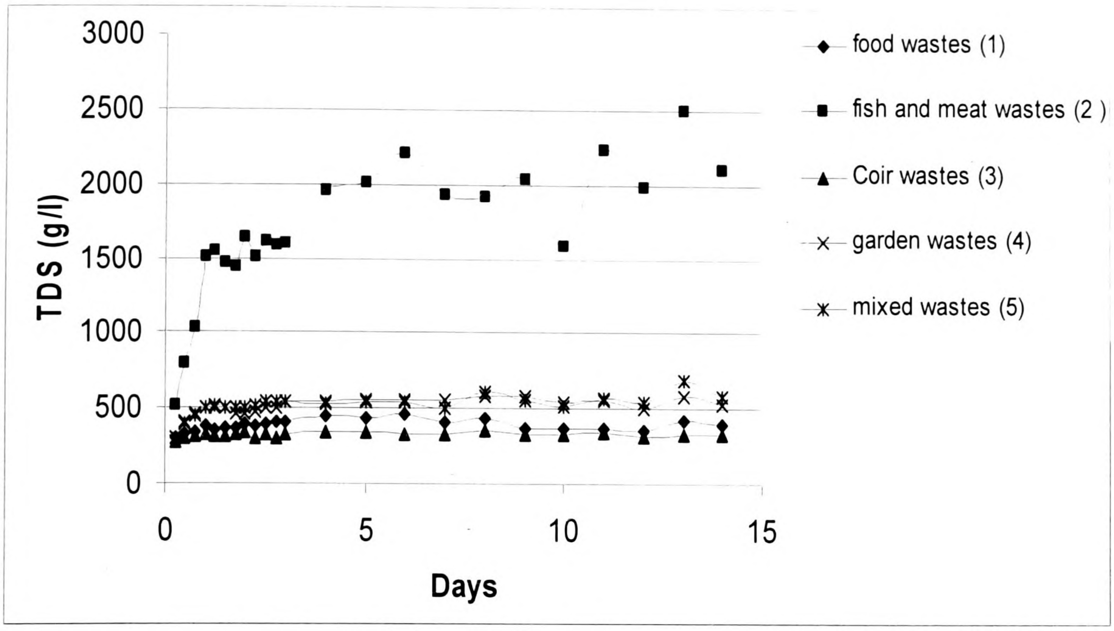


Figure 4.6 TDS variation in all five types of wastes

In somewhat similar pattern, the TDS values of other four types of waste were changing, but lower levels of TDS were observed and between them, the similarities were more than type 02. These similarities were to an extent in the first 72 hours between type 05 (Mixed wastes) and type 04 (Garden wastes) and there was a rapid increase of substrate within this period (Figure 4.7). This could be attributed to the rapid growth of microorganisms. With the availability of microorganisms, rapid degradation of waste occurred. In type 04, the rate of substrate supply for the microbes was constant. But in type 05 after rapid increase of TDS within 72 hours, addition rate of TDS was constant about up to 7 days from the start. Then again a decrease of TDS was observed ending up at a constant rate. These changes of substrate availability would have occurred with the variations of the types of microbial growth. In other words, there may have been a start of another type of microbial growth to change the substrate level in the leachate. Addition rate of substrate to the liquid in the type 01 (Food wastes) and type 03 (Coir wastes) were lower than type 02, type 04 and type 05.

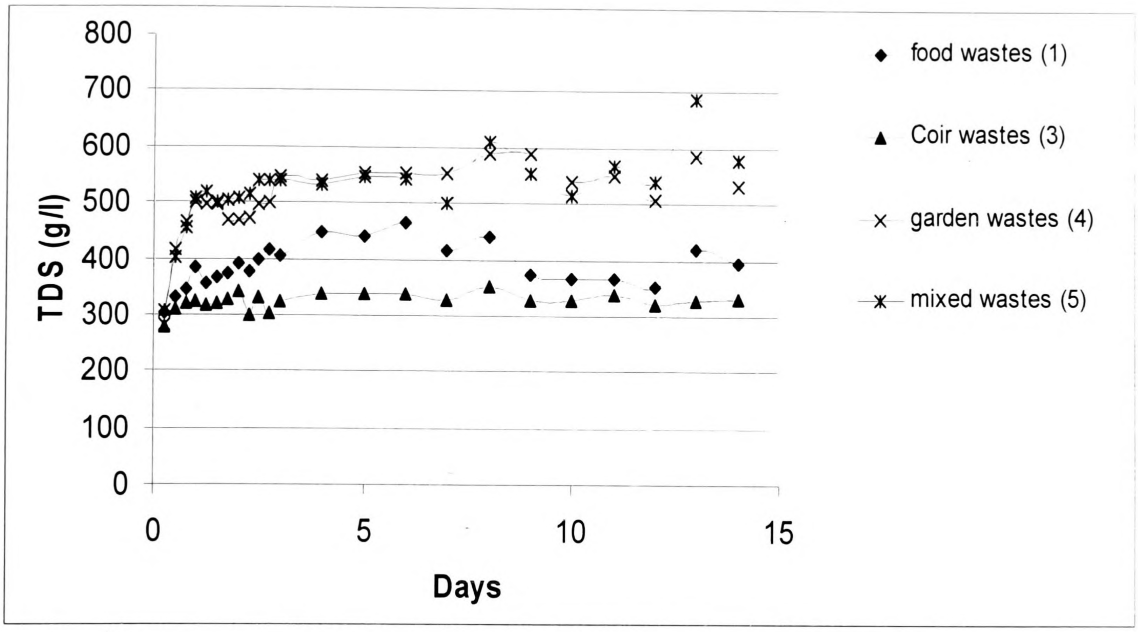


Figure 4.7 TDS variations in the experimented 4 types of wastes except type 02

4.2.2. Total Solids (TS) and Volatile Solids (VS) Analysis

Degradation of organic matter in anaerobic condition is sequential process initiated by hydrolysis of complex organic matter to simple compounds like carbohydrate, amino acids and fatty acids. The simple carbohydrate and acids provide energy for growth of fermenting bacteria, producing volatile acids and hydrogen (Antonio, 2006). The volatile acids are then partially oxidized to produce additional hydrogen and acetic acid, which are the main substrates used by methonogens to produce methane (Tchobanoglous et.al., 1993). Therefore volatile solids content can be used as a key indicator for microbial activity. These activities when critically analyzed and it seams to have followed a logarithmic pattern as shown in figure 4.8. In effect, all of the five types of wastes had increased the microbial activities in similar patterns of logarithmic growths. The increases that had taken place of microbial action in type 02, type 04 and type 05 were similar and they were rapid increases in comparison to other two types of type 01 and type 03. Initial solids content was high in type 04, type 02 and type 05, so that the observed high microbial activities may have been due to substrate availability for the growth of anaerobic microbes. It should be noted that the TS of initially fed type 04 was about thrice of other waste types (Figure 4.9). But during microbial growth that difference was not observed. It may be due to the optimum microbial growth that had occurred with the available conditions. Since microbial growth is controlled not only by substrate but also temperature, initial microbial level, pH, moisture level. It could then be confirmed that the optimum growth of microorganisms in type 04 column had taken place due to the rapid clarity in color of the leachate emissions of garden waste within 11 days.

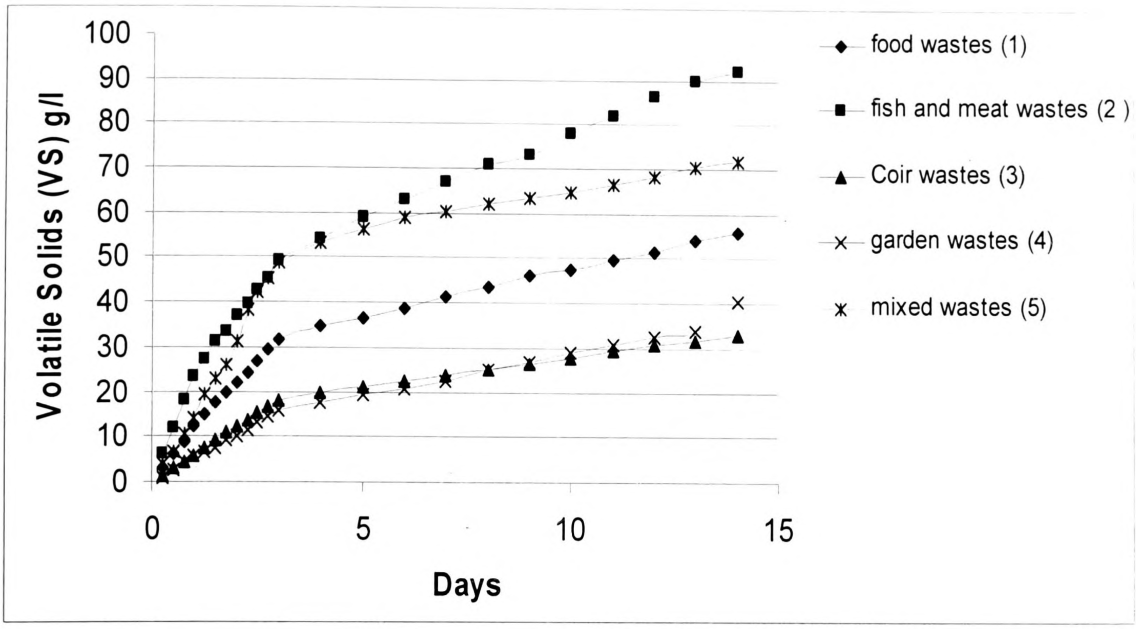


Figure 4.8 Relationship of Volatile Solids (VS) variations with the time between five types of wastes (14 days).

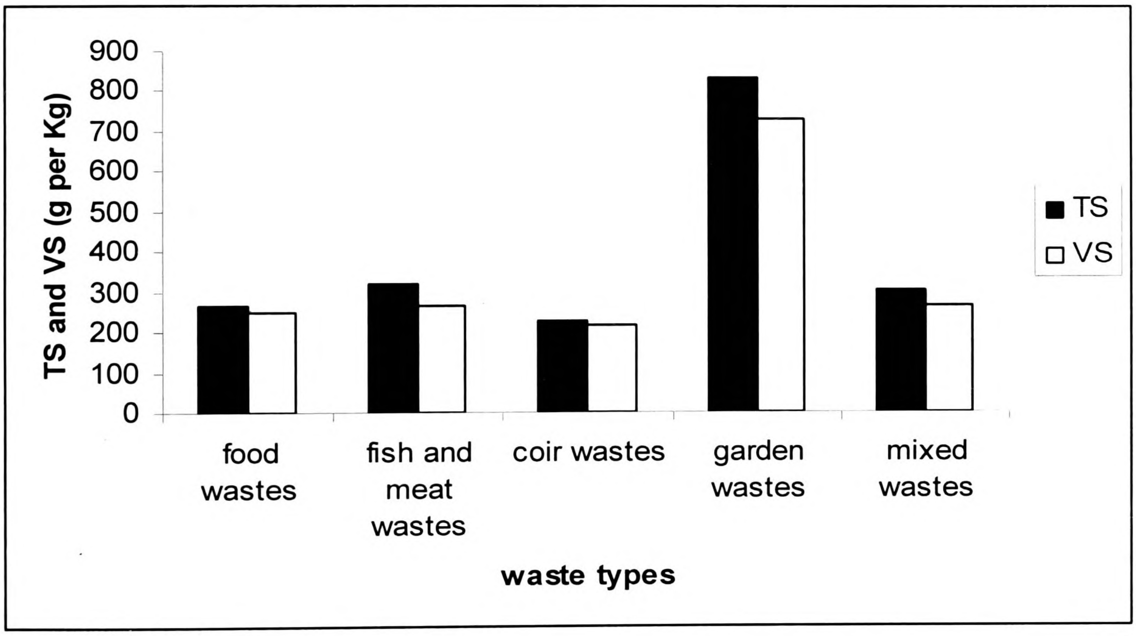


Figure 4.9: Moisture percentages of initially fed five types of wastes to leaching columns.

4.2.3 Volatile Suspended Solids Analysis

VS and VSS in leachate can be used as indicative parameters to express microbial growth dynamics. The VS loss of the organic substrate is accumulated in leachate and it is proportional to the microbial activity and therefore microbial growth can be expressed as proportional percentage of VS or VSS accumulation of the leachate (Paramsothy, 2004). In the case of type 02 showed a linear increase of VSS with the time (Figure 4.8). In other words, there was a high growth of microbes on type 02, since rapid degradation of type 02 had taken place. Similarly a linear microbial population increase could be predicted in the type 03 and type 04 (figure 4.10). In contrast, type 01 and type 05 showed logarithmic increase of VSS with the time. The degradation of type 01 and type 05 have taken placed in logarithmic pattern.

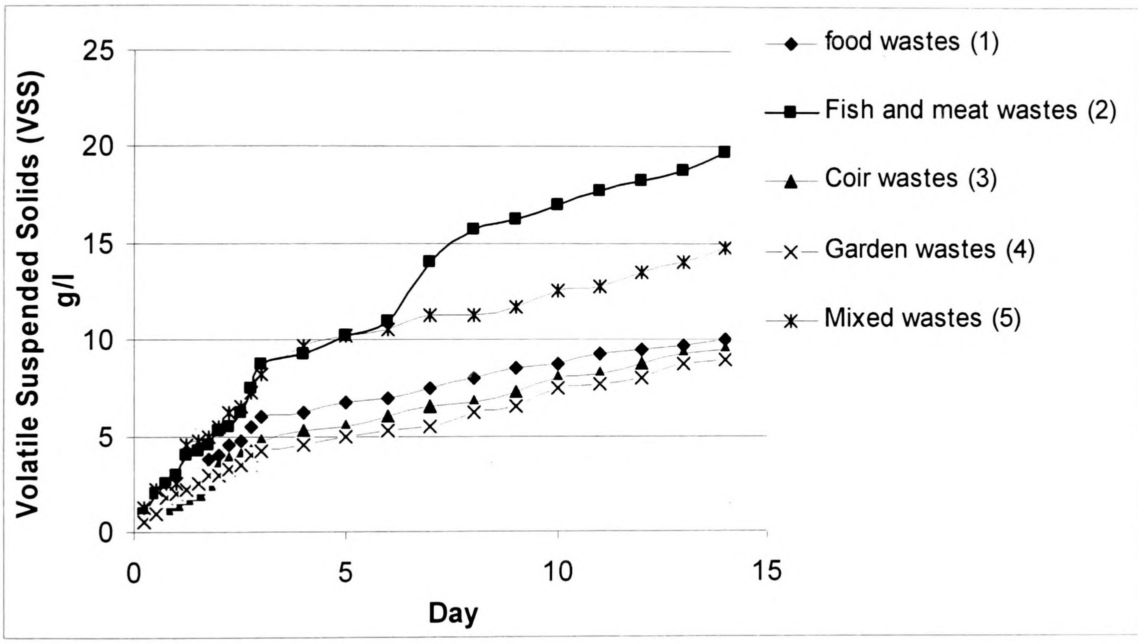


Figure 4.10 Relationship of VSS variation of five typed of wastes with the time and their predicted curves (14 days).

4.2.4 pH and other physical properties

In the analysis of the results obtained for type 03, the colour changes could be understood better since type 03 consisted low TS content as well as low microbial activity. Initially it was light yellow and after about 2 days it turned to dark brown then with the activity of microbes color degradation occurred rapidly and within 10 days it turned to light yellow, again. Similar pattern was followed by other waste types, especially type 04 waste's leachate colour which of dark brown degraded rapidly to light yellow during the experimental period. Type o1 waste was contaminated with cooked beetroot and the leachate of it was red in colour. That red colour of the type 01 waste's leachate was disappeared during the experiment period and it was taken e 3 days period. It can be understood better that rapid degradation of all five types of wastes has taken place by application of leaching column.

pH of leachate of all this five wastes varied within the acid range (Appendix 01) which is lower than pH 7. Acid formers were active in these leaching columns to degrade the waste during first 14 days period.

CHAPTER 05

CONCLUSIONS

General objectives of the present study of leaching could be achieved.

- It could be determined that 20:1 liquid to solid ratio is better comparatively to 5:1 ratio to apply to the leaching column to study on waste characteristics. Here application of 20:1 L/S ratio leads to better biochemical degradation

- A better cost effective system for leaching column study could be developed.

- All the waste types take more than 14 days for stabilization.

- Highest organic content is possessed by garden waste with minimum moisture content. Fish and meat and mixed waste even possess high organic strength comparatively to coir and food wastes.

- Increase of TS and VS occur in logarithmic order, during the degradation period in all waste types.

- Rapid decrease of organic content occurs with the time in all waste types. High degradation occurs in mainly fish and meat wastes compared to other waste types

RECOMMENDATIONS

- Redesigning the leaching column study with mean of electrical recirculation of the leachate as well as develop the leaching column with stainless steel metal would lead to study the degradation of organic waste in leaching column with more precious standard data and it can be compared with the data of this method .

- Comprehensive study on each organic waste type degradation pattern in leaching column as well as anaerobic digestion would be successful study to acquire information on degradation pattern of each waste type and compare the suitable treating method.

REFERENCES

1. Antonio J., Cardosa , Audery D.L., Bina S.N., Valerie J.H., Lisa R.R. (2006) Lysimeter comparison of the role of waste characteristics in the formation of mineral deposits in leachate drainage system, SAGE publications, www.sagepub.com

2. Anaerobic digestion.com (2007) the anaerobic digestion, anaerobic digestion chemistry, www.anaerobicdigestion.com

3. Atekana, E.A., Rowe, R.S., Werkema jr, D.D. and Legalle F.D. 2004. The relationship of total dissolved solids measurements to bulk electrical conductivity in an aquifer contaminated with hydrocarbon, Journal of Applied Geophysics 56 (2004) 281-294.

4. Basnayake B.F.A., Menikpura S.N.M., Jayakody K.P.K., Chandrasena A.S.H. (2007), Development of a protocol for organic waste characterization of MSW, 11th International Waste Management and Landfill Symposium, S. Margheritadi Pula, Cagliari, Italy

5. Benton franklin health district (2002) Total Dissolved Solids, www.bfhd.wa.gov

6. Brauer C.De et al. (2005) Characterization of organic matter during maturation of Municipal Solid Wastes in order to identify chemical parameters indicating stabilization, International Workshop "Hydro-Physico-Mechanics of landfills, LIRIGM, Grenoble1 University, France.

7. Fossberg M. (1999) Solid waste management in Asia, Urban Development Sector Unit, East Asia Pacific Region

8. Garcia-Heras, J.L. (2002), Reactor sizing, process kinetics and modeling of anaerobic digestion of complex wastes. Ed. Mata – Alvarez, J. Biomethanation of the organic fraction of municipal solid wastes, department of Chemical Engineering, University of Barcelona, Barcelona, Spain

9. Hesbach P. and Lamey S. (2001) US Department of Energy, National Energy Technology Laboratory, Pittsburgh

10. Ishwar P.M. (2003) Importance of leaching tests, Ish Inc.

11. Juanga J.P., Kuruparan P. and Visvanathan C. (2007) Optimizing Combined Anaerobic Digestion process of Organic Fraction of Municipal Solid Wastes, Environment Engineering and Management field of study, Asian Institute of Technology, Thailand

12. Kim A.G. (2005) Leaching methods applied to the characterization of coal utilization by products, ORISE Research Fellows, National Energy Technology Laboratory, US Department of Energy, Pittsburgh

13. Kumara R., Sharma P., Tiku D.K.(2005) Aerobic method removing Total Dissolved Solids (TDS) from tannery waste water, PatentStorm LLC, www.patentstorm.us.

14. Loehr R.C. (1974) Waste characteristics, In Agriculural waste management problems, processes and approaches, Acadamic press, Inc., 111 fifth Ave., Newyork

15. Paramsothy A., Wimalaweera R.M., Basnayake B.F.A. and Wijesingha D.T.N. (2004) Optimizing hydrolysis/acidogenisis anaerobic reactor with application of microbial reaction kinetics, post graduate institute of Peradeniya, University of Peradeniya, Peradeniya

16. Schaefer J. (2006) waste characterization, Enviroment science and service division with the waste hazardous material division, Michigan department of environment quality

17. Schaefer J. (2006) waste characterization, Waste Management Guide, Michigan Department of Environment Quality and Waste Hazardous Material Division, Lansingh

18. Tchobanoglous G., Theisen H. and Vigil S.A. (1993) Integrated Solid Waste Management, Engineering principles and management issues, McGrow Hill International Edition, New York

19. Timothey T.G. (1998) Leaching characteristics of Asphalt road wastes, Florida center for Solid and Hazardous Waste Management, University of Florida

20. Timothey T.G., Yong-Chul J., Thabet T. and Jenna J. (2001) Leaching tests for evaluating risks in solid waste management decision making, Department of Environment Engineering Science, University of Florida

21. Timothy T., Yong-Chul J.and Thabet T. (2003) A guide to use leaching tests in solid waste management decision making, Department of Enviroment Engineering Science, University of Florida

22. Van der Sloot H.A., Hoede D., Cresswell D. and Barton J. (2001) Leaching Behavoiur of Synthetic Aggregates, Waste management 21, 221-228

23. Vavilin V., Rytov S., Lokshina L.Y., Pavlostathis S.G. and Barlaz M.A.(2002) Distributed Model of Solid Waste Anaerobic Digestion, Effect of Leachate recirculation and pH adjustment, Water Problems Institute, Russian Academy of Science, Moscow

24. Verma S. (2002) Anaerobic digestion of biodegradable organics in Municipal Solid wastes, Department of Earth and Environment Engineering, Foundation School of Engineering and Applied Sciences, Columbia University

25. Wikipedia (2007) biodegradable wastes, www.wikipedia .com

26. Wikipedia (2007) Food wastes, www.wikipedia .com

27. Wikipedia (2007) Salinity, www.wikipedia.com

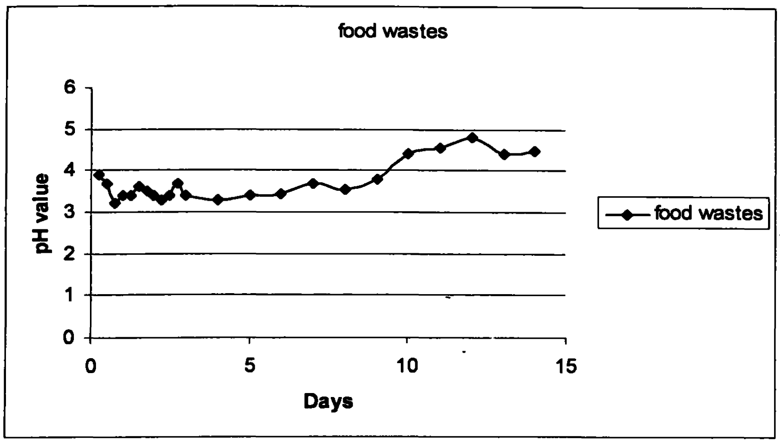
28. Wikipedia (2007) Waste types, www.wikipedia .com

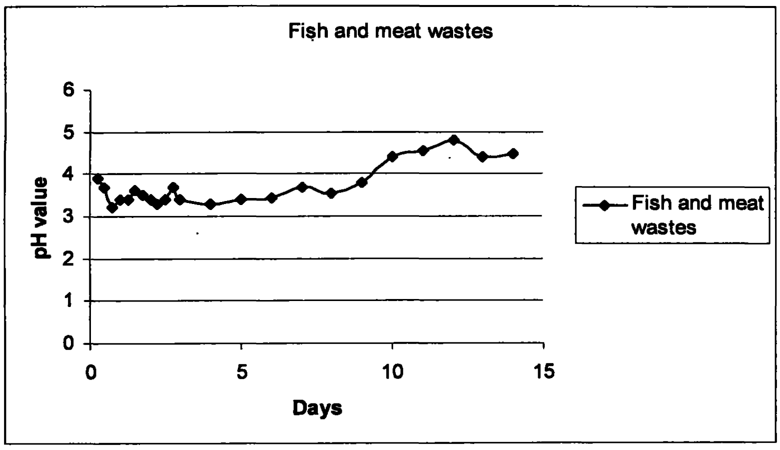
29. www.edugreen.teri.res.in (2007) Types of solid wastes

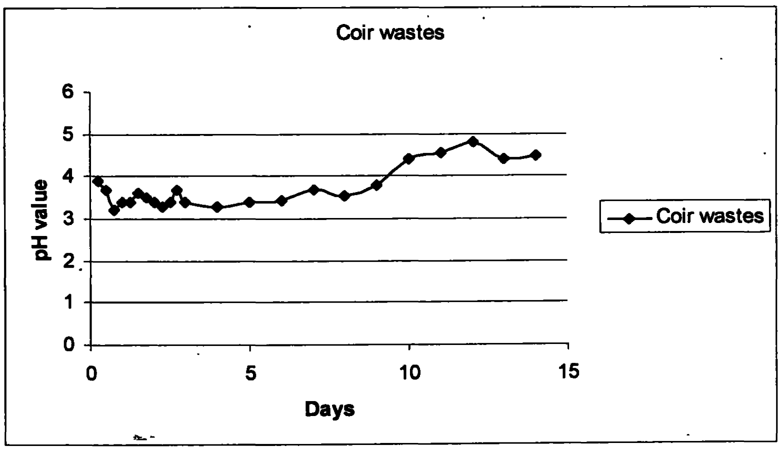
30. Yonge (2006) Total and volatile suspended solids CE 415/515, www.cmer.wsu.edu.

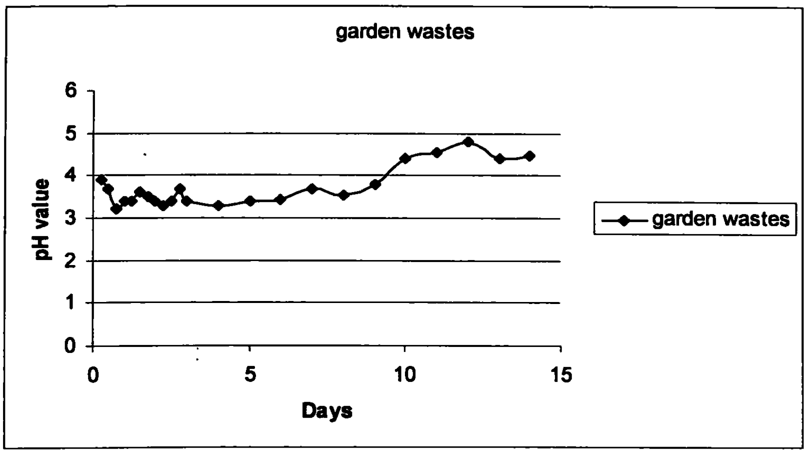
Appendix i

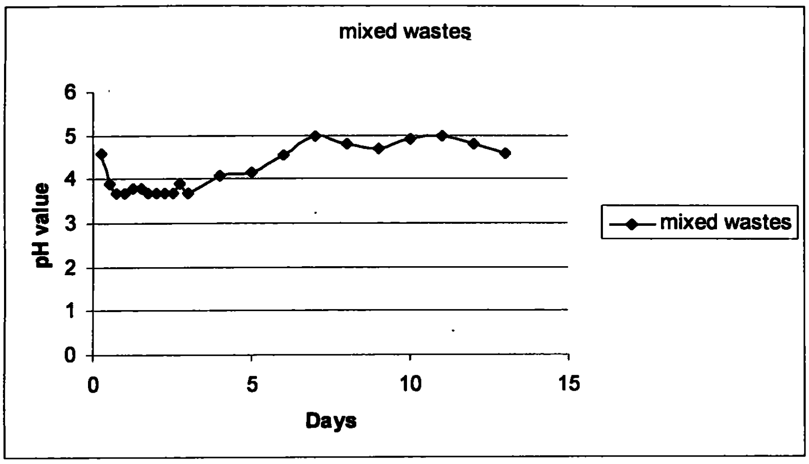
pH variation of the leachate of five types of wastes during leaching column study








garden wastes
pH value
Days
0
5
10
15
0
1
2
3
4
5
6
garden wastes


mixed wastes
pH value
Days
0
5
10
15
0
1
2
3
4
5
6
mixed wastes

National Digitization Project

National Science Foundation

Institute : Sabaragamuwa University of Sri Lanka

1. Place of Scanning : Sabaragamuwa University of Sri Lanka, Belihuloya
2. Date Scanned : 2017-09-25
3. Name of Digitizing Company : Sanje (Private) Ltd, No 435/16, Kottawa Rd, Hokandara North, Arangala, Hokandara
4. Scanning Officer

Name : B.A.C Gadarawan

Signature : ....

Certification of Scanning

I hereby certify that the scanning of this document was carried out under my supervision, according to the norms and standards of digital scanning accurately, also keeping with the originality of the original document to be accepted in a court of law.

Certifying Officer

Designation : Librarian

Name : T. N. Neighsoorei

Signature : ....

Date : 2017-09-25

Mrs. T.N. NEIGHSOOREI
(MSSc.PGD.ASLA,BA)
Librarian
Sabaragamuwa University of Sri Lanka
P.O.Box 02 Belihuloya, Sri Lanka
Tele.0094 45 2280045
Fax:0094 45 2280045

"This document/publication was digitized under National Digitization Project of the National Science Foundation, Sri Lanka"