An Investigation into the Mechanical Biological Pretreatment of Garden Waste using Forced Aeration and its Impact on Carbon Emissions Reduction Potential

by

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ABSTRACT

Disposal of garden waste is a major concern globally and particularly in a developing country like South Africa, current waste management systems do not facilitate any waste management pretreatment technique before final disposal. Global warming, results from increasing anthropogenic carbon emissions and its consequences will be a dramatic climate change if no action is taken. In this study, the potential of Mechanical biological pretreatment using forced aeration was studied as an option for garden waste pretreatment before Landfilling. The study examined the impact of the treatment process on carbon emissions reduction.

Commercial and Domestic garden waste were biologically treated in closed drums and static aerated reactors, using a forced aeration system. The treatment process was monitored for 14weeks in small drums and large reactors. Representative samples were collected every fortnightly, and analysed for physical and chemical parameters on solid matter (C/N ratio, TS, VS, RI_7, Biogas) and on Eluate (BOD_5, COD, Conductivity, pH, NOx-N and NH_3-N). The production of biogas during anaerobic decomposition was also studied by simulating a Landfill at different time frames.

The results obtained from this study showed that this technology extensively enhanced waste stabilization and decreased organic matter content within the duration of treatment. The waste segregation and shredding during mechanical treatment aided the breakdown by making available most of the organic matter. High organic fractions found in the input samples were decreased significantly after the treatment period. The biogas production rate was observed to be more in Domestic garden waste compared to Commercial garden waste and the cumulative volumes show a decrease in the production of carbon emissions for both substrates with time.

It was concluded that the forced aerated system could be used as an alternative method for the aerobic pretreatment of garden waste component before disposal in Landfill, thereby saving land resources by volume and mass reduction of the waste. This will also reduce health and environmental risks by reducing carbon emissions from garden waste which is significant to global warming control.

DEDICATION

To my mum, my dad, my love and my little princess

PREFACE

I, Yemisi Iyilade, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part, submitted it at any university for a degree. Where use has been made of the work of others, it has been duly acknowledged in the text. This research work was carried out in the School of Civil Engineering, Surveying and Construction, University of KwaZulu-Natal, Durban, under the supervision of Prof Cristina Trois.

This dissertation has been prepared in accordance with the Style Guide for Dissertations prepared by the Civil Engineering programme, University of KwaZulu-Natal, Durban.

....	....
Yemisi Iyilade	Date

As the candidate's supervisor I have approved this dissertation for submission.

....	....
Prof Cristina Trois	Date

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I want to say a very special “thank you” to my family and friends for their time and for being there when I needed them. Among them, I want to especially thank my sweetheart Johnson and my little Princess Gloria, you are so special to me.

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CHAPTER ONE

Introduction

Municipal solid waste (MSW) is generally constituted by organic compounds that will degrade mainly into Methane (CH_4) and Carbon dioxide (CO_2) if disposed off in landfills (Binner, 2002). Landfilling is the main disposal route in most developing countries (Trois et al, 2007). This could lead to pollutants emitted over a long period of time requiring control and treatment (Klaus et al, 2005). Greenhouse gas (GHG) emissions may lead to global warming, severe health issues, pollution and a negative impact on the environment. A major goal of waste management is to reduce GHG emissions (Strangeland, 2007). Disposal of MSW is a great concern in developing countries because of the increase in population and urbanisation. Pretreatment of waste prior to disposal is considered an appropriate and efficient way to minimize carbon emissions and their environmental impacts. Pretreatment is needed to reduce the emission potential of MSW and to improve the landfill performance. Study has shown that biological treatment of MSW before disposal produces a lower GHG emission compared to untreated waste (Norbu et al, 2005; Leikam and Stegmann, 1999).

About 30% of the overall MSW waste collected at the Bisasar landfill site in Durban South Africa is garden waste, which is composed of weeds, leaves, branches, hedge trimmings and grass cuttings. This fraction is slowly biodegradable waste and generally suitable for composting (EPA, 2003). It also fills up valuable ground space and contributes to the production of toxic gases such as methane when disposed off directly in landfills. In South Africa, garden waste is generated in large quantities and primarily disposed off in domestic landfills. An option of treatment that could reduce and stabilise green waste in the most efficient way is needed (Trois and Polster, 2006). By extracting garden waste from the waste stream, the biodegradable waste input to landfill would be reduced.

Several technologies are available for waste treatment including incineration, composting and Mechanical Biological Pretreatment. The use of an appropriate treatment option is essential and the choice between options is site specific. The Mechanical Biological Pretreatment (MBP) process is gaining importance as a suitable and cost effective solution in most developing countries, including South Africa (Trois et al, 2007; De Gioannis et al, 2007; Bockereis and Steinberg, 2005), because of it's relatively low cost (Münnich et al, 2006), reduction of organics, and the potential for landfill volume reduction (Adani et al, 2004). Also since landfilling is the most common

MSW disposal option in South Africa, the use of MBP could have a great impact in reducing the gaseous and liquid emissions resulting from landfill operations, by enhancing the waste stability and shortening the aftercare period.

Mechanical Biological Pretreatment includes both mechanical and biological processes (Soyex and Plickert, 2002). It is already an established complex technology for the pretreatment of MSW prior to deposition in landfills. Pretreatment using forced aeration provides an adequate aeration which prevents the waste from becoming anaerobic. The aim of this study was to investigate the efficiency of MBP using forced aeration as a garden waste pretreatment option, and to assess the impact of this process on carbon emissions reduction potential. The objectives of the research are:

i. To make a systematic inquiry into the Mechanical Biological Pretreatment of garden waste using forced aeration.
ii. To establish if proper segregation, separation of organic waste and substrate particle size reduction are crucial steps of the MBP process to achieve maximum carbon emission reduction and best compost quality.
iii. To assess the reduction of biogas production potential as a function of the duration of the composting process.

The investigation was carried out by pretreating and analyzing two types of garden waste. Commercial garden waste (CGW) collected from premises such as parks around Durban which is currently disposed off in general landfills, and Domestic garden waste (DGW) collected from private households. To investigate the influence of this treatment, lab scale experiments were carried out on a small and a large scale. CGW and DGW were collected and treated in two static aerated reactors simulating the large scale experiment and in two in-vessel 200litre drums simulating the small scale experiment. By providing both experiments with identical waste substrates, direct comparisons were made between the two scales. An anaerobic process simulating a landfill was also investigated, to characterize and monitor the carbon emissions from the pretreated waste over different time frames. Representative samples of each waste substrate were characterized every fortnightly throughout the duration of the treatment. Furthermore the factors that affected the biological process such as temperature, intensity of aeration, duration and moisture content were monitored and measured.

Treatment and disposal of garden waste are major concerns for most municipalities, and very few treatment systems are operational in South Africa. The question examined here is how can Mechanical Biological Pretreatment using forced aeration be improved to reduce carbon emission potential of garden waste? The process must be well understood to be controlled and optimized. It is important to understand the physical and biochemical processes that govern the decomposition process and the influence of the pretreatment on the carbon emissions reduction potential. The results of this study are intended to demonstrate the contributions of waste composition, shredding and a forced aeration technique to the pretreatment of garden waste.

This research began with the project background and a general literature review in Chapter two on solid waste management, global warming and its effect on the climate, the South African waste management legislation, and Mechanical Biological Pretreatment options. This was followed by Chapter three which is the summary of the laboratory methods to guide further work on this research. Chapter four presents the results of the biogas production, process monitoring, eluate and solids reduction for the treated wastes in the small scale experiment. Results and discussion for the large scale experiment are presented in Chapter five. Chapter six concludes with recommendations for implementation of this technique to local municipalities as well as waste managers in similar developing countries as South Africa. The plan and structure of this study are presented in the figure below.

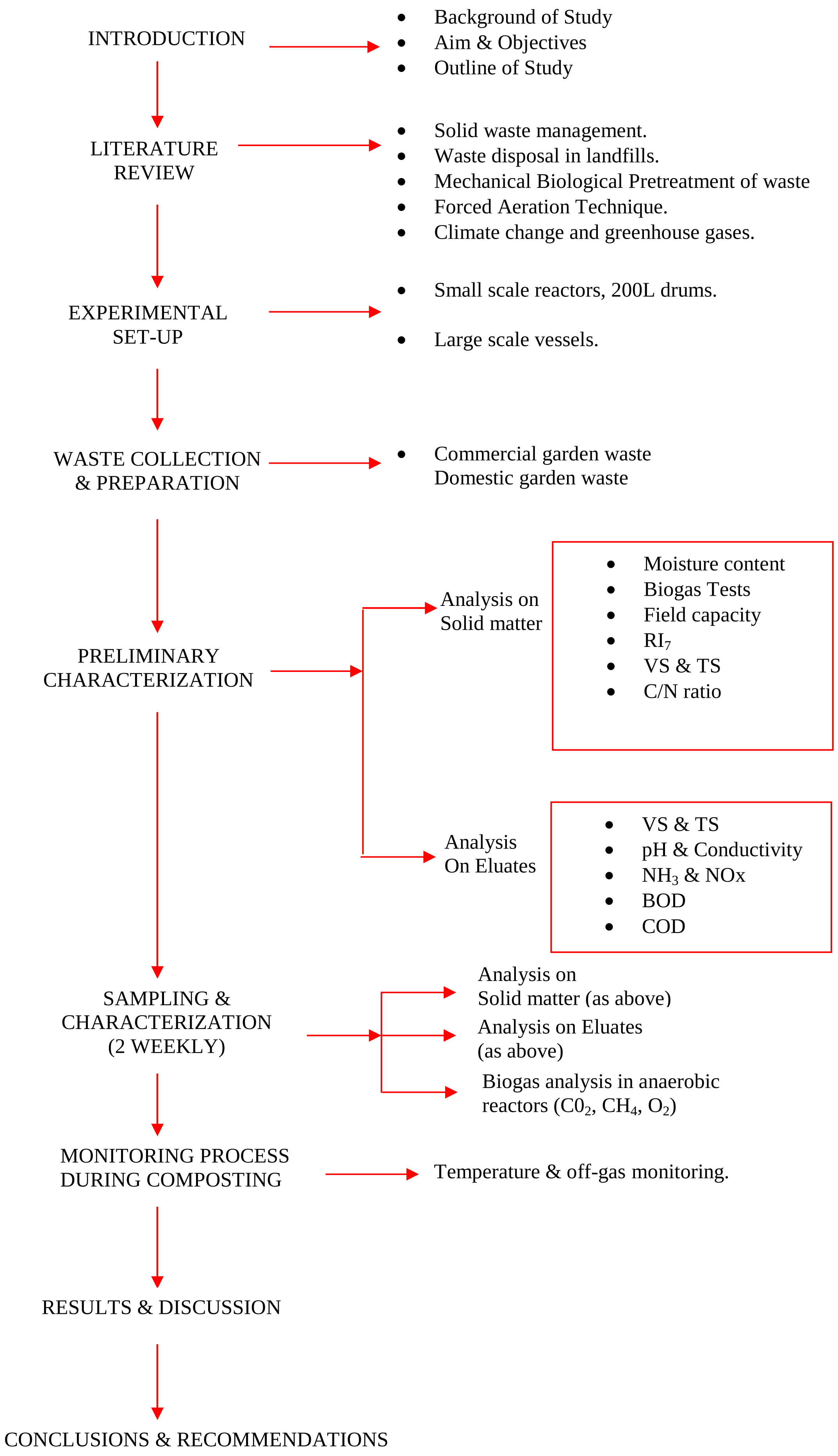


Figure 1-1: Structure of the research work.

CHAPTER TWO

Literature review

2.1 Solid waste management.

Solid waste management is a process that provides for the collection, composition, source separation, treatment and disposal of solid waste (Komilis et al, 1999). The rapid growth of population coupled with urbanization and economic development have caused a change in lifestyle, increasing the rate at which municipal solid waste is generated. It is important that waste be avoided or reused as much as possible, to avoid harmful effects on the environment, and only the residual waste which can neither be avoided nor reused be disposed off (Soyez and Plickert, 2002). The most economical and widely practiced alternative for the elimination of municipal solid waste (MSW) is landfilling (Komilis et al, 1999). Direct landfilling of waste without prior treatment is an environmental hazard, it produces harmful emissions such as Leachate and Biogas, due to uncontrolled degradation of the organic compounds contained in solid waste. These emissions contribute to global warming, they constitute toxic effects on the water environment, they deplete land resources, and also result to human health problems. These risks associated with landfills in general affects the state of the environment (Visvanathan et al, 2005). In order to avoid these harmful effects on the environment, municipal solid waste should be pretreated prior to landfilling (Soyez and Plickert, 2002).

In Europe the landfill design requirement has been defined by the European Union (EU) Landfill directive of 1999 (99/31/EC) as a control of the biodegradable fraction of MSW going to the landfill. "*The amount of the biodegradable organic matter deposited must be reduced by 25%, 50% and 65% by 2006, 2009, and 2016 respectively on the basis of the quantities of MSW generated in 1995. Member states use different strategies to divert the organic fraction of MSW from landfill. These include composting of the biodegradable fraction to convert it into fertilizer, incineration of MSW followed by landfilling or recycling of combustion residues and most recently, the Mechanical Biological Pretreatment (MBP) of MSW prior to landfilling*" (Lornage et al, 2007). There are no regulations in South Africa regarding MBP. The EU Landfill Directives were used as an indication in the absence of local standards. Approximations were applied where the EU standards were not applicable to local conditions. Solid waste management is a very essential process to prevent or reduce the discharge of pollutants to create sustainable development in all countries, and to maintain the earth's quality (Komilis et al, 1999).

2.2 Solid Waste

Waste can be defined as a heterogeneous mixture of different solid products varying in composition according to its source, country of production, time of the year, and the waste collection method used. For each level of waste management planning, the definition of waste depends on the individual (Williams, 1998).

The South African white paper on integrated pollution and waste management provides the following definition of waste "*Waste is an undesirable or superfluous by-product, emission or residue of any process or activity which has been discarded, accumulated or been stored for the purpose of discarding or processing. It may be gaseous, liquid or solid or any combination thereof and may originate from a residential, commercial or industrial area. This definition includes industrial wastewater, sewage, radioactive substances, and mining, metallurgical and power generation waste*." (Griffiths, 2009) *Hazardous waste* is defined as a dangerous waste that is difficult to threat and contains substances harmful to the human body and the environment. *Garden waste* is composed of weeds, grass clippings, flowers, pruning, branches, bush, trees and shrub trimmings. Commercial garden waste consists of garden waste from industrial premises which are mainly trees and big branches, while Domestic garden waste contains leaves, grass clippings and weeds, from private households.

One major problem of landfill sites is the amount of biodegradable waste disposed off, which also includes green waste (Komilis et al, 1999). In South Africa garden waste is mostly disposed off in domestic landfills. An option of treatment that could reduce and stabilise waste in the most efficient way will always be essential due to the large volumes generated (Trois and Polster, 2007). One step that could be taken towards solving waste disposal problem is to pretreat garden waste into a useful form, instead of dumping them. The selection of any waste pretreatment option is affected by the waste composition (Komilis et al, 1999). Garden waste can degrade relatively easily, hence it is perfect for aerobic decomposition (composting). Using the MBP process and a forced aeration technique, the waste would be transformed to nutrient rich compost that can serve as fertilizers for flower beds and gardens.

2.3 Waste disposal by Landfilling

Landfilling is an economical and widely used disposal method for municipal solid waste (MSW) and residual waste (Komilis et al, 1999). Significant problems with landfills are simply due to their large numbers, the expense of land area they occupy, and the environmental hazards caused by the pollutants they expel. Waste management programs encourage reduction of the amount of waste disposed off in landfill and a reduction of the harmful hazards caused by carbon emissions on the environment (Visvanathan et al, 2005).

According to Binner (2002), the experience gathered from the dumping of solid waste in landfill sites has shown that the dumping of waste that is neither pretreated nor sorted can lead to considerable environmental pollution through the release of both Leachate and Biogas. The emphasis of waste management is on reduction, reuse, and recovery before disposal. Each local community or country must then decide on its own best option in dealing with its waste issues. The major landfill gases that need to be reduced are methane (40-60%) and carbondioxide (30-40%), the others are minor and include nitrogen, hydrogen sulphide and oxygen (Williams 1998).

2.3.1 The key process stages of anaerobic decomposition in landfills.

There are four key biological and chemical phases of anaerobic decomposition in landfills (Figure 2-1)

2.3.1.1 Hydrolysis

In the first phase of decomposition, aerobic bacteria break down the long molecular chains of complex carbohydrates, proteins, and lipids into carbon dioxide. This leads to a reduction in the nitrogen content of the pile. The process continues until all the oxygen is totally depleted, which could be days or months depending on the initial content of oxygen in the waste when it was disposed off in the landfill (Bockreis and Steinberg 2005).

2.3.1.2 Acidogenesis

The second phase begins when the oxygen in the landfill has been totally depleted. The anaerobic bacteria (bacteria that live in the absence of oxygen) will then convert the compounds produced in phase I into formic acids, acetic, lactic and alcohols such as ethanol and methanol. These acids then mix with moisture in the waste resulting in the dissolution of some nutrients, making more nitrogen and phosphorus available to the bacteria. During the process carbon dioxide and hydrogen are produced. If oxygen is introduced at this stage, the process will return back to Phase I (Bockreis and Steinberg 2005).

2.3.1.3 Acetogenesis

The third Phase begins when some anaerobic bacteria consume the organic acids produced in Phase II and form acetate. This creates an encouraging environment for methane-producing bacteria to establish themselves. Methane and acid producing bacteria have a symbiotic relationship, meaning they are mutually advantageous to each other. The acid producing bacteria produce the carbon dioxide and acetate while the methanogenic bacteria consume them (Bockreis and Steinberg 2005).

2.3.1.4 Methanogenesis

The fourth phase is the methanogenesis phase, which is the main landfill stage with a gas composition of approximately 60% methane and 40% carbon-dioxide. The methanogens from phase III converts the consumed compounds into carbon-dioxide, methane and water. The percentage volume of the gas produced in this phase is usually in the range 45% to 60% of methane, 40% to 60% of carbon dioxide, and 2% to 9% of other gases. Methanogens are sensitive to pH, a suitably pH range is between 6.5 and 8. The gas is produced at a stable rate for about 20 years; and will continue to be produced for many more years after the waste is disposed off in the landfill (Bockreis and Steinberg 2005).

2.3.1.5 Oxidation

This is the final stage of waste degradation, when all the acids are used up in the production of the landfill gas methane and carbon dioxide. The methane production decreases, all the way to complete disappearance, and is usually evident after a very long period, over 100 years. New aerobic micro-organisms are then formed to begin the process all over again (Bockreis and Steinberg 2005).

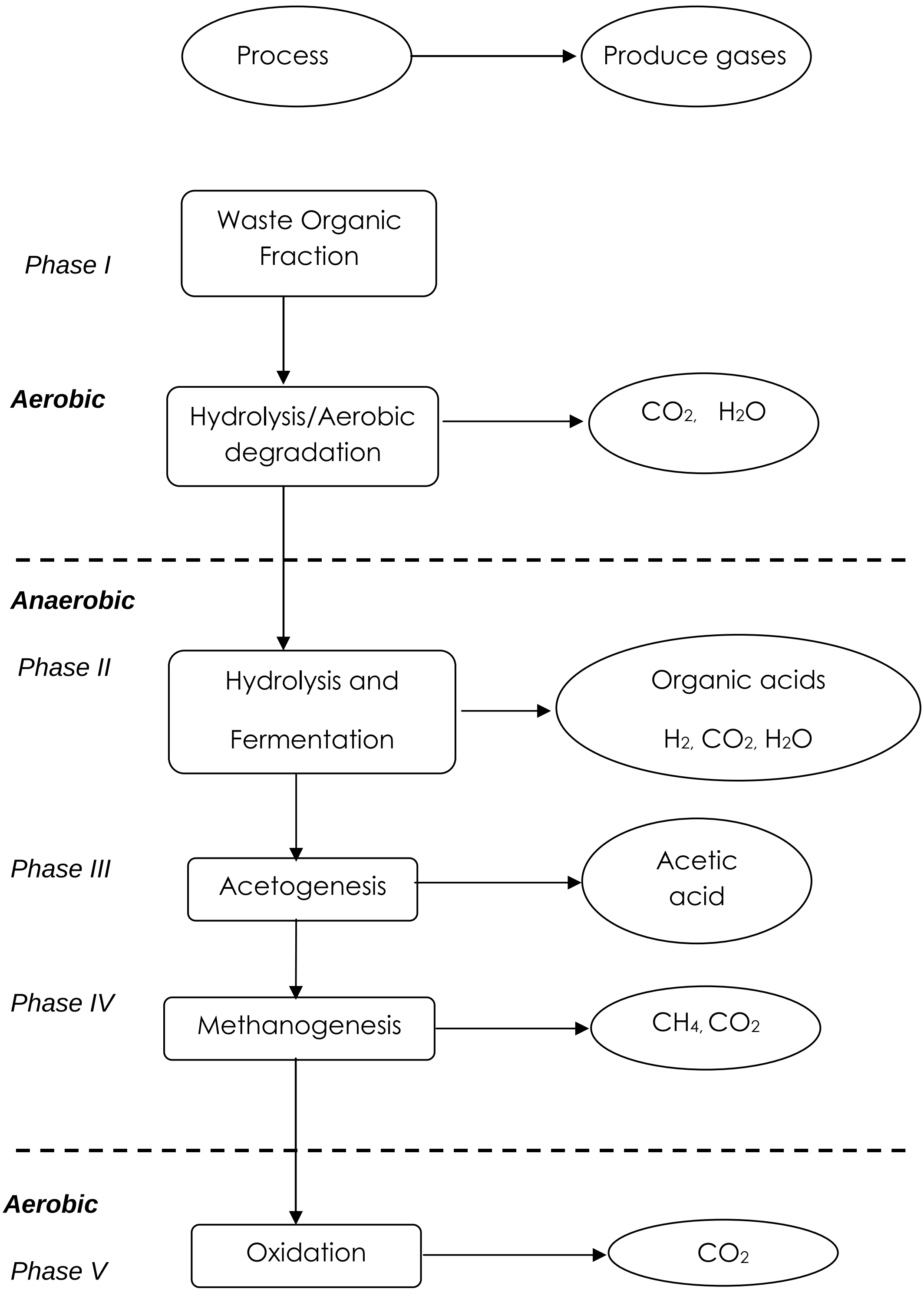


Figure 2-1: Major Stages of anaerobic waste degradation (Williams, 1998)

2.4 Climate Change and Greenhouse gases.

Among the environmental impacts produced by solid waste management, those related to climate change issues are of particular interest. The emphasis of the waste management hierarchy, in on avoiding, minimizing and reducing greenhouse gases resulting from waste production processes (Stangeland, 2007). Waste management processes such as waste selection, recycling, pretreatment and landfilling can be assessed and improved in terms greenhouse gas emission. The increase of methane and carbon- dioxide gas concentrations in the atmosphere has lead to a lot of changes in the climate (Stangeland, 2007). According to the intergovernmental panel on climate change (IPCC) increasing emissions of greenhouse gases (GHG) will rise the average global temperature by 1.1 – 6.4^{o}C by the end of the 21st century (The IPCC 2007a). The climate models of the IPCC indicate that if the global average temperature increases by more than 2^{o}C a dramatic climate condition leading to melting polar ice caps, rise in sea level of up to 1m by 2100, extreme climate events, permanent flooding and extinction of species, will occur if no prompt action is taken (Williams, 1998).

The result of an increase in greenhouse gas (GHG) emissions is global warming, which causes severe health issues, pollution and a negative impact on the environment. A major goal of any waste management process is to reduce these carbon emissions (Strangeland, 2007). To avoid a dramatic climate change as a result of high temperature increase, the intergovernmental panel on climate change (IPCC) has stated that global GHG emissions should be reduced by 50% - 80% by 2050 (The IPCC 2007b). About 99% of gas emissions from Mechanical Biological Pretreatment (MBP) of waste are Methane (CH_4) and Carbon-dioxide (CO_2) which are the major greenhouse gases (GHG). The remaining 1% comprise of a range of odoriferous and toxic gases. During the Mechanical Biological Pretreatment process, 90% of the carbon emitted form greenhouse gases, while the 10% of carbon left is absorbed into the soil (Binner et al, 1999). Waste is the third largest source of carbon greenhouse gas emission after Agriculture (live stock farming and rice cultivation) and fossil fuel distribution, processing and mining (Binner et al, 1999).

The EU has set a goal to to diminish global warming by reducing the production of greenhouse gas emissions (Bogner, 2007). Mechanical Biological Pretreatment (MBP) of waste is one effective option that would contribute towards the realisation of this goal because the GHG emissions from pretreated waste are smaller compared to that from fresh and untreated waste disposed directly into the landfill (Soyez and Plickert, 2002).

2.4.1 Carbon-dioxide (CO_2) emissions

Carbon-dioxide is the most important greenhouse gas, as stated by the international panel on climate change (IPCC). CO_2 is released in greater amounts and represents about 50% of the global warming attributed to greenhouse gases. Global carbon-dioxide emissions are increasing much more. According to IPCC 2007a, "*Between 2000 and 2005 emissions grew four times faster than in the preceding 10years. Global growth rate were 0.8% from 1990 to 1999. From 2000 to 2005 they reached 3.2%. It has also been estimated that atmospheric CO_2 concentrations by 2100 will be in the range of 650 to 970ppm – more than double or triple pre-industrial levels*". As the major contributor to global warming, any effective environmental management program must first address the issue of carbon emission reduction potential.

2.4.2 Methane (CH_4) emissions

Methane is the second most important greenhouse gas after $CO_{2,}$ but the largest GHG emission from the waste sector (Binner, 2002). Due to an increased rate of landfill recovery, the growth of landfill emissions has diminished in many countries. According to Bogner, 2007, in the last two decades there has been a decrease in the landfilling rate of most EU countries. The increase of CH_4 is a great concern, because methane is a powerful ozone depleting substance (ODS) and it also causes radiation forcing. Ozone depletion causes skin cancer and eye cataracts in humans (Williams, 1998). The concentration of methane in the atmosphere is increasing. With a lifespan of between 12 and 17years and a global warming potential of about 24.5 times higher in relation to CO_2 it is responsible for approximately 25% of anticipated warming (Stepniewska et al, 2003). Methane from landfills accounts for between 7% and 20% of the global anthropogenic sources of methane emissions (Binner, 2002). Pretreatment of garden waste prior to landfilling will significantly contribute to the reduction of methane emission reduction potential.

2.5 South African Waste Management Legislation.

The South Africa legislation "*allows for the landfilling of untreated waste and focuses on the concentrate and contains approach which results in a long term environmental risk. The Polokwane Declaration signed in 2001 during the first South Africa waste summit has set a new standard towards the reduction of waste generation and disposal* *by 50% and 25% by 2012 and the development of a zero waste plan by 2022*" (Trios et al, 2007)

Under the European Landfill Directives, dated April 26th 1999 (Council Directive 1999/31 EC), The EU has set a target for the amount of biodegradable municipal waste that is disposed off in the landfill, 75% of baseline (1995) levels by 2006, 50% by 2009 and 35% by 2016 (Cossu and Raga, 2007). The national waste management policy of South Africa aims to minimize the amount of waste produced and the quantity of waste sent to the landfill for disposal. Taking the Landfill Directive as a framework "A diversion of 50% overall household waste" was outlined as National Landfill Diversion targets in 1998 in the Policy document "Changing Our Ways" (Griffith, 2009).

Climate change is one great challenge facing the world today due to the continuous increase in greenhouse emissions (Binner, 2002). The reduction of carbon emission is an ambitious goal of the South African climate protection program. In 1994, the department of water and environmental affairs (DWAF) approved minimum requirements for disposal of waste in landfill in order to reduce the environmental impacts of GHG emissions (Griffiths, 2009). The aim is to guarantee the best option of treatment (Blight et al, 1999). As an effort towards an integrated waste management which is concerned with contributing to a healthy environment and a strong economy, it is of much concern to investigate the influence of Mechanical Biological Pretreatment of garden waste using forced aeration on carbon emission reduction. Apart from stabilizing the waste, MBP reduces GHG emissions. Forced aeration provides a total control of the process, which is important because the most effective microbes for converting organic wastes to useful products are aerobic which means that they depend on oxygen.

2.6 Solid Waste Pretreatment Techniques.

Waste pretreatment is a process applied to waste before disposing in a landfill. The purpose of pretreatment is to accelerate the stabilization of the biodegradable component and eliminate GHG emissions that would be produced if disposed directly in the landfill. Pretreatment will alter the characteristics of the waste streams prior to disposal in the landfill. The two basic options that exist for waste pretreatment are thermal pretreatment (incineration) and biological pretreatment (Komilis et al, 1999)

The biological treatment is generally a Mechanical Biological Pretreatment applied as a single treatment operation or in combination with thermal pretreatment (Griffiths, 2009). The choice of pretreatment techniques depends on costs and environmental or local conditions (Komilis et al, 1999). After some study, Mechanical Biological Pretreatment has been suggested to be the most appropriate option for waste stabilization in South Africa (Trois et al, 2007).

2.7 Mechanical Biological Pretreatment.

Mechanical Biological Pretreatment (MBP) has been defined as the processing of incoming solid waste through a combination of mechanical and other physical processes with biological processes (Komilis et al, 1999). The aims of MBP include stabilizing the biodegradable organic matter, limiting the amount of biogas emissions, leachate, mass and volume reduction of waste to be landfilled (Lornage et al, 2007).

Some countries such as Austria, Germany and Italy have already started using these systems, and due to their increasing success, they have now been established as processes for waste to energy and landfill control. According to Bockreis and Steinberg, (2005), in 2004 there were 15 facilities in Austria, 60 in Germany and more than 90 in Italy, having a total of approximately 13million tone with larger plants having a capacity of 600 – 1300 tonnes/day. Recently this concept has attracted considerable attention in other areas of the world, including South Africa, and has received support from Environmental Organizations (Trois et al, 2007; De Gioannis et al, 2007).

In Mechanical Biological Pretreatment, the waste goes through mechanical and biological steps producing a stabilised waste and a reduced volume of the organic carbon compounds (Bogner J, 2008). The mechanical pretreatment includes operations such as sorting, shredding, and crushing. This is usually the first step of the process. The biological pretreatment steps consist of aerobic composting, anaerobic digestion, or the combined processes (Visvanathan et al 2005). Aerobic systems mostly in use for MBP include windrows, containers, boxes, drums, or tunnels. The biological process will accelerate the waste stabilization with significant mass and volume reduction thereby conserving landfill space (Soyex and Plickert, 2002). The objective of Forced aeration is to condition the waste to optimum characteristics for biological pretreatment.

2.7.1 Mechanical pretreatment.

During mechanical preparation, the waste material is separated by sorting, shredding and screening. Sorting can be done using screens, powerful magnets, rotating sieve drums, and air classifiers. A screen size of between 60mm and 90mm could be used. According to Leikam et al, 1999, shredding has been observed to increase homogeneity, the rate of biological degradation, increased contact between the pile, nutrients and micro-organisms and the surface area of the waste pile. Another research done by Komilis et al, 1999, observed that MSW shredded to 25mm produced more methane than 10mm shredded MSW. 15mm shredded MSW also produced 16 times more methane than MSW shredded for 2.5mm. This finding suggested a relationship between methane production and shredding. Mechanical pretreatment is recommended for volume reduction and efficiency of waste to be disposed (Leikam et al, 1999).

2.7.2 Biological Pretreatment

The main options for the biological pretreatment of solid waste are anaerobic decomposition, aerobic decomposition or a combination of both. The major objectives of a biological pretreatment are

- To degrade the organic compounds in the waste material under optimum conditions to a more stable product, which will also reduce the emission potential of the waste before landfilling?
- To improve methanogenic conditions in the landfill.

From the study of aerobic degradation, some factors have been observed as a great influence on the choice of pretreatment processes. These include waste composition, moisture content, and the percentage of organic component (Komilis et al, 1999). The authors also observed that the organic content in Biogas and Leachate is reduced during the biological pretreatment of MSW, depending on the degree of decomposition. The biogas production was influenced by the treatment process. The organic content of the untreated waste was two times more than the treated, subsequently increasing the methane production and reducing the methane emission potential after disposal. A reduction of 90% was achieved by aerobic pretreatment of waste. Some other parameters that were also reduced during the process were the volatile solids by 25% to 30%, COD, and BOD_5 (Komilis et al, 1999).

2.8 Factors affecting the aerobic decomposition process.

There are some essential factors involved in the degradation process and they are indicators that should be monitored to evaluate the process. The process should be optimised to control the rate of decomposition. The micro-organisms which are the major contributor to the decomposition process must be provided with sufficient moisture and aeration. The factors to be considered are:

2.8.1 Carbon-Nitrogen relationships (C: N ratio)

The C: N ratio is the ratio of carbon to nitrogen in the organic waste. This ratio affects the microbial activity in the waste. A C: N ratio of range 20:1 -25:1 has been suggested to be the most efficient C: N ratio for composting MSW (Norbu et al, 2005). During the decomposition process carbon is used by the organisms for energy and nitrogen is used for building the cell structure. Too much carbon in the pile would slow down the decomposition process, increasing the composting time and the microbes will starve from the shortage of nitrogen (Bass et al, 1995) On the other hand when carbon is low, the microbes dispose off the excess nitrogen as ammonia (WSU, 2009).

2.8.2 Composting Structures

Aerobic decomposition and stabilization of waste is mostly done in open piles, windrows, or bins. The exact structure type used depends on the waste composition, cost of construction and environmental conditions. The aerobic process can only be maintained by frequent turning, this will provide sufficient air throughout the pile and also making the waste piles to be loosely stacked to allow space for air in the interstices (Bass et al, 1995). The height of the windrow or pile should not be too high for ease of turning. Frequent turning is required to increase the decomposition rate and also to prevent anaerobic conditions. A trench is dug around the pile or windrow for the collection of leachate, and the base of the windrow is covered with stiff wire mesh or loose material to enable airflow to the bottom of the pile (WSU, 2009).

2.8.3 Particle Size

Particle size reduction increases the air flow rate, homogeneity, and the rate of decomposition of the waste. Shredding or particle reduction is most useful when composting fibrous materials such as wood, leaves, and plants, because it reduces the volume of the pile and makes a larger surface area available, for access by the microbes (Bass et al, 1995). Particle size reduction sometimes depends on the waste composition and condition. The high moisture content in vegetable matter might make it difficult to control in aerobic composting when shredded; hence the type of waste material determines when to shred (WSU, 2009).

2.8.4 Moisture Content

Moisture allows the easy movement of the microbes and the nutrients in the waste pile. It is an essential part of the decomposition process. A moisture content of between 30% and 70% is necessary to create an aerobic environment for biological activity (Norbu et al, 2005). In a composting pile, high moisture content would lead to anaerobic conditions, while low moisture content would inhibit the activities of the microbes. The satisfactory moisture content varies with the type and character of waste material used (WSU, 2009).

2.8.5 Temperature

During the decomposition process the microbial activities lead to a release of heat as a result of the biological oxidation of carbon (Norbu et al, 2005). This heat is retained within the pile as a result high temperatures begin to develop. An increase in the temperature leads to an increase in the rate of decomposition. At temperatures above 50^{o}C thermophilic bacteria dominate and breakdown the organic matter content at a greater rate. 55^{o}C to 70^{o}C is the optimum temperature range. Temperatures above 70^{o}C could result in nitrogen loss. A drop in temperature means the pile is going anaerobic. Temperature is influenced by the type of waste material, the airflow rate, moisture content and the ambient temperature (WSU, 2009). Continuous aeration and frequent turning is essential to maintain the temperature of a pile.

2.8.6 Aeration

Aeration is a step in the Mechanical Biological Pretreatment process where air is added to the waste pile for mixing purposes and to enhance biological growth (Gioannis et al, 2006). The purpose of aeration is to dissolve oxygen into the waste so that the microorganisms can utilize it while they break down organic material. Aeration can be used to regulate and control the moisture content and odour during the decomposition process. The main aeration techniques are, forced aeration, natural convection and physical turning.

Physical turning of the waste pile is the most commonly used method of aeration. This could be done with hand or mechanically using tractors, depending on the size of the pile. During turning operation, the airflow rate is controlled to supply a minimum oxygen concentration of 10% within the pore space of the waste material; this is to prevent anaerobic conditions. However excess airflow could result to a low temperature and a decrease in the decomposition process (Kulcu et al, 2004). In natural aeration method air is supplied to the waste pile by diffusion and convection, but cannot be used effectively for wastes with high moisture content (Barrington et al, 2003).

2.8.6.1 Forced Aeration

In Forced aeration air is introduced in the form of pipes to the composting container, or reactors, through a blower or an air compressor. The airflow could be either continuous or intermittent, depending on the design of the system. The air is drawn into perforated pipes connected to the waste material (Sartaj et al, 1997). Many composting companies are presently using this process mainly because of its effectiveness and control of airflow rate (Mathsen, 2004). Assisted or 'forced' aeration is essential to provide the bacteria with suitably oxygen they would need to work with effectively. "The most effective microbes for converting organic residuals *(wastes)* to premium top soil and soil conditioners are aerobic microbes. Aerobic meaning they work in the presence of oxygen, and they consume oxygen" (Crockett, 2007b).

Using forced aeration in aerobic waste degradation provides several advantages. Firstly, the pile can remain static that is it does not have to be routinely turned to facilitate better aeration. Another advantage of forced aeration is that it basically gives a "kick start" to the degradation process by ensuring that decomposition proceeds at a high rate. Moreover forced aeration produces aerobic conditions which prevent the process from going septic. Yet another advantage of forced aeration is that it is easier to control temperature from 55℃ to the 70-75℃ tem perature range (Crockett, 2007b). All these advantages ensure a high efficiency satisfying a high oxygen demand, resulting in a lower volatile organic compound emissions and control over odour and Leachate.

There is also a disadvantage associated with using forced aeration, when temperature reach the higher level and when conditions allow, large amount of steam might be produced. This steam has the tendency (depending on windrow conditions) to hover over the pile and condense. Such condensation can turn a drying pile into a mess. Also when the air blower pushes air into the pile, the forced air is vented over the pile's entire surface area, the forced air carries and delivers odours to areas where they may become a nuisance. The technology is also expensive (Gioannis et al, 2007). Since the most effective microbes for converting organic waste to useful material are aerobic microbes, it is therefore necessary to try the forced aeration technique. If MBP is to be used as a pretreatment technique before dumping in a landfill, its process technology must be oriented towards the improvement of landfill characteristics (Williams, 1998). In order to achieve the greatest possible decomposition of organic carbon compounds, it is important to control the decomposition process. This can be done using forced aeration.

2.9 Composting Methods

Composting can be done using bins, turned windrows passive windrows, static aerated piles and in-vessel systems. The method used depends on the materials and volume to be decomposed, the duration of composting, available space and resources (Resmgmt, 1996).

2.9.1 Bin Composting

Bin composting is composting in a bin using natural aeration, hand or mechanical turning. The waste is turned and mixed on a regular base. Constant turning speeds up the process and provides the aerobic bacteria with the oxygen needed to break down materials. Bin composting is a low technology, medium labour approach producing a medium quality product (Resmgmt, 1996).

2.9.2 Windrow Composting

Windrow composting is the production of compost in piles or windrows. A windrow is an elongated pile of material with a triangular or trapezoidal cross-section. The compost is produced by natural aeration, over long periods of time. Windrow composting is already being used to compost green wastes and aeration is usually provided through turning or forced aeration (Williams, 1998). In a compost pile, the airflow rate is affected by the pore space of the waste material. Uniformity in the waste material and particle size greatly improves the speed of the decomposition process and product quality (Resmgmt, 1996). Windrow composting is advantageous in so many ways; these include thorough mixing of waste materials, breakdown of larger bulking materials that will not be recovered for reuse and a variety of windrow turners at competitive prices. The primary disadvantage of a windrow composting system is a comparatively large land area requirement and the risk of odor production, particularly when the windrows are turned. Another disadvantage could be its use in rainy climate which may require installation (Resmgmt, 1996).

2.9.2.1 Passive Windrow Composting

In a passively aerated windrow there is no turning, rather aeration occurs naturally, this means that the waste material remains untouched until the end of the composting period. The waste material is wet initially to a suitable moisture content and the windrow is covered with a layer of finished compost to help prevent moisture loss, produce uniform compost and to reduce odour problems. Passive windrow is a low technology and labour method of composting. Composting can take from six months to two years (Resmgmt, 1996).

2.9.2.2 Turned Windrow Composting

Turned windrow composting is the production of compost in windrows that are turned and aerated by a windrow turner, which can be self powered or powered by a farm tractor. In this method the waste material is stacked in long parallel rows separated by paths for equipment access. The process depends on natural ventilation with frequent turning and mixing of the piles to maintain aerobic conditions. Most times a structural roof or enclosed building is used to control moisture and temperature conditions and to manage odors. Volume reduces during the compost process. Frequencies of turning are determined by the moisture content, type of material and a sudden drop in temperature. Turned windrow is a low technology and medium labour approach (Resmgmt, 1996).

2.9.3 In-vessel System

This is an enclosed system mainly used for composting kitchen waste, sewage sludge garden waste, and other organic wastes unsuitable for open air composting, due to likely odour problems. In this system, the process monitoring parameters such as the temperature, airflow rate and the moisture content can be easily adjusted and controlled. Organic material is aerobically decomposed in the enclosed container, rotating drum, reactor, or other structures. The waste material could be aerated by fans or air compressors through ducts connected to the base (Williams, 1998). The air-flow could be continuous or intermittent depending on the volume and type of waste material. An irrigation system could be provided for moisture and optimum control. Leachate produced is collected separately and odours controlled using a biofilter (Resmgmt, 1996). The advantages of these systems are firstly the process can be controlled to achieve optimum temperature and aeration. Secondly since they are fully enclosed they have few pests and odour problems, making it easy to operate in a limited space. Thirdly it is a high technology and low labour system (Williams, 1998).

2.10 Biological organisms in the aerobic decomposition process

During aerobic decomposition, microbes degrade organic matter to form carbon dioxide, water, heat and humus. There is an ecosystem of different microorganisms responsible for the decomposing process. The breakdown of the organic material by the bacteria raises the temperature and accelerates the decomposition during the process. When the temperature drops, fungi, worms and insects assist the bacteria in further decomposition (Mathsen, 2004). In an ideally aerated, aerobic bed of biologically active material, there is sufficient oxygen for every microbe. At all times, every microbe would live in just the right moisture environment to transfer nutrients to, and waste products from, its own metabolism. Sufficient air flow would be passing through every interstitial space of the bulk media to maintain the optimum temperature required by the dominant species at any given phase of microbial activity. The decomposition of waste proceeds in three phases, the mesophilic phase (20^oC -45^oC), the thermophilic phase (45^oC -75^oC) and the maturation phase (Williams, 1998).

The mesophilic microorganisms are some species of bacteria and fungi that break down the readily degradable compounds between 20^oC -45^oC. Heat is then generated in the process leading to an increase in temperature. At 45^oC and above, the thermophilic microorganisms take over to breakdown the substrate. Plant and human pathogens are destroyed at temperatures over 65℃. When all the degradable carbon sources have been consumed the compost starts to cool and become stable. Mesophilic bacteria and Fungi later reappear at the beginning of the maturation phase. At this point the biological process is slow but the compost continues to mature (Mathsen, 2004).

2.10.1 Bacteria

Bacteria are the smallest living organisms found in numerous quantities. They make up 80 to 90% of the billions of microorganisms typically found in a gram of compost. They are single-celled but could be structured as rod-shaped bacilli, sphere-shaped cocci or spiral-shaped spirilla. Bacteria breakdown the organic compounds in the compost pile with the help of enzymes. The heat generated during the decomposition process leads to a rise in temperature. Mesophilic bacteria can be found in the mesophilic phase of between 0℃ -40℃ and the thermophilic bacteria in the thermophilic phase of above 40℃ (Resmgmt, 1996)

2.10.2 Actinomycetes

Actinomycetes are filamentous bacteria that are very similar to fungi, they lack nuclei but they grow by multiplying their cells and long thread-like filaments. During the decomposition process they degrade the complex organics like lignin, chitin, proteins and cellulose. Like fungi they can break down hard debris using their enzymes, they can be observed mostly in the thermophilic phase (Resmgmt, 1996).

2.10.3 *Fungi*

Fungi are molds and yeasts, responsible for the decomposition of many complex plant polymers in soil and compost. They are known to breakdown the hard waste materials in the compost pile. They grow by multiplying their cells and filaments. Fungi are saprophytes because they feed on dry, dead or decayed material to obtain energy. They dominate in the mesophilic and thermophilic phases of composting (Resmgmt, 1996).

2.10.4 Protozoa and Rotifers

Protozoa are one-celled microscopic animals. Their role in the decomposition process is very little and they are usually found in minute quantity. Rotifers are microscopic multicellular organisms also found in films of water in the compost. Like the protozoa they feed on organic matter, and can also ingest bacteria and fungi (Resmgmt, 1996)

2.11 Summary of Literature review

When municipal solid waste is disposed off directly into the landfill, anaerobic biological breakdown processes produce landfill gas and Leachate. Biogas (CO_2 and CH_4) forms about 90% of the converted organic carbon while the remaining 10% is released in the Leachate (Binner, 2002). Climate change is one great challenge facing the world today due to the continuous increase in greenhouse emissions (Stangeland, 2007). The South Africa waste management legislation has set requirements aimed to protect the public from health hazards and negative impacts of the greenhouse gas emissions on the environment (Griffith, 2009). According to a study by Kaartinen, 2004, the organic carbon content of the input waste could be reduced to as much as 40% – 60% and the methane emissions reduced to as much as 90% with Mechanical Biological Pretreatment (MBP) of waste compared to the untreated waste (Kuele et al, 2003). However it was observed by Binner, 2002 that in practice the percentage reduction depends on the specific MBP process employed. In general MBP is beneficial to waste management in so many ways. Most importantly it can assist in reducing the quantity of biodegradable waste disposed off in landfills. Although there will still be a potential for methane generation from residual waste that cannot be used or recycled (Bockreis et al, 2005), MBP in the future can be developed and improved to control and convert waste in landfills to more useful products.

Presently the forced aeration technique of Mechanical Biological Pretreatment is gaining much interest because the process could be controlled to achieve a desired temperature and oxygen level during active aerobic decomposition (Kulcu et al, 2004). The study explains the relevance of the Forced Aeration process, in reducing the amount of biodegradable organic matter deposited in landfill, by optimum control of the process. This process could be controlled by varying the aeration flow rate. Advantages of this technique include low costs, odour control, use of less land area, and an aerobic process. With the use of an insulative cover and continuous aeration the organic waste can be degraded aerobically under a controlled temperature, resulting to stabilised compost within a short treatment duration.

This study aimed at determining the efficiency of Forced Aeration for garden waste in comparison to the traditional composting process (turned windrow composting) with respect to energy consumption and potential of carbon emission reduction. A similar study has never been carried out in South Africa, and never with this particular focus. The information obtained from this research on the carbon emission yields from the pretreatment of Commercial garden waste and Domestic garden waste using forced aeration is needed to evaluate the contribution of Mechanical Biological Pretreatment to the production of greenhouse gases. Such knowledge can be used to compare waste management techniques and optimize waste management policies in a developing country, such as South Africa. The next chapter documents the design and methodology followed during this study.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

The aerobic degradation of garden waste was analysed during the mechanical biological pre-treatment process using a forced aeration technique. Two types of garden waste commonly available in the ethekwini municipality were treated using forced aeration at two different scales. Samples were taken every two weeks and analysed for physical and chemical parameters to assess the efficiency of the composting process. The process was set and controlled based on the following findings and methods available in literature:

- Moisture contents ranging from 52% to 60% (wet weight) do not limit composting of most organic substrates (Soyez and Plickert, 2002).
- A minimum value of 15% (by weight) of oxygen present at the headspace of compost vessels has been found to not limit the composting process (Soyez and Plickert, 2002).
- Thermophilic temperature ranges between 50℃ to 70 ℃ that occur frequently in active substrates and temperatures higher than 70℃ can significantly affect decomposition rates (Kulcu and Yaldiz, 2004), but the upper end is unnecessary for full sanitation of the pile from pathogens.
- A Carbon to Nitrogen ratio between 25 and 30 has been suggested for optimum composting (EPA, 2003).

To maintain control of the process and to make the necessary measurements, a laboratory procedure was carried out. An experimental set-up was designed to degrade commercial garden refuse and domestic garden refuse components aerobically. The study involved setting up of two in-vessel reactors and two static aerated piles, with assisted aeration supplied using an air compressor. The experiment was divided into two runs; the first phase was conducted at small scale in two in-vessel 200l reactor drums and the second phase at a large scale in two static vessels (4.5m^3). The systems were designed to operate with minimal or no anaerobic biological activity by controlling the aeration rates and the air distribution. At the beginning of pre-treatment preliminary characterisation of the substrates was carried out. Representative samples were collected every two-weeks, and characterised.

The Environmental Engineering laboratory at UKZN (School of Civil Engineering) was used in the preparation, analysis and storage of equipments and samples. The experimental set-up was designed according to the Standard Method for the Examination of Water and Wastewater (SMEWW) 21st edition (Eaton et al, 2005), which was also used as a guide for all the laboratory procedures and analysis. This chapter explains the experimental methods carried out to achieve the main objectives of the study:

1 To make a systematic inquiry into the Mechanical Biological Pretreatment of garden waste using a forced aeration system.
2 To establish that proper segregation, separation of organic waste and substrate particle size reduction are crucial steps of the MBP process to achieve maximum carbon emission reduction and best compost quality.
3 To assess the reduction of biogas production potential as a function of the duration of the composting process.

3.1 Waste Collection and Preparation.

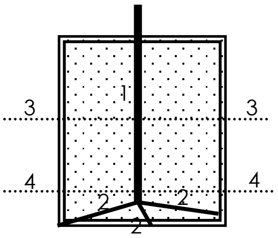
Two types of garden waste were selected for the two runs of experiment. Commercial Garden Waste (CGW) collected from Bisasar Road landfill site and the Domestic Garden Waste (DGW) collected from ten households in the neighbourhood of Westville, in Durban, South Africa. The Bisasar Road landfill site was established in 1980, and is situated approximately 8km north of the Durban central business district. The landfill is operated by Durban solid waste (DSW); it covers an area of 44ha (Trois et al, 2007). The site receives an average of five thousand tons of waste per day. Both samples were used in each run of the experiment. For the purpose of this research Commercial garden waste will be designated as CGW and Domestic garden waste as DGW.

For the first run of experiments, 37.31kg of DGW and 50.78kg of CGW were collected and placed in two drums, named thereafter as reactor 1 and reactor 2 respectively. Both samples were pre-treated simultaneously. CGW was shredded for homogenisation; using an industrial high speed shredder (Morbark 2600 model) to a particle distribution range of 30mm - 50mm. DGW had a particle size range of approximately 50mm to 80mm. The moisture content of the input waste samples was adjusted to about 60% for optimum degradation.

3.2 Experimental Set-up

3.2.1 Drum reactors (Small-scale experiment)

The 200L drum reactors were made of plastic material and were insulated with wool about 25 mm thick. Each drum weighed 8.54kg empty. Each of the drums were connected to pipes, which were then connected to an electric blower (air compressor) through a solid PVC pipe in its bottom for injecting air at different rates, allowing the control of the degradation process. CGW was then placed in reactor 1 and DGW in reactor 2. Each drum was designed using one 30mm solid PVC pipe and three 25mm PVC pipe. The smaller pipes were perforated with 5mm holes on both sides to allow for a uniform distribution of air. The layout of pipes and sampling position for the temperature and off-gas analysis are shown in figure 3-1.



1. 30mm Solid PVC pipe

2. Perforated PVC pipe with 5mm holes on both sides at 5cm centre to centre

3. level of sampling for top of pile, 500mm from the base of the drum.

4. level of sampling for bottom of pile, 250mm from the base of the drum

Figure 3-1: Layout of pipes and sampling points in each drum during the small-scale experiment

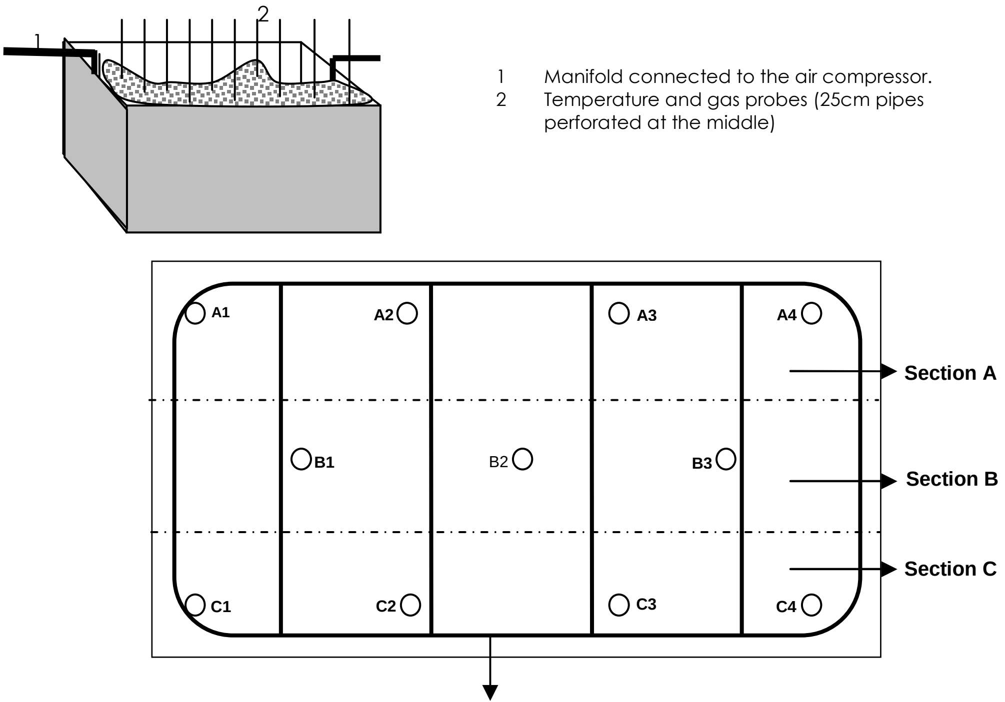
Composting was conducted for 14weeks and the required parameters of the process were measured. The process was monitored by measuring the temperature developed in the samples with thermocouple (MT-630) from the middle and the bottom of the reactor. The air flow rate through the waste during the pretreatment was evaluated by monitoring the air compressor’s working time which was controlled at intervals by a timer and a manometer. This ensured that the reactors operated under aerobic conditions. No water was added during the pretreating process. The system was left undisturbed while the off-gas and temperature was constantly monitored. The reactors were also insulated to maintain an optimum internal temperature. The experiment was performed at room temperature. The reactor set-up is shown in plate 3-1.

Plate 3-1: Reactor set-up during the aerobic treatment of CGW and DGW in the small scale experiment.

3.2.2 Static Aerated Reactors (Large-scale experiment)

We progressed further at a large-scale with a static aerated reactor by increasing the volume of waste treated and to assess the influence of the airflow rate in an in-vessel composting system. Two reactors were constructed as troughs using steel and were covered with plastic sheets, to form an enclosed structure. The troughs were 3m long, 1.5m wide and 1m deep. The two troughs were then connected to an air compressor through PVC perforated pipes and placed outside in the open. CGW was placed in trough 1 and DGW in trough 2 to decompose aerobically. DGW was transferred to a smaller trough of size 1.2mlong, 1.2mwide and 0.62m deep by the 8th week, for proper control, stabilisation of waste and to avoid extreme compaction of the pretreatment to affect aeration. The substrates were aerobically treated for 14 weeks and the required parameters of the process were measured. Preliminary characterisation was carried out on both CGW and DGW to determine the initial value of the parameters, and representative samples were collected and characterised every fortnightly during the biological pre-treatment process. The reactor set-up and the layouts of pipes and sampling points is shown in plate 3-2 and figure 3-2.

Plate 3-2: Static aerated in-vessel reactors set-up during the aerobic treatment of CGW and DGW in the large-scale experiment.



1 Manifold connected to the air compressor.
2 Temperature and gas probes (25cm pipes perforated at the middle)

Manifold of PVC pipes, 5mm diameter perforation on both sides at 5cm center to center.

Figure 3-2: Layout of pipes and sampling points in each reactor during the Large-scale experiment.

3.3 Solid Matter Sampling Method.

In waste analysis, a good sampling method is important. There is need for the sample to represent the waste material during the laboratory procedures. Due to the small sample amount investigated, particular care was taken in sampling to ensure a satisfactory representation. Samples were collected every two-weeks for analysis during the course of the experiment. The quartering method was used as the sampling method to obtain a representative sample for the analysis, by dividing the sample in four equal parts (1, 2, 3, and 4); the 1st part was then mixed with the 3rd part while the 2nd part was mixed with the 4th part. Each part (1st, mixed with 3rd and 2nd mixed with 4th) was divided again into 4 equal parts. A quarter of each of the four parts was combined and divided into 4 equal parts. A quarter of the latter was used as the representative sample to carry out the analysis (Asah, 2007). When it was not possible to analyse collected samples immediately, samples were properly preserved in a fridge at 4 ºC.

Plate 3- 3: A quartered waste

3.4 Analytical Methods

The aerobic biological process was monitored by the evolution of the solid matter composition, physical and chemical characteristics. The input, intermediate (bi weekly) and the output materials were characterised using standard eluate tests. Temperatures, Off-gas and Biogas composition from the reactors were monitored three times a week with a thermocouple (MT -630) and a gas analyser type GA 2000. The analysis was conducted according to the Standard Method for the Examination of

Water and Wastewater (SMEWW) 21st edition (Eaton et al, 2005). Representative samples collected every 2weeks were analysed to assess the moisture content, field capacity, total solids and volatile solids (TS and VS), carbon to nitrogen (C:N) ratios, respiratory index at 7 days (RI_7). These samples were then placed in anaerobic reactors and their capacity to produce methane gas was analysed using the liquid displacement method. Eluate tests were conducted by mixing the wet waste with distilled water in a solid to liquid ratio of 1:10, and placing it in a shaker for 24hours. After 24 hours the eluate was then filtered using a 0.63 μm coarse sieve. Eluates were analysed for BOD_5, COD, total solids, volatile solids, ammonia-nitrogen (NH_4-N), nitrate-nitrogen (NOx-N), pH value and conductivity. Full characterisation was done on the input sample, and subsequently every two weeks sample.

3.4.1 Moisture Content

The Leachate and Biogas production during the waste biodegradation process depends on the moisture content of the waste. Moisture content below a 40% reduces biodegradation significantly, however high moisture contents are to be avoided because they could produce anaerobic conditions (Williams, 1998). The moisture content test aims at determining the amount of pore water in the waste sample. A metal pan was weighed empty, and then a representative sample was placed in the pan and weighed to determine the weight of the pan plus the wet waste which is represented as Mw, it was then placed in an oven and dried for 24 hours at a temperature of 105 ^{0}C. After 24 hours the sample was weighed again and represented as Md. The moisture content was calculated using equation 3-1

$$\boxed{W(\%) = \frac{Mw - Md}{Mw} * 100} \qquad \text{Equation 3-1}$$

Where:

W (%) is the moisture content percentage.

Mw is the mass of the wet sample (g)

Md is the mass of the dry sample (g)

3.4.2 Field Capacity

Field Capacity (FC) is the maximum moisture content held in compacted waste by capillary action (Asah, 2007). Since waste in the landfill is at field capacity, analyses in the anaerobic reactors for biogas determination were carried out on waste at field capacity to simulate landfill conditions. The instruments used in carrying out the FC test consist of a beaker and a funnel with the bottom neck sealed firmly with a cotton plug and a sieve wire. The funnel was then placed on the beaker and weighed (W1). A representative amount of waste was placed in the funnel and weighed (W2). Water was then poured slowly into the waste until full saturation, and then the excess water is left to drain out by gravity for some time. When the water stopped moving down the funnel, water and wet waste were then weighed as (W3). The difference in weight between the weights of funnel and contents before and after pouring water in (W3 –W2) gives the amount of water retained by the waste (WR). The amount of water per 100gram of sample was then calculated as shown in equation 3-2

$$\boxed{Fc\ (ml/100g) = \frac{W3 - W2}{W2 - W1} * 100} \qquad \text{Equation 3-2}$$

Plate 3-4: Field capacity test set-up.

3.4.3 Total Solids (TS) (Section 2540B of SMEWW, (Eaton et al, 2005))

Total Solids (TS) is the solids left after drying a sample in the oven at 105^{o}C to a constant weight (Eaton et al, 2005). TS analyses were done in triplicates. The evaporating dish (crucible) was ignited at 550 ^{o}C for 1hr in a muffle furnace, and then cooled in a desiccator. A representative sample was evaporated in a weighed dish and dried to a constant weight in an oven at 105°C. The increase in weight over that of the empty dish represents the total solids.

Plate 3-5: Desiccator for storing crucibles.

3.4.3.1. TS on Eluate: For the TS test on eluate, a crucible with an identification number was weighed to determine the weight of crucible dry (W_1). 25ml of the representative sample was then pipeted into the pre-weighed crucible. The sample was then evaporated to dryness in an oven at 105 ℃ for 24 hours. After 24hrs it was then allowed to cool in a desiccator and weighed (W_2). The value of the total solids in the eluate was calculated from Equation 3-3

$$\boxed{\text{TS (mg/l)} = \frac{(W_2 - W_1)}{\text{Sample volume (ml)}} * 1000} \quad \text{Equation 3-3}$$

Where

W_2 = weight of dried residue + dish (mg) and

W_1 = weight of dish (mg)

3.4.3.2 TS on Dry solid: To characterise the Dry matter for TS, the crucibles were weighed dry (W1), then a representative sample placed in the crucible to about ¾ full and weighed (W3). This was then evaporated in a drying oven at 105 ºC for 24h. After 24h it was then allowed to cool in a desiccator and then weighed (W2). The amount of total solids was calculated from Equation 3-4.

$$\boxed{TS\ (\%) = \frac{(W_2 - W_1) * 100}{W_3 - W_1}}$$ Equation 3-4

Where

W_2 is the weight of dried residue + dish (mg)

W_1 is the weight of dish (mg) and

W_3 is the weight of wet sample + dish (mg)

3.4.4 Volatile Solid (VS) (Section 2540E of SMEWW, (Eaton et al, 2005))

The weight loss on ignition is called volatile solids; it grossly estimates the total organic content of a sample (Eaton et al, 2005). The VS analysis was done in triplicate.

3.4.4.1 VS on Eluate: The residue from section 3.4.3.1 (page 38) was ignited to a constant weight in a muffle furnace at a temperature of 550ºC for 25minutes. The furnace was already heated up to 550ºC before the sample was inserted. The crucibles were then allowed to cool in air until the heat had been dissipated. It was then transferred to a desiccator for final cooling in a dry atmosphere. As soon as the dish cooled to a balanced temperature, it was then weighed. The volatile solids were calculated from Equation 3-5

$$\boxed{VS\ (mg/l) = \frac{(A - B) * 1000}{\text{Sample volume (ml)}}}$$ Equation 3-5

Where

A = weight of residue + dish before ignition (mg)

B = weight of residue + dish after ignition (mg).

3.4.4.2 Vs on Dry solid: The dried sample from section 3.4.3.2 (page 38) above was transferred to the heated furnace of temperature 550 ºC and ignited for 1hr and 30minutes. The crucibles were then allowed to cool in air until the heat had been dissipated, and then cooled to a balanced temperature in a desiccator and weighed.

The VS on Solids was calculated from Equation 3-6

$$\boxed{VS\ (\%) = \frac{(A - D) * 100}{(A\text{-}B)}} \qquad \text{Equation 3-6}$$

Where

A = weight of dried residue + dish mg

B = weight of dish mg

D = weight of residue + dish after ignition.

Plate 3-6: Furnace used for firing samples.

3.4.5 Respiratory Index (RI_7)

The respiratory index (RI_7) can be defined as "the rate of oxygen uptake of a sample under specific conditions" (Gomez et al, 2006). RI_7 is a respiration measurement at seven days that describes the amount of organic matter easily available for biodegradation under aerobic conditions which is equivalent to oxygen consumed in seven days by an indigenous micro flora in the sample. It can also be defined as (mgO_2/gdm), the milligram of oxygen consumed per gram of volatile solids (VS) per 168hours (Soyex and Plickert, 2002). The RI_7 test has many advantages: measuring of organic matter contents, the rate of degradation, identifying toxic compounds, determining the degree of stability and calculating the oxygen consumption rate (Gomez et al, 2006).

The RI_7 was determined using the Oxytop type WTW System. 75g of sample were taken to field capacity and placed in an airtight 1500 ml vessel with a pressure sensor lid. Five drops of potassium hydroxide are added on to the top of the vessel before the pressure sensor lid is placed to absorb the carbon dioxide produced during biodegradation. As a result a negative pressure develops. The data was collected and recorded by the computer. The change in pressure that was caused by the consumption of oxygen was then calculated using the ideal gas law. The respiration index after seven days (RI_7) was then obtained by dividing the amount of oxygen (mg) consumed by the amount of dry matter (g) multiplied by 7. The calculations are shown in Appendix A. Figures 3-7 show the principle set up of the Oxytop system.

Plate 3-7: Respiratory Index (RI_7) set-up in the incubator.

3.4.6 Biogas production (Liquid displacement method).

The anaerobic decomposition of waste produces methane (CH_4) and carbon-dioxide (CO_2) as the major components. The biogas production potential was measured using the Liquid displacement test (biogas test). The test assesses the reactivity of waste in landfills by reproducing the landfill condition in the laboratory (Binner and Zach, 1999). One litre glass burette with two-way stop cocks at upper end was used. One of the stop cocks was connected to the displacement liquid bottle, while the other was exposed to the atmosphere. The bottom end of the glass burette was connected to a 1500ml amber bottle containing the waste sample which was at field capacity. The room was thermostatically kept at an ambient temperature range of 25℃ -30℃ and the samples places in a water bath. The glass burette was filled with an acidic salt solution which is the displacement liquid, an acidic solution made by dissolving 200g Sodium Chloride in 800ml of distilled water, and adding 30ml of Sulphuric acid and a few drops of methyl orange indicator. The displacement liquid ensured that the gas produced during the degradation process is not absorbed. The liquid was gradually as gas was produced in the sample vessel. The amount of liquid displaced was equal to the amount of gas produced at any point in time. The gas quantity in percentage of CO_2, O_2 and CH_4 volume by volume in air was then measured using a gas analyser (Model GA 2000).

Plate 3-8. Set-up of the anaerobic biogas test for the determination of gas production potential.

3.4.7 Chemical Oxygen Demand (COD) (section 5220D)

The Chemical Oxygen Demand (COD) estimates the amount of organic matter present in an aqueous solution that is subject to oxidation by a strong chemical oxidizer (Perez et al, 2007). The measured COD is expressed in mg/l of oxygen needed to produce the oxidation. The COD test was carried out in accordance with the Standard method following the open reflux method (Clesceri et al 1998). Each sample was refluxed in strong Sulphuric acid solution with 1.5ml of potassium dichromate ($K_2Cr_2O_7$), an oxidizing agent which is reduced to chromic ion (Cr3+) at the end of the test. After digestion, the remaining unreduced $K_2Cr_2O_7$ was titrated with a catalyst, ferrous ammonium sulphate (FAS), to determine the amount of $K_2Cr_2O_7$ consumed and the oxidizable matter calculated in terms of oxygen equivalent. Equation 3-8 shows the reduction of dichromate ion to oxidize organic matter.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \qquad \text{Equation 3-8}$$

During the digestion process the organic matter present in the sample was oxidized and the yellow dichromate was reduced to the green chromic ion. After this process the test tubes were cooled to room temperature. The amount of COD was colorimetrically determined at 600nm by measuring the amount of chromic ion produced using a spectrophotometer (Hach dr/2000). The accuracy and quality of reagents was checked by preparing a potassium hydrogen phthalate standard. The samples were analyzed in triplicates. Distilled water was used as blank which contained the reagents and a volume of distilled water equal to that of the sample and these acted as controls for the experiment. The analysis carried out the digestion of the sample at 150°C for two hours. COD was calculated from the equation 3-9.

$$\text{COD as mg/L} = \frac{(A-B) \times M \times 8000}{\text{mL (sample)}} \qquad \text{Equation 3-9}$$

Where:

A = mL FAS used for blank,

B = mL FAS used for sample,

M = molarity of FAS, and

8000 = milliequivalent weight of oxygen x 1000 mL/L.

Plate 3-9: Heater for COD bottles.

Plate 3-10: Sample in spectrophotometer.

3.4.8 Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand (BOD) estimates the amount of biologically degradable organic matter present in a given volume of waste at a defined temperature over a specified time period and is expressed in mg/l of Oxygen (Roppola et al, 2006). BOD_5 reflects the amount of oxygen consumed by aerobic bacteria in five days of organic matter degradation at 20^oC. The BOD_5 test was performed using an Hg free www 2000 oxitop® system by measuring differences in pressure via electronic sensors, as a result of oxygen consumption. The procedure to obtain BOD_5 was as follows; a sample volume of eluate was put in airtight 300ml incubation bottles with a flared month. Depending on the range of BOD estimated in the experiment, the total volume of the BOD bottle was different. Table 4.1 summarizes this relation between BOD measuring range and sample volume.

The bottles were sealed with a rubber sleeve containing KOH, to absorb CO_2 and eliminating some of the potential for algae growth that could render erroneous data. A nitrification inhibator ATH (N- allylthiourea) was added to inhibit the action of nitrifying bacteria. A white magnetic stirring bar was placed inside the bottle. The bottles were then sealed with the oxytop® membrane. The incubator was thermostatically controlled at 20 ± 1^oC with constant agitation for 5days. The dissolved oxygen was measured after incubation. The analysis was done in duplicate for accuracy and precision. Results were directly obtained from the oxytop® system.

Table 3-1: Relationship between BOD measurement range and sample volume.

Sample Volume	Measuring range (mg/l)	ATH (drops)
428	0 - 40	10
360	0 – 80	10
244	0 – 200	5
157	0 – 400	5
94	0 – 800	3
56	0 – 2000	3
21.7	0 – 4000	1

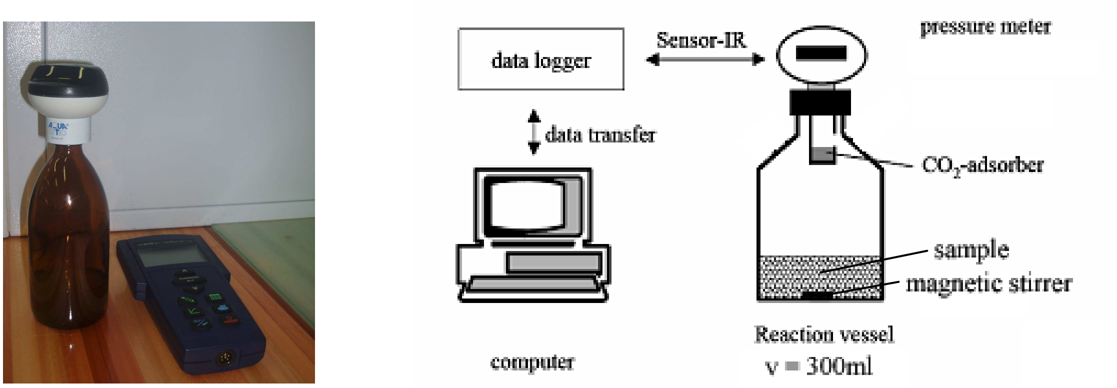


Figure 3-3: Principle setup of the Oxytop test system for the determination of BOD_5 and respiratory index (RI_7)

The instrument calculates BOD_5 in mg/l. The equation 4-7 below was used to obtain the pressure change due to oxygen consumption by the biodegradation process.

$$\Delta P = \frac{BOD_5}{\left(\frac{M}{RT_m}\right)\left(\frac{V_t - V_l}{V_l} + \alpha\frac{T_m}{T_o}\right)}$$ Equation 3-7

Where

BOD_5 is results from the test (mg/l)

M is molar mass of oxygen (32.0 $gmol^{-1}$),

R is the gas constant (83.144 L hPa mol^{-1} K^{-1}),

T_m is the measuring temperature of 20^oC (293.15 K),

T_0 is 273.15 K (STP),

V_t is the bottle volume (ml),

V_l is the liquid phase volume (ml),

α is the Bunsen absorption coefficient (0.03103), and

ΔP is the difference in partial oxygen pressure (hPa).

3.4.9 Ammonia and Nitrates (NH_3 and NO_3) (SABS Method 217:1990)

In the presence of HCL, sodium hydroxide (NAOH), and cupric sulfate ($CuSO_4$) catalyst, amino nitrogen of many organic materials is converted to ammonium. Free ammonia also is converted to ammonium. After addition of base, the ammonia is distilled from an alkaline medium and absorbed in boric or sulfuric acid. The ammonia may be determined colorimetrically, by ammonia-selective electrode, or by titration with a standard mineral acid (Eaton et al, 2005). According to SABS method 217 (1990) the sample is distilled in alkaline conditions while the distillate is collected continuously in boric acid and diluted to 250 ml in distilled water. The distillation unit is pre-heated to distil water until about 250ml of distilled water is obtained in the collector. 50ml of Boric acid which is used as absorbent solution was then measured out in an Erlenmeyer flask and a few drops of mixed indicator. The flask is introduced in the adapter of the cooler ensuring that it is submerged well below the level of the absorbent solution. Once the sample tube and the Erlenmeyer flask with the boric acid are properly placed, 50ml of NAOH is measured into the sample.

The distilling is then initiated, to distil a minimum of 150ml. Amino nitrogen in the sample is converted to ammonium. Free ammonia also is converted to ammonium. The solution formed is titrated with standard hydrochloric acid solution until the solution changes from purple to green, to determine the amount of ammonia. After ammoniacal nitrogen has been removed, Devarda's alloy and Magnesium oxide are added into the remaining sample and distilled again in boric acid. The distillate is then titrated against standard hydrochloric acid and the nitrate/nitrite nitrogen determined. For precision a rapid checking of Nitrogen recovery in the distilling unit was done. It consists of distilling sulphate Iron ammonia (mohr salt) whose Nitrogen contents is known. Once distilled the quantity of detected Nitrogen is evaluated and calculated. The Nitrogen value is calculated from the following equation.

$$P=14 * NHCL * VHCL \qquad \text{Equation (3-10)}$$

Where

P=detected Nitrogen (mg/l)

NHCL= HCL normality (M)

HCL volume consumed in the evaluation (ml)

Plate 3-11: Nitrate and Ammonia distiller

3.4.10 pH test

pH is a measure of acidity or alkalinity of a solution numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale commonly in use ranges from 0 to 14. A pH meter Orion LABTECH model 410A was used to measure pH of the eluates. The pH probe was calibrated between 4 and 7 before each measurement. For quality control electrodes were thoroughly rinsed between samples.

Plate 3-12: The pH measurement set-up.

3.4.11 Conductivity

Conductivity has been defined as "*a measure of the capacity of water to pass an electric current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions(ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge). It is measured with a probe and a meter*" (Spellman F 2003). The conductivity test was carried out using the Corning Checkmate 11 sensor. The sensor was placed into a beaker containing the eluate and the value read. For quality control electrodes were thoroughly rinsed between samples.

Plate 3-13: The corning checkmate sensor.

3.4.12 Carbon to Nitrogen ratio (C/N ratio)

The carbon to nitrogen ratio is a measure of the total carbon and the total nitrogen in the waste sample. This method uses the Walkley – Black procedure (Horneck and Miller, 1998), using a Truspec carbon/nitrogen analyser. An air dried sample is placed into a 500 ml Erlenmeyer flask and potassium dichromate solution is added to the sample from a burette. The sample is dispersed into the solution by swirling. 20 ml of sulphuric acid is added rapidly, but cautiously. Swirling ensure effective mixing. The sample is set in a flask to cool on asbestos sheets for about 30 minutes. 5-10 drops of an indicator and excess dichromate is added to the solution and titrated with iron (2) ammonium sulphate solution giving a dark violet brown to a sharply green colour. Repeats are made for smaller samples if the iron (2) titration is less than 5.0 ml. The organic carbon content can be calculated using equation 4-11 below.

$$\boxed{\text{Carbon } (\%^{m}/_{m}) = \frac{(A-B) * M * 0.3 * 1.17}{m}} \qquad \text{Equation 3-11}$$

Where

A = Volume of the iron solution from standardisation (ml)

B = Volume of iron solution from measurement (ml)

M = Molarity

m = Mass of the sample

For the measurement of total nitrogen a Leco FP528 nitrogen analyser which analyses small samples (less than 250 mg) was used. 0.1500 g ± 0.05 g of sample was weighed in a tarred tin foil cup and recorded. An appropriate secondary reference material was then ran every 20 samples. Nitrogen concentrations were calculated by the instrument software, and the results downloaded from the instrument database. The analytical data obtained from the nitrogen analyser was then evaluated by plotting the concentrations for the nitrogen in the reference material on the control charts. The analysis was carried out by the Bemlab (PTY) LTD in Cape Town.

3.4.13 Temperature

Temperature measurement indicates a balance of moisture, air and nutrients available for the microbes during composting. Towards the end of the process, the temperature drops below 40^{o}C, implying the maturity and stability of the waste (Kulcu et al, 2004). The ambient temperature in this work was monitored everyday. The temperatures of the pile in both experiments were measured four times a week using a temperature probe. Two readings were obtained for each pile at two different sampling positions, the middle reading and the bottom reading (Figure 3-1). Temperature measurement was done using a thermocouple, type (MT -630) as seen in Plate 3-14.

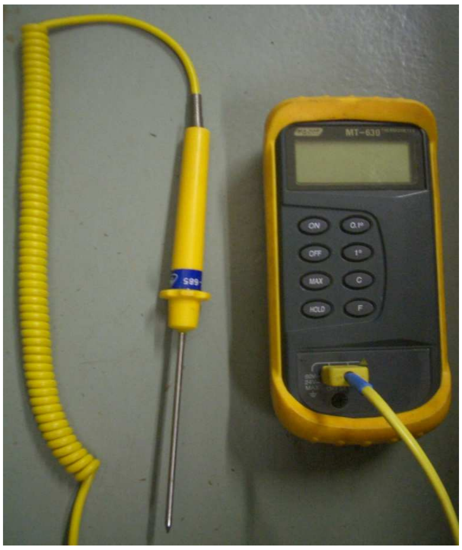


Plate 3-14: The thermocouple

3.4.14 Airflow rate

Aeration flow rate determines the performance and the rate of decomposition of the composting pile. A high flow rate would increase the energy transfer in the pile and reduce the temperature. While a low flow rate would reduce the amount of oxygen needed by the microbes thereby resulting in anaerobic conditions (Kulcu et al, 2004). A minimal oxygen concentration of about 18% in is needed to provide an optimum aerobic condition (Soyez et al, 2002; Bari et al, 2000)

According to Crockett (2006), to efficiently aerate using forced aeration, piles of horse manure & wood shavings that were over 126m^{3} in volume, 10.7m long, 10.7m wide, and 2.2m high with 4" diameter aeration vanes under the pile and an aeration pressure of 2/3" have to be employed. They used a blower of capacity 21240L/min. To hold the oxygen level above 15% the carbon-dioxide levels must be less than 2% to ensure optimal conditions. To achieve this they provided 283L/min of fresh air per cubic yard of compost. In this research, an aeration rate of range 10L/min – 15L/min was applied as the volume of waste used the previous study was approximately 28 times more than in our case study (large-scale) investigations. The airflow was controlled intermittently using a timer preset cycle of two hours aeration followed by four hours pause. A rotameter was used to determine the amount of air going into the pile. The rotameter is shown below. The off-gas concentrations from each experimental campaign were measured using a probe as seen in Figure 3-1 and 3-2. The monitoring was done four times in a week.

Plate 3-15: The rotameter used to control air-flow rate.

3.5 Precision and Repeatability

Accuracy checks were carried out to eliminate the possibility of errors. Each of the analysis carried out on the solid matter and eluates were done in duplicates, to aid in quality assurance. Samples were refrigerated at $4^{o}C$ until when needed for analysis to reduce microbiological decomposition of solids. The samples were brought to room temperature before analysis and analysed as soon as possible. Standard deviation, averages and variance were done for each set of test as a repeatability check for the analysis; the equations used are as shown below. The results presented in the next chapter are the average values obtained from the analysis.

$$Average = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \text{Equation (1)}$$

$$\mathrm{var}\,iance = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - x)^2 \qquad \text{Equation (2)}$$

$$s\tan dard\ deviation = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - x)^2} \qquad \text{Equation (3)}$$

Where

x_i = value of the analysis data

n = number of observation or data

x = average of the analysis data

CHAPTER FOUR

Small scale experimental results and discussions

4.1 Introduction

The results of the small scale experiments are presented in this chapter as a summary of the accomplished goals. Raw data obtained during the experiments and calculations are reported in appendix B. In the first experimental campaign, commercial garden waste (CGW) was biologically treated in drum 1, and domestic garden waste (DGW) in drum 2. The two degradation processes were carried out simultaneously. The results obtained using the selected testing methods are presented in the sections below.

4.2 Process Monitoring Indicators

Process monitoring parameters such as the airflow rate, temperatures, and off-gas quality and production were recorded during composting. The off-gas concentrations were measured four times in a week, via the gas probe in percentage with a gas analyser (type GA 2000). The continuous measurements of off-gas allowed the assessment of carbon dioxide, methane and oxygen concentrations. The temperature measurements represented the state of the waste material surrounding the probes since the primary cause of heating in an aerobic treatment is surplus microbial metabolic heat.

4.2.1 Airflow rate

The airflow rates used ranged from 40l/hr to 120l/hr, with the air compressor working intermittently. There was no fixed airflow rate, rather it was adjusted according to the off-gas results obtained. The aeration was disrupted between the first and second week, as a result of a malfunction in the air compressor, the problem was resolved immediately. Figures 4-1 and 4-2 show the influence of aeration on the off-gas turnover for both samples.

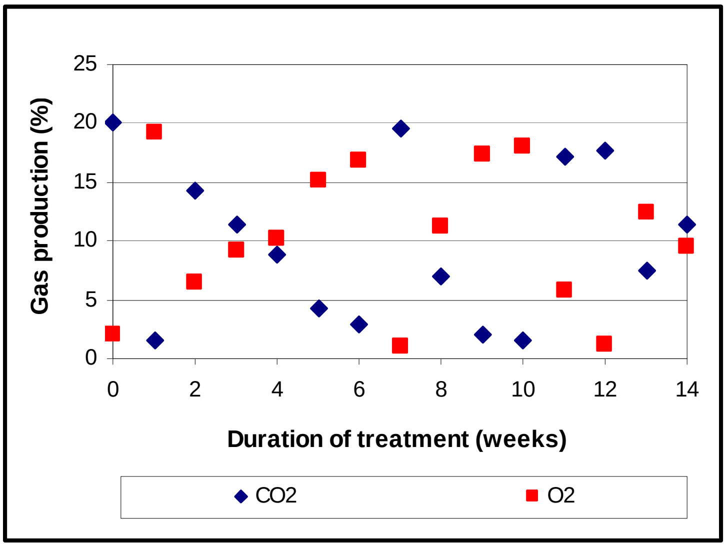


Figure 4-1: Off-gas production rate for CGW during the aerobic degradation process in drum 1.

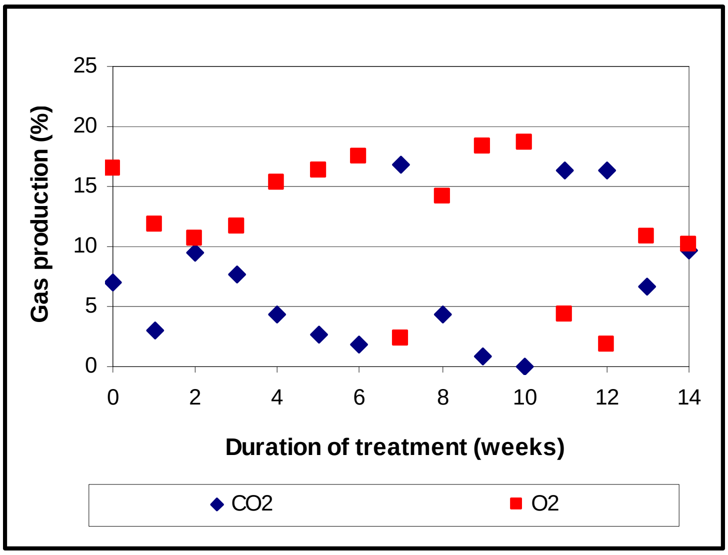


Figure 4-2: Off-gas production rate for DGW during the aerobic degradation process in drum 2.

From these figures, the measurement of O_2 composition confirms the aerobic degradation of the process. The airflow rate fluctuated continuously throughout the entire treatment period. We observed that the microbial population was affected negatively in both drums by excess aeration. Since the production of CO_2 is caused by the mineralization of organic matter, it can be concluded that the CO_2 rate fluctuated in both drums in proportion to the activity of micro-organisms during the process.

4.2.2 Temperatures

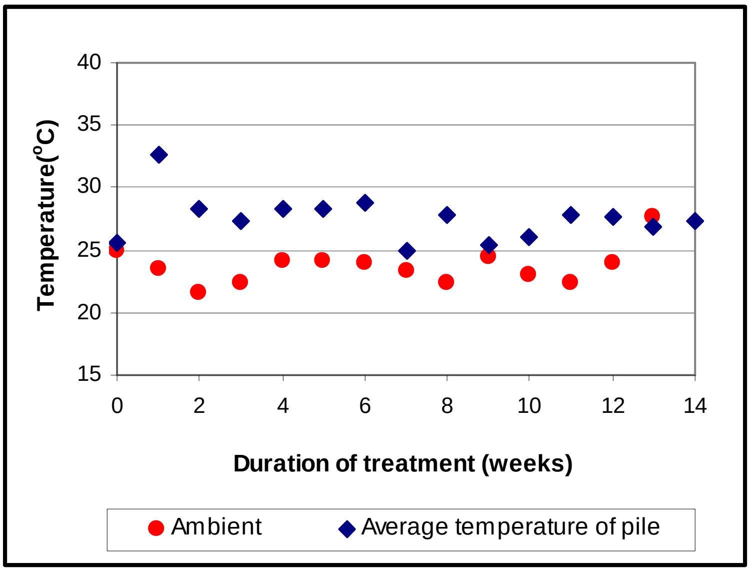


Figure 4-3: Changes in temperature and ambient temperature for Commercial garden waste in drum 1 during the period of treatment.

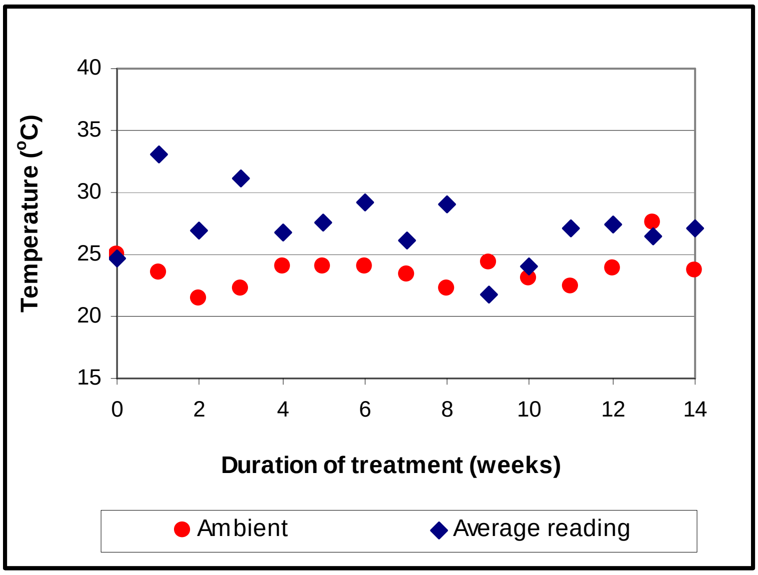


Figure 4-4: Changes in temperature and ambient temperature for Domestic garden waste in drum 2 during the period of treatment.

The temperatures development in the drums is shown in Figures 4-3 and 4-4. During the period of study, the temperature of the waste pile ranged from 21 to 34°C and from 19 to 34.9°C in drum 1 and 2 respectively**,** while the ambient temperature ranged from 19 to 27 °C. Temperatures were very low, and remained at approximately the same levels in both drums, corresponding most clearly to the ambient temperature. 34.9°C was the highest temperature detected in this run. We assumed that the temperature was not rising because the bacteria were not active, since heating is an indicator of microbial activity as observed by Crockett (2007a). The cause of low bacterial activity could be the excess aeration rate. This resulted in a slow degradation process since the most efficient micro-organisms are aerobic thermophilic bacteria at temperatures above 50°C. Another explanation could be the activities of anaerobic bacteria, when the oxygen was depleted, between the first and second week. These conditions may have lead to an accumulation of some anaerobic by-products such as Volatile Fatty Acids (VFA), leading to unstable and acidic compost. This enhanced the fast development of a mesophilic phase, with a temperature stabilised at about 30°C (Figures 4-3 and 4-4).

4.3 Characterisation of Solid Matter

Analyses on the solid matter are important in the control of the biological treatment process and for assessing the rate of degradation of the organic matter. To characterize the waste samples, chemical and physical examinations of both substrates were carried out on the input material and on a representative sample collected every two weeks during the entire treatment period. The results of the total dry matter reduction for CGW and DGW samples are presented in Table 4-1 below.

4.3.1 Moisture Content

The initial moisture content of CGW was 38% and 55% for DGW. For both samples the moisture content was increased to approximately 60% for optimum degradation at the beginning of the process.

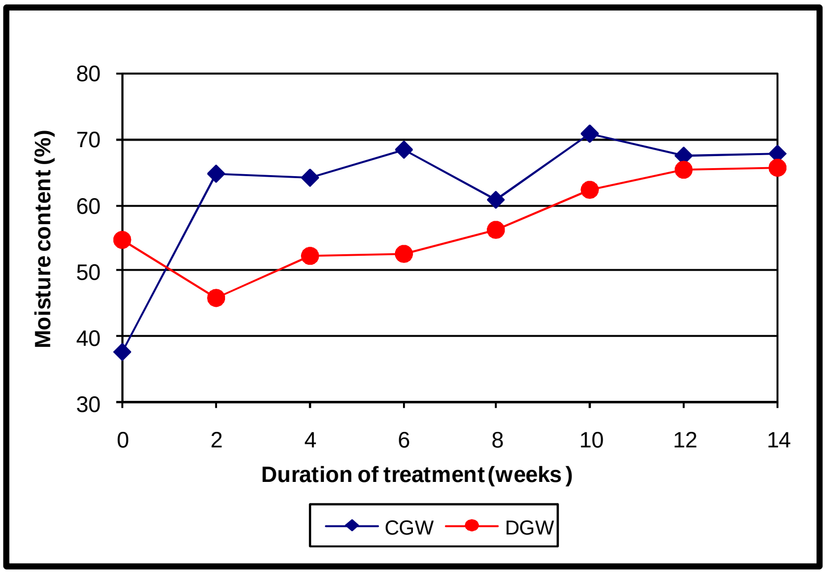


Figure 4-5: Variations in moisture content for CGW and DGW during the small-scale aerobic treatment in drums 1 and 2.

As seen in Figure 4.5, the moisture contents of both samples increased continuously during the treatment process. This could be due to the heat generated in the decomposition process, as a result of microbial metabolism. This heat was accumulated and retained within the composting mass, and thus increased the moisture content, hence no additional water was added.

4.3.2 Carbon to Nitrogen ratio (C/N ratio)

The information presented in Figure 4-6 show the ratio of Carbon to Nitrogen for the two types of waste substrates.

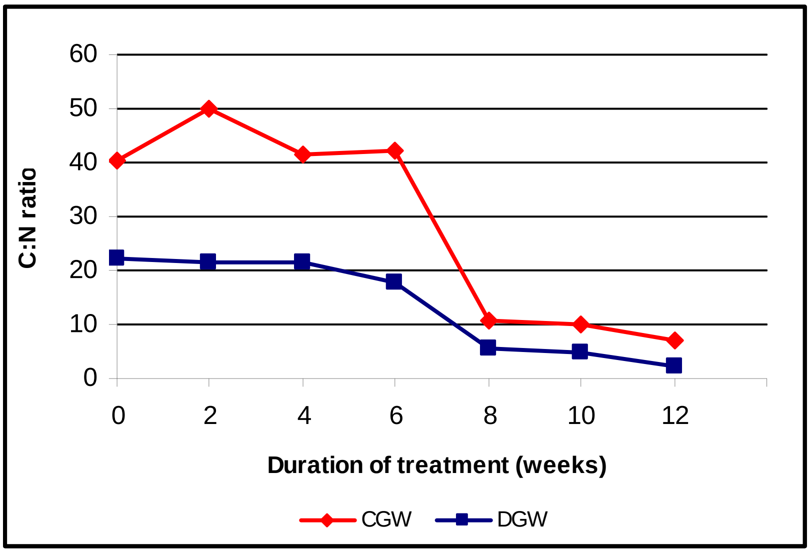


Figure 4-6: Variations in C/N ratio for CGW and DGW dry solid, during the small-scale aerobic treatment in drums 1 and 2.

The C/N ratios of the samples differ significantly from each other. The ratios of the untreated waste of CGW and DGW had values of 40.2:1 and 22.3:1 respectively. A reduction in C/N ratio was generally observed as the substrate matured. The C/N ratio decreased sharply during the 7th week of treatment. This decrease of the C/N ratio could be explained as the transformation of carbon into carbon dioxide followed by a lower decrease in the concentration of organic acids. The decrease of C/N ratio reflects the high organic contents in the acid phase, its sharp decrease in the methanogenic phase which could be a result of the persistence of nitrogen in the waste, thus the decrease in C/N reflected decomposition. At the end of the process, the values of C/N ratio varied between 2 and 7. According to EPA (2003) this corresponds to a stable form of the organic matter.

4.3.3 Total Solid (TS) and Volatile Solid (VS) on Dry matter

Figures 4-7 and 4-8 show the concentrations of TS and VS for CGW and DGW during the treatment period.

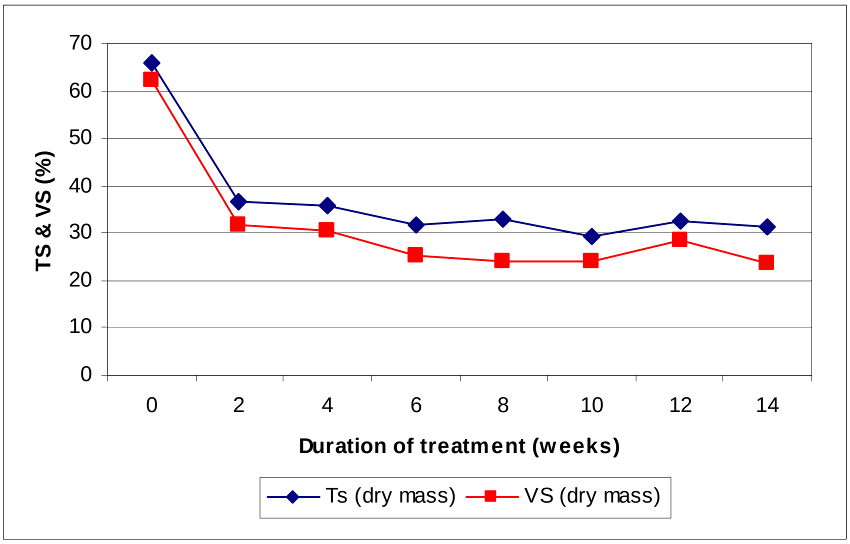


Figure 4-7: Evolution of TS and VS content for CGW during the small-scale treatment process in drum 1.

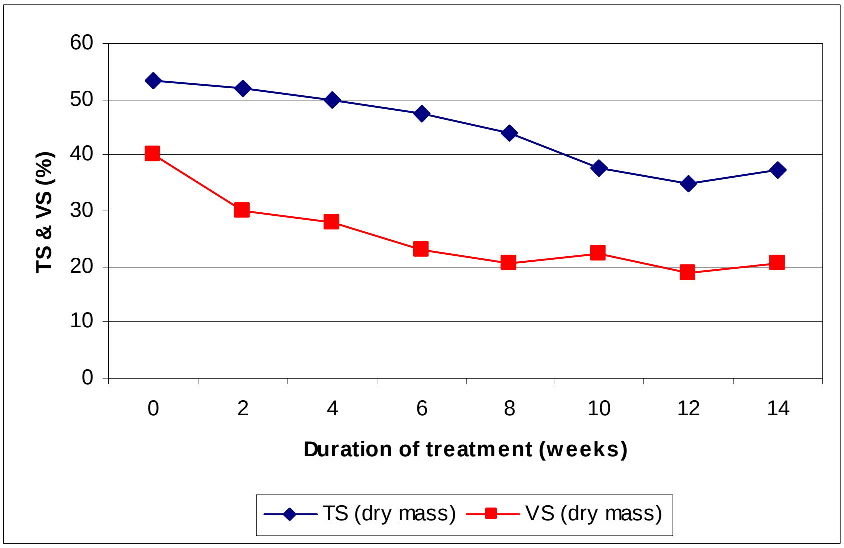


Figure 4-8: Evolution of TS and VS content for DGW during the small-scale treatment process in drum 2.

The initial concentrations of TS were high in both drums with an initial value of 66% for CGW and 53% for DGW. The reduction in TS is directly related to the microbial respiration according to Kulcu and Yaldiz (2004). Initial concentrations of VS were 62% for CGW and 40% for DGW. The CGW displays a higher VS concentration leached out from the solid matrix with respect to the DGW. A decrease in the volatile solid indicates that the biological constituents in the samples were reduced during the treatment as stabilization progressed.

4.3.4 Respiratory Index (RI_7)

The respiration index RI_7 for the waste samples collected from drum 1 for CGW started at 14.80mgO_2/gdm and reached 5.32mgO_2/gdm at the end of the biological treatment while DGW in drum 2, started at 15.92mgO_2/gdm and reached 1.93mgO_2/gdm.

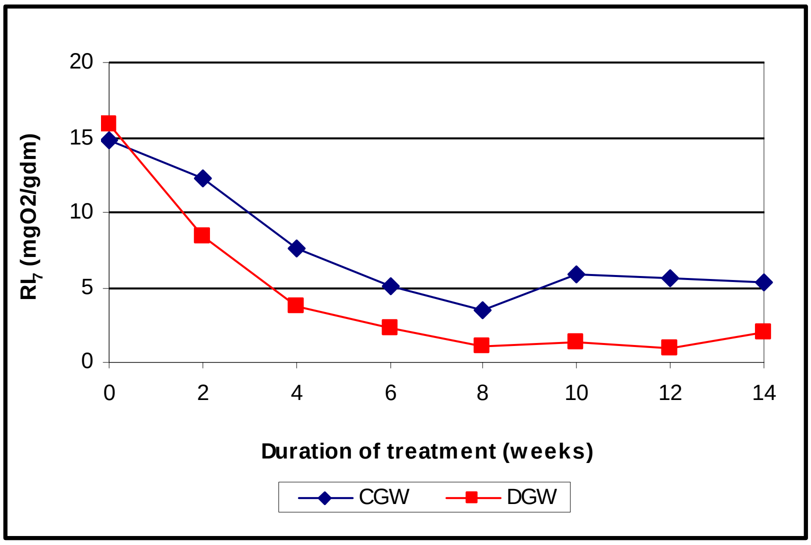


Figure 4-9: Respiration index (RI_7) measured for CGW and DGW, during the small-scale treatment process in drums 1 and 2.

This was evident from Figure 4-9. The highest values were measured for Commercial garden waste. The RI_7 values were higher in the input samples, but diminished gradually after several weeks. The diminishing values obtained reflect the reduction in biological activity during the process and also the amount of readily degradable substrate present in the waste composition.

4.4 Eluate Tests Results.

Table 4-2 presents the results of the eluate tests.

4.4.1 Conductivity

The changes in conductivity are presented in Figure 4-10.

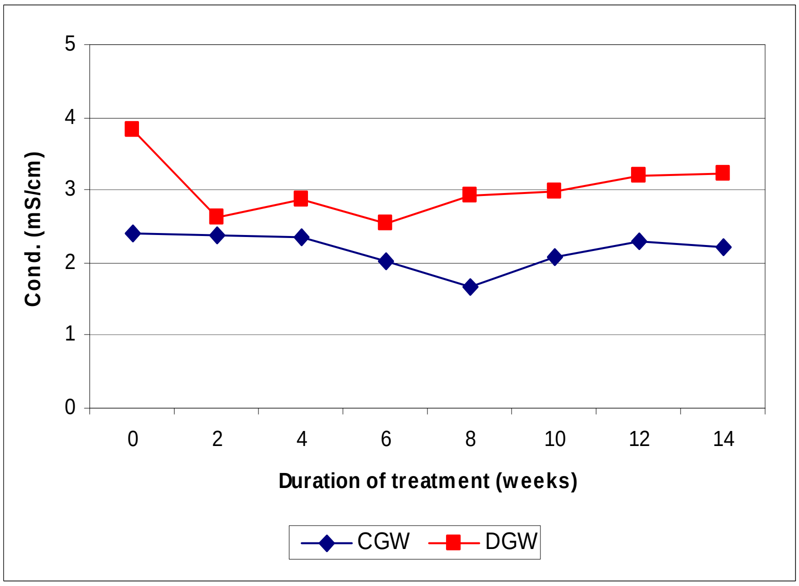


Figure 4-10: Variations in conductivity for CGW and DGW during the small-scale treatment process in drums 1 and 2.

Initially the conductivity values were 2.4mS/cm for CGW and 3.8mS/cm for DGW. The conductivity for CGW reached a minimum value of 1.7mS/cm after 8weeks of pre-treatment, and a minimum value of 2.6mS/cm was recorded during the 6th week of sampling for DGW. Subsequently the conductivity values increased simultaneously with the NO_3-N as shown in Table 4-2. This could be explained as the increase in NO_3-N lead to a build up of an electrical conductivity in the drums. At the end of the testing period 2.2mS/cm and 3.2mS/cm were observed for CGW and DGW respectively.

4.4.2 pH

Figure 4-11 show the values of pH varying with time during the experiments.

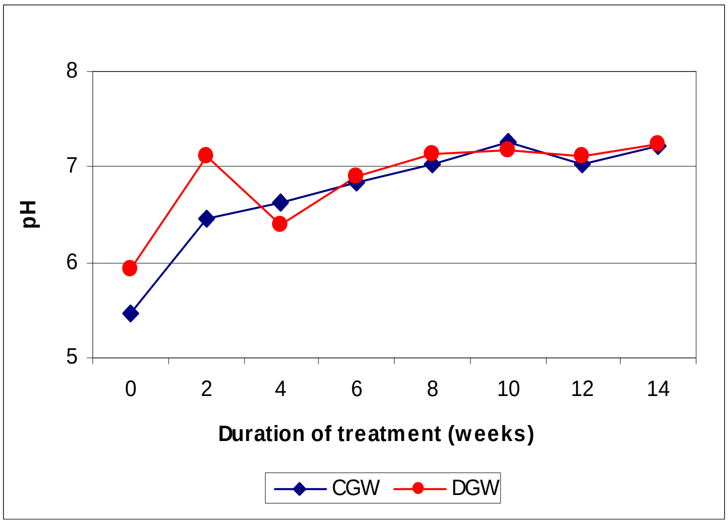


Figure 4-11: pH variations for CGW and DGW during the small-scale aerobic treatment process in drums 1 and 2.

The pH varied from 5.46 to 7.21 and from 5.94 to 7.24, respectively for CGW and DGW. The values were within the optimal of 5.5 to 8.5 for compost microorganisms (Norbu et al, 2005). The pH of DGW shifted towards the alkaline range within two weeks of treatment. A low pH was observed for DGW in the fourth week of sampling. This might be due to the reduction of organic matter to mineral acids, which is a result of anaerobic conditions, leading to an acidification of the medium as a result of VFA accumulation. Generally, the pH values for both samples increased gradually in both reactors during the treatment period. pH changes were caused by the decomposition of organic acids (Adani et al, 2006). The increase of pH values can be considered as an indicator of maturity, and the alkalinity increase can act against some pathogenic fungi since a large number of fungi grow only under acid conditions (Norbu et al, 2005).

4.4.3 BOD_5 and COD

The range of concentrations of BOD_5 and COD in the eluate tests measured for Commercial garden waste and Domestic garden waste from drums 1 and 2 respectively, are reported in Table 4-3.

Table 4-3: Variations in BOD_5 and COD content for Commercial and Domestic garden waste in drums 1 and 2.

Sample	Duration (weeks)	BOD_5 (mg/l)	COD (mg/l)	BOD_5/COD
CGW	0	1657	15603.2	0.11
	2	1007	10723.5	0.09
	4	411.5	1088.5	0.38
	6	406	1707.4	0.24
	8	299.5	2068.2	0.14
	10	224	1534.4	0.15
	12	577	7375.2	0.08
	14	362	2099.1	0.17
DGW	0	1290.5	5631.9	0.23
	2	805	4699.5	0.17
	4	694.5	1756.9	0.39
	6	187	783.2	0.24
	8	833.5	5637.2	0.15
	10	369	1624.6	0.23
	12	855	7086.4	0.12
	14	608	4987.3	0.12

The data in Table 4-3 show values ranging from 187 to 1007mg/l for BOD_5 and from 783 to 15603mg/l for COD.

Changes in organic concentrations of COD for CGW and DGW are shown in Figure 4-12.

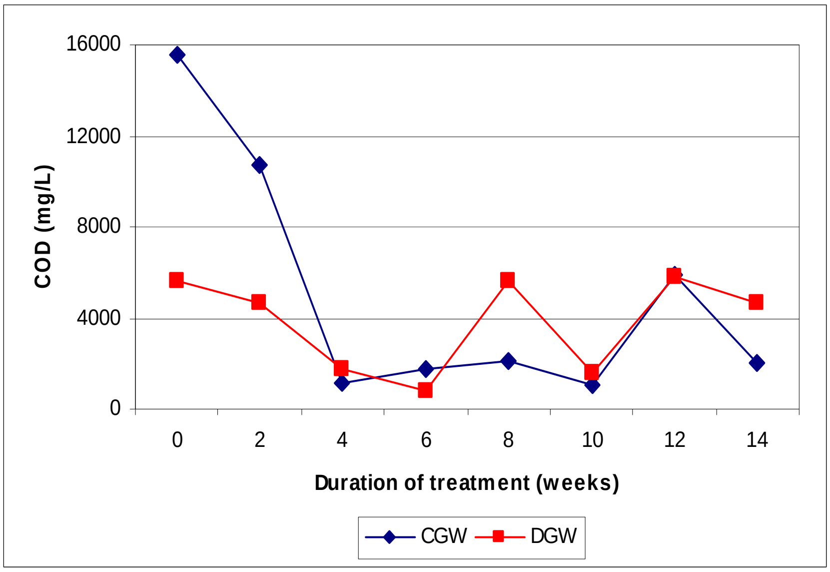


Figure 4-12: Variations in COD concentration for CGW and DGW during the small-scale aerobic treatment process in drums1 and 2.

The development of the organic load in the Eluate characterised by the chemical oxygen demand shows that the value was high at the start, but had a rapid reduction in the 4th week. This indicates the rapid degradation of organic compounds by enhancing the metabolism of aerobic microorganisms, due to aeration.

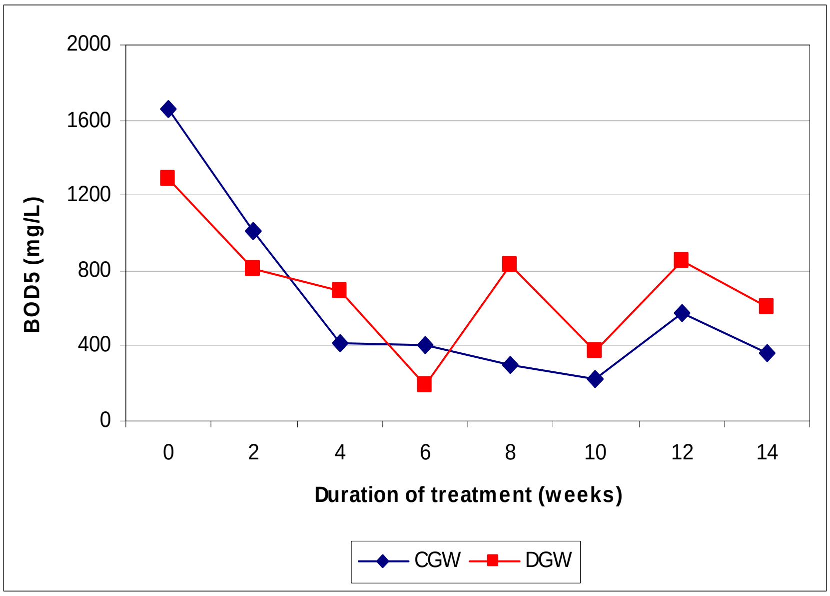


Figure 4-13: Variations in BOD_5 concentration for CGW and DGW during the small-scale aerobic treatment process in drums 1 and 2.

The BOD_5 values were fluctuating, and difficult to measure accurately in both waste samples, this could be due to the presence of highly dissolved organic carbon. The values are depicted in figure 4-13. A similarity between the BOD_5 values and COD concentrations of both samples can also be observed from about the 6th week, as seen in figures 4-12 and 4-13. The ratio of BOD_5 to COD (BOD_5/COD) was calculated for each sample (table 4-3), since it may reflect the overall waste biodegradability (Godley et al, 2004). Although, the values for BOD_5 and COD were very different for the two samples, the BOD_5/COD was very similar. According to Cossu and Raga (2007), very different materials may have similar values for BOD_5/COD ratio. This ratio increased with time following the degradation of the material. However, in general no information on the extent of the stabilization process can be expected from the comparison of the BOD_5/COD in the samples, probably due to the degree of heterogeneity of the Domestic garden waste compared to the Commercial garden waste. The final BOD_5/COD ratios were within the range of 0 and 0.2 suggesting that some biodegradable organic carbon have been extracted, and a certain biological stability of the samples have been attained during the degradation process.

4.4.4 Ammonia (NH_3-N) and Nitrate (NOx-N) contents

The evolution of the ammoniacal nitrogen content at different stages of the biological pretreatment is reported in Figure 4-14.

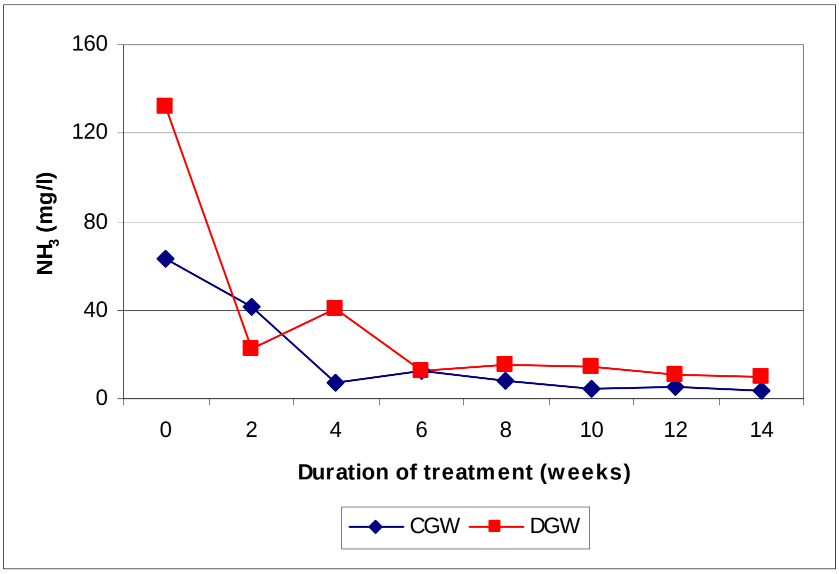


Figure 4-14: Variations in concentration of NH_3-N for CGW and DGW during the small-scale treatment process in drums 1 and 2.

From Figure 4-14, it can be seen that the value of NH_3-N decreased during the treatment process. Ammonia was present in a higher concentration in the input samples. This confirms a high concentration of Nitrogen in garden waste. A gradual decrease for both samples can be noticed from the 6th week of pretreatment.

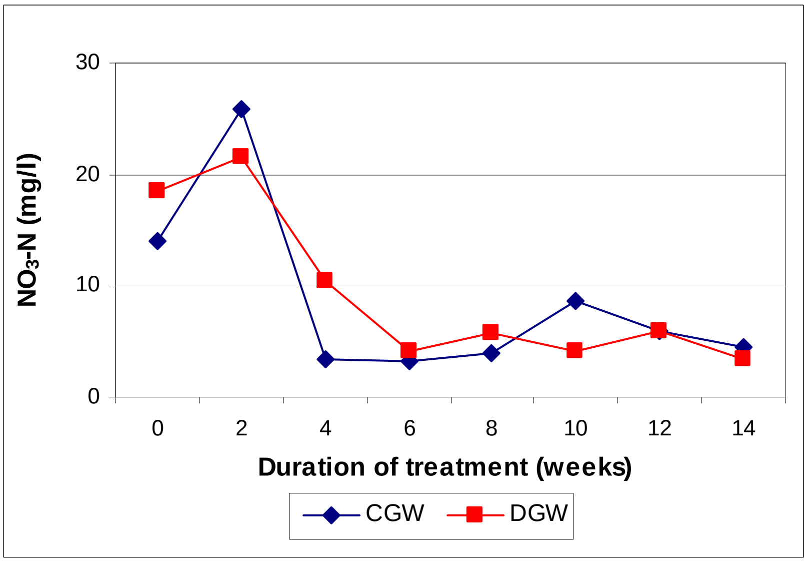


Figure 4-15: Variations in concentration of NO_3-N at different stages of the aerobic treatment process, for CGW and DGW in drums 1 and 2.

Results for the variations in NO_3-N are presented in figure 4-15. The increase in NO_3-N contents during the second week indicates the degradation of ammonia to nitrate leading to an increase in nitrification. The subsequent increase of NO_3-N in the 10th week for CGW and the 8th and 12th week for DGW indicates a great decomposition of organic material with the release of available nitrogen compounds. The nitrogen distribution in both drums showed that at the end of the process, ammonia is decreased.

4.4.5 Total Solids and Volatile Solids in Eluate

Figure 4-16 and 4-17 show the concentrations of TS and VS for CGW and DGW in the Eluate samples during the treatment period. From the results the concentration can be seen to decrease gradually.

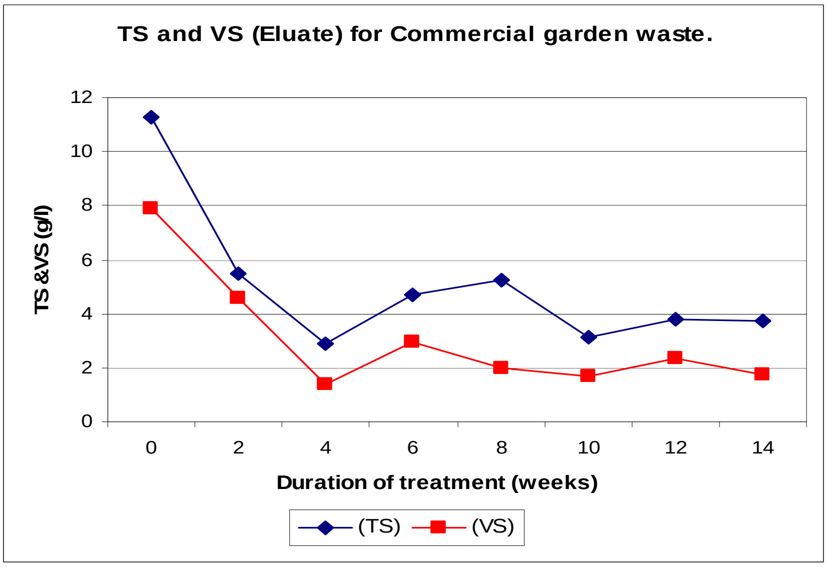


Figure 4-16: Changes in TS and VS content for Commercial garden waste during the small-scale treatment process in drum 1.

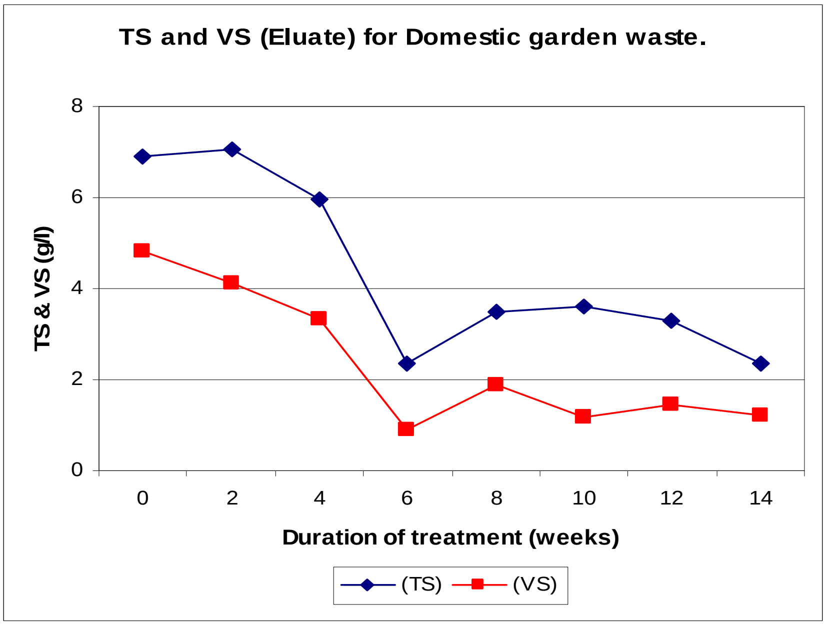


Figure 4-17: Changes in TS and VS content of Domestic garden waste during the small-scale treatment process in drum 2.

4.5 Biogas Production

The biogas production from the samples taken every two weeks during the pretreatment was studied in anaerobic reactors that employ the Liquid displacement method as described in section 3.4.6. The gas production for the fresh waste samples of CGW and DGW is presented in Figure 4-18.

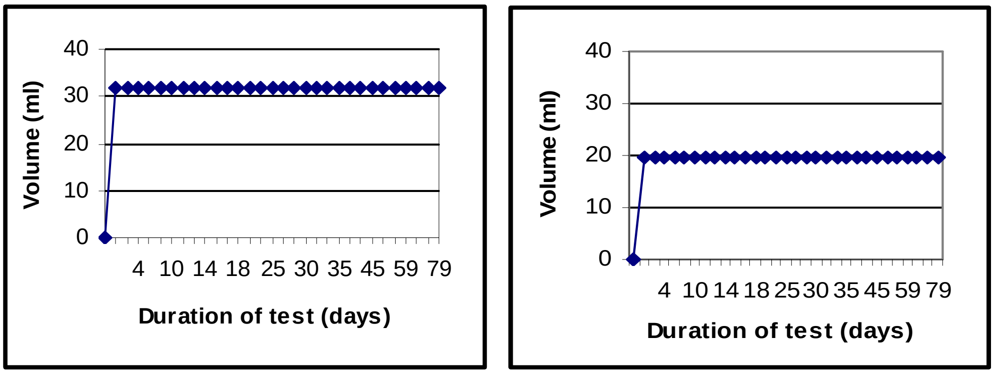
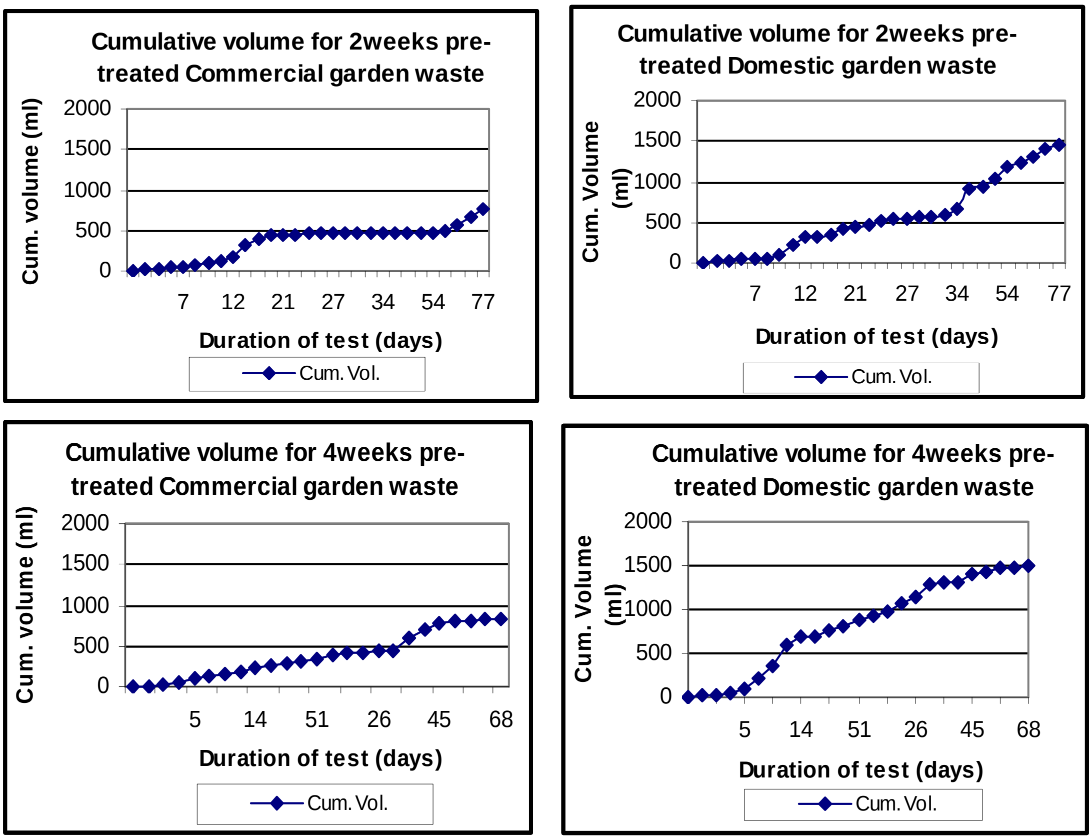


Figure 4-18: Gas volumes for the input waste samples of commercial and domestic garden waste in drums 1 and 2 respectively.

From these figures it can be seen that biogas production was inhibited after 10 to 15 days from commencement of the experiment. This could be as a result of an imbalance in the growth rates of fast growing acid genetic bacteria and aceto-clastic methanogens that occur during the first stage of decomposition as observed by Adani et al, 2004.



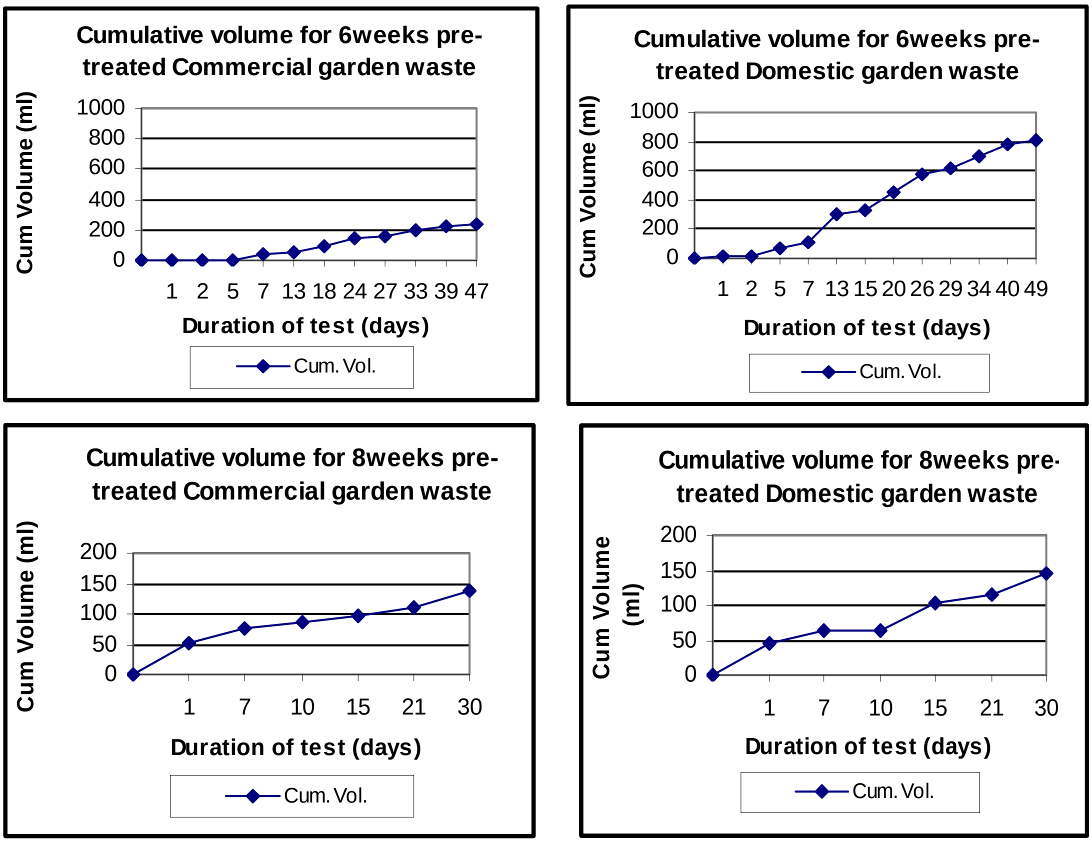
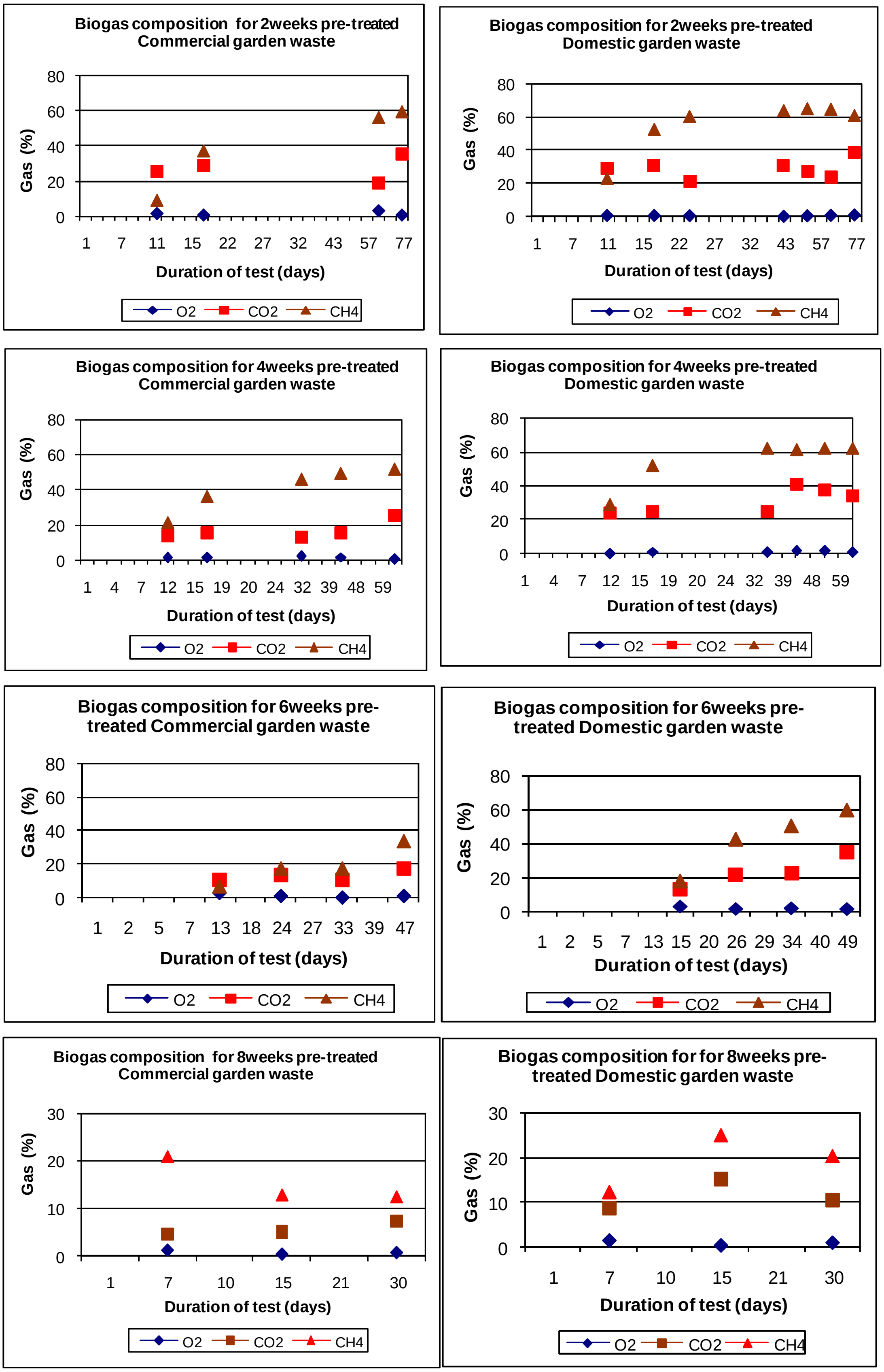


Figure 4-19: Cumulative gas volumes for Commercial and Domestic garden wastes at different stages of treatment in drums 1 and 2 respectively.

Figure 4-19 show the cumulative gas volumes of Commercial garden waste and Domestic garden waste after 2weeks, 4weeks, 6weeks and 8weeks of treatment. The maximum volume can be observed in the 4weeks pre-treated waste. After 8weeks of treatment the volume of gas produced is seen to decrease. Comparing the 2-weeks treated and the 8-weeks treated waste, the volume of gas produced was reduced by 60%. Figure 4-20 show the gas composition (in percentage) for the 2-weeks, 4-weeks, 6-weeks and 8-weeks pretreated CGW and DGW waste samples. The 2-weeks and the 4-weeks samples display a concentration of CH_4 and CO_2 more similar to typical degradation patterns in landfills. While, although the treatment was not efficient as expected (temperatures never reached 70^oC or higher) a certain degree of stabilization occurred as demonstrated by the decreased methane % in the 6-weeks and 8-weeks samples. Overall, the DGW seems to be were easily biodegradable than the CGW.



Biogas composition for 2weeks pre-treated Commercial garden waste

Biogas composition for 2weeks pre-treated Domestic garden waste

Biogas composition for 4weeks pre-treated Commercial garden waste

Biogas composition for 4weeks pre-treated Domestic garden waste

Biogas composition for 6weeks pre-treated Commercial garden waste

Biogas composition for 6weeks pre-treated Domestic garden waste

Biogas composition for 8weeks pre-treated Commercial garden waste

Biogas composition for for 8weeks pre-treated Domestic garden waste

Figure 4-20: Biogas composition rate for Commercial and Domestic garden waste at different stages of treatment in drums 1 and 2 respectively.

4.6 Output Material.

Table 4-4: Eluate and Solid test results of the output material of Commercial garden waste and Domestic garden waste samples.

ANALYSIS RESULTS ON ELUATE TEST								
SAMPLE	**TS**	**VS**	**PH**	**COND.**	**COD**	**BOD**	**N-NH_3**	**N-NO_3**
	(g/l)	**(g/l)**		**(mS/cm)**	**(mg/l)**	**(mg/l)**	**(mg/l)**	**(mg/l)**
CGW(final sample)	8.25	5.37	7.22	3.62	5781.56	1172.5	38.8	16.8
DGW(final sample)	24.42	12.76	7.38	3.83	6008.49	812.0	16.4	10.5

ANALYSIS RESULT ON DRY SOLID TEST						
SAMPLE	**TS**	**VS**	**Moisture**	**Field capacity**	**C:N**	**RI_7**
	(%)	**(%)**	**Content (%)**	**ml/100g**	**ratio**	**(mgO2/gdm)**
CGW(output)	34.88	28.43	64.84	26.02	31.30	3.29
DGW(output)	46.11	18.19	55.84	37.29	21.25	1.68

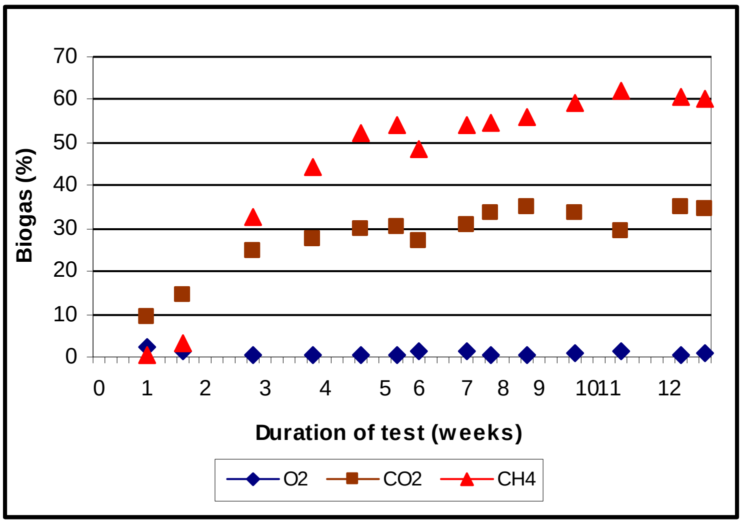


Figure 4-21: Biogas composition from the output CGW sample.

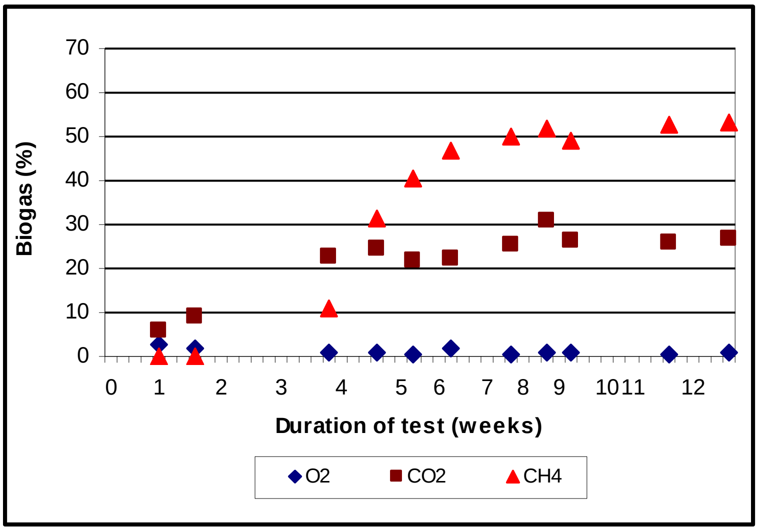


Figure 4-22: Biogas composition from the output DGW sample.

4.7 Summary of the first experimental campaign.

During the first experimental campaign, we observed some limitations.

1. The disruptions of airflow between the first and second weeks lead to a depletion of oxygen.
2. The microbial population was affected negatively by excess aeration as a result of a high airflow rate.
3. The volume of waste in the drums was small and quickly reduced.

Further investigations were therefore needed to assess the use of a low airflow rate and a large volume of substrate on the stability and degradability of the waste material. We also needed to prevent the slow degradation and a low temperature level. To achieve this we designed a system for the second experimental campaign, in the form of a trough made with steel and plastic sheets, for proper enclosure. The aeration was supplied through a manifold of several perforated PVC pipes. The details of the structure were presented in section 3.2.2. The results of the Large-scale experimental campaign are presented in the next chapter.

CHAPTER FIVE

Large scale experimental results and discussions.

5.1 Introduction

In the second experimental campaign, Commercial garden waste (CGW) was biologically treated in reactor 1, and Domestic garden waste (DGW) in reactor 2. The two processes were carried out simultaneously. The comparison of the results obtained using the selected testing methods for the two samples are shown below. Raw data obtained during the experiments and calculations are reported in appendix C.

5.2 Process monitoring indicators

Temperatures and airflow rates are relevant indicators to control the aeration and monitor the degradation patterns.

5.2.1 Airflow rate

The daily aeration rates in both windrows, ranged from 10l/h to 60l/h depending on the oxygen consumption within the pile. The oxygen concentration in the off-gas was maintained at an average range between 8% and 15%. 3.15m^3 of CGW were aerobically treated in reactor 1, at an airflow rate of 30l/hr, while 0.86m^3 of DGW were aerobically treated in reactor 2, and the airflow rate maintained at 10l/hr. During the entire process only a maximum of 0.6% of methane was detected at the bottom of the reactors. Figures 5-1 and 5-2 reveal the influence of aeration on the off-gas production for both samples.

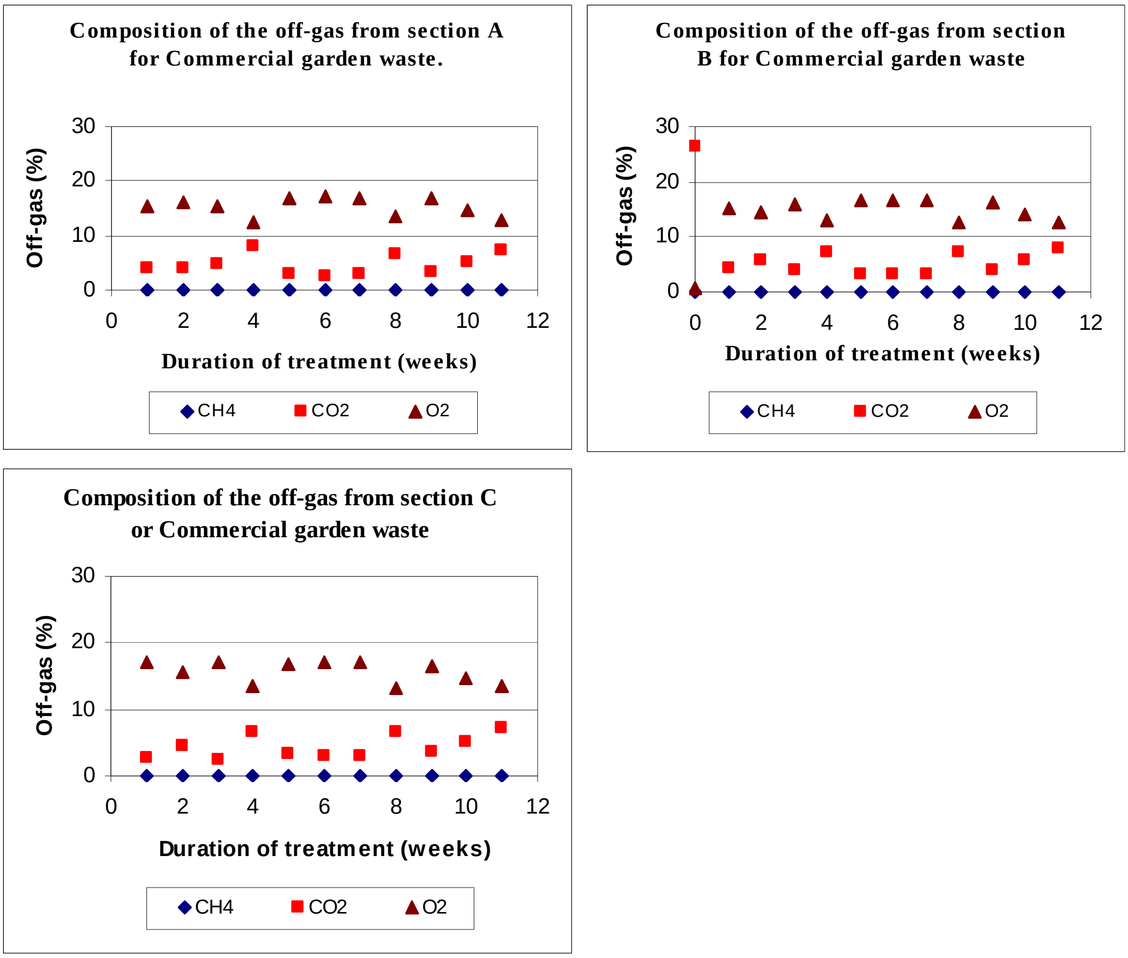
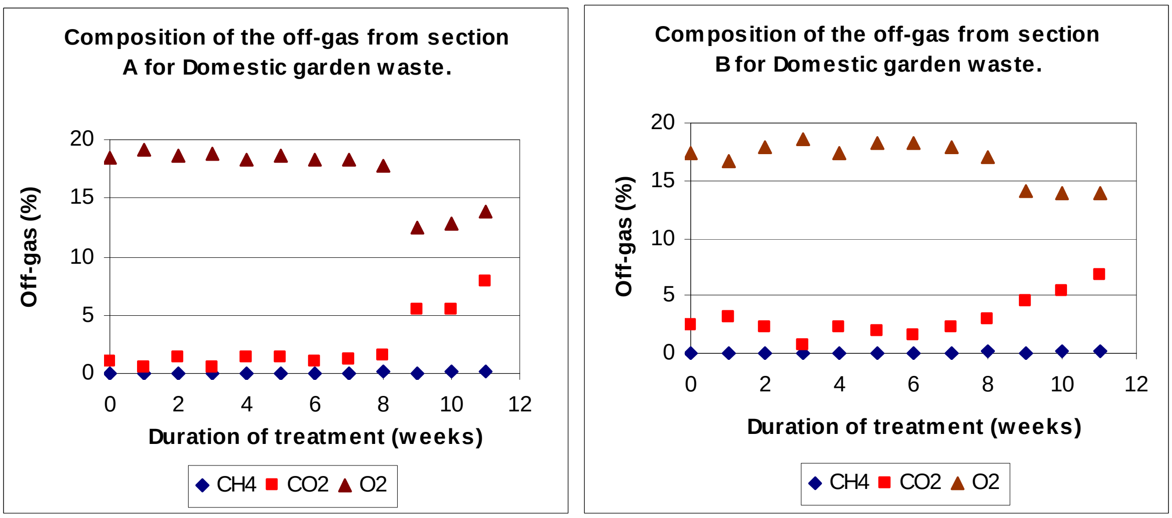


Figure 5-1: Composition of the off-gas during the composting process for Commercial garden waste.



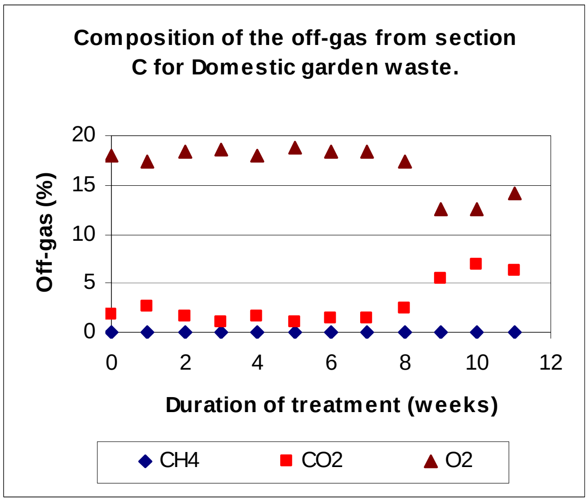


Figure 5-2: Composition of the off-gas during the composting process for Domestic garden waste.

From figure 5-2, during the 8th week a drastic change was observed in the off-gas analysis. This was due to the transfer of DGW substrate to a smaller trough of size 1.2m long, 1.2m wide and 0.62m deep, for proper control and stabilisation and to avoid extreme compaction of the pretreatment as the waste was getting water logged. Temperature profiles and concentrations of oxygen and methane showed that with the aeration rates used oxygen supply was not limited, and that aerobic conditions were maintained throughout the process, thus avoiding undesirable fermentation with a consequent slowing down of the degradation (Adani et al, 2004). The percentage of CO_2 in the off-gas increased in proportion to micro-organism activity during the process.

5.2.2 Temperature

The temperature developments in the reactors are reported in Figure 5-3 and 5-4.

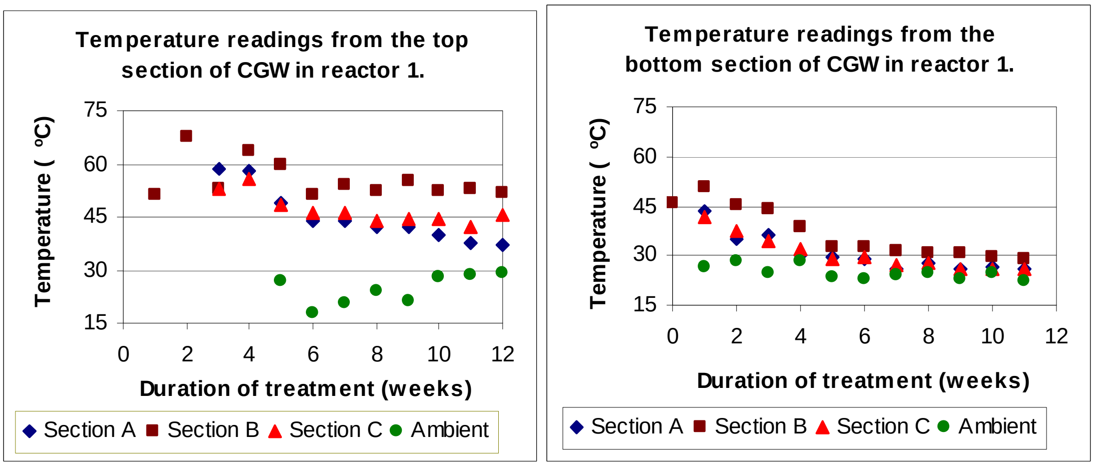


Figure 5-3: Temperatures and ambient temperatures for CGW in reactor 1

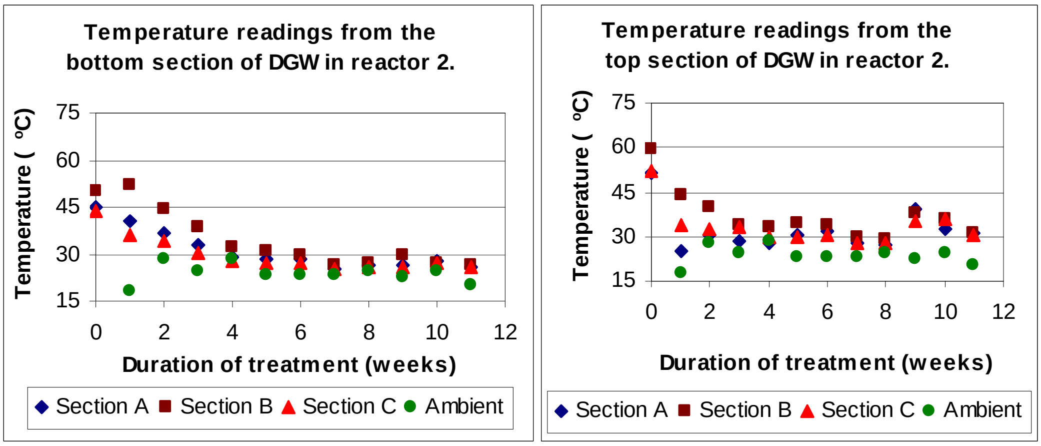


Figure 5-4: Temperatures and ambient temperatures for DGW in reactor 2

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Thermophilic conditions (Temperature: 70°C and 65°C) were reached on the 2nd day for reactor 1 and on the 4th day for reactor 2. The thermophilic phase (i.e., temperatures above 50°C) was maintained in the middle pile for about 4 weeks in reactor 1 and for 2 weeks in reactor 2. It was observed that through the control of moisture and airflow rate, it was possible to reach mesophilic and thermophilic conditions speedily. As the temperature increased the organic matter was degraded through bacterial respiration, this was confirmed by the decrease in moisture content after 2weeks of biological treatment from 60% to 47% for CGW and 60% to 54% for DGW.

In reactor 1, the highest temperatures occurred between the first and the second week, with values ranging from 50°C to 70°C. After 5weeks of treatment, the temperatures set asymptotically to 30°C - 38°C, until the end of the process. In reactor 2 temperatures increased daily, with the first and second week ranging from 40°C to 62°C, and then decreasing to an average of 35 °C by the third week. The final drop in temperature after 8 weeks indicates a decrease in the degradation rate and suggests that full stabilization could be reached in 8 – 10 weeks. This justifies the termination of treatment as further aeration would not contribute to further stabilization (Bari et al, 2000).

It was noticed that the turnings in the 3rd week of aerobic treatment in DGW played an important role in the temperature development during the treatment process. The significant increase of the fine fraction material and temperature in the subsequent week shows that additional turning during biological treatment can partially balance the absence of a particle size reduction (shredding) before the treatment process. This goes to conclude that an unshredded waste still needed to be turned to fluff, homogenize and even out the porosity and microbial distribution as observed by Crochett (2007b) to increase the biological activity.

5.3 Characterisation of the solid matter

This section presents the characterisation on the solid material treated during the second campaign.

5.3.1 Total Solid (TS) and Volatile Solid (TS)

TS and VS concentrations observed from reactors 1 and 2 are presented in figures 5-5 and 5-6.

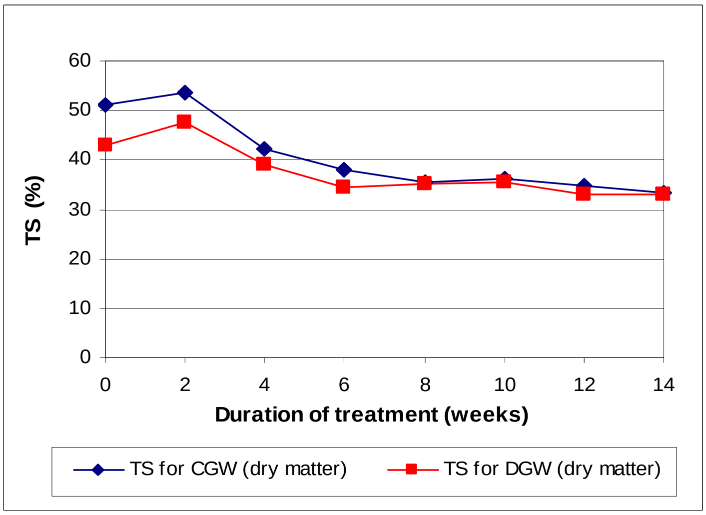

Figure 5-5: Evolution of Total Solids (% dry mass) for CGW and DGW during the large-scale treatment in reactors1 and 2.

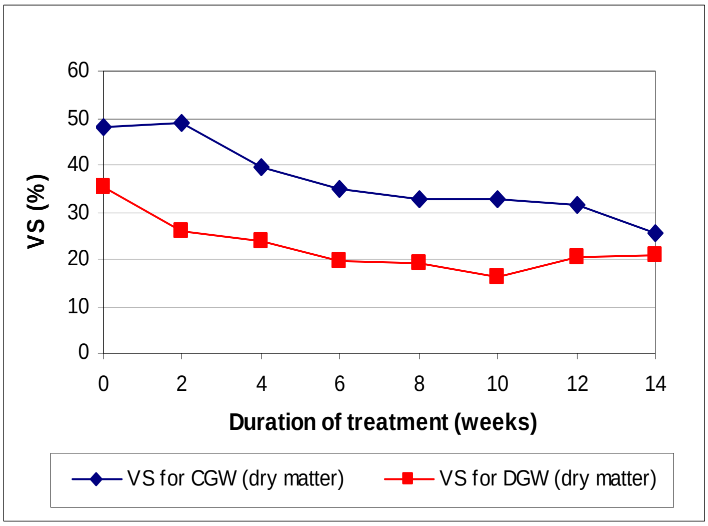

Figure 5-6: Evolution of Volatile Solids (% dry mass) for CGW and DGW during the large-scale treatment in reactors1 and 2.

The concentration of TS seems to be comparable for the two substrates, while the percentage of VS in the CGW is higher than that in the DGW which suggest a higher degradability and a large presence of readily degradable organic particles. The decrease in TS and VS from both substrates during the treatment is an expected result of the decomposition of the organic particles in CO_2 and water.

5.3.2 Moisture content

The moisture content measured for the input waste collected was 48% and 59%, for CGW and DGW respectively. The moisture content of the CGW sample was then adjusted to about 60% for optimum degradation. Figure 5-7 show the variations in moisture content during the treatment period.

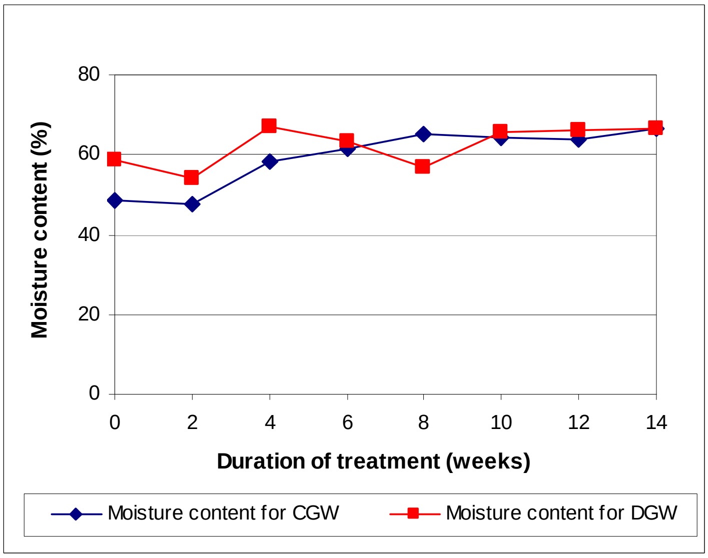

Figure 5-7: Variations in moisture content (% total mass) for CGW and DGW during the large-scale aerobic treatment in reactors 1 and 2.

After two weeks of pretreatment, the moisture content dropped to 47% in reactor 1 and 54% in reactor 2. The water losses are due to the combination of heat produced during the biological reaction and the influence of aeration (Adani et al 2004). By adding water to CGW in reactor 1 on the 12th day, the moisture content was restored to around 50%. Excess moisture was observed in the DGW by the 4th week, this caused the pores between the particles to be filled with water, limiting oxygen transport. During the weekly monitoring of the reactors, it was observed that the moisture at the bottom of the pile dried up quickly and hence the reactor was irrigated regularly. The rapid decrease of the moisture content during the intense thermophilic stage might have been a limiting factor that affected the efficiency of the process. At the end of the process the stabilised product had a moisture content of 64% for CGW and 66% for DGW.

5.3.3 Respiratory Index (RI_7)

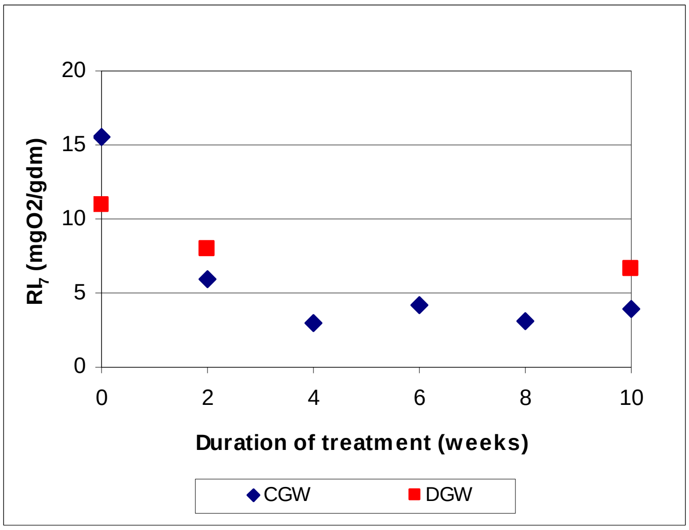

Figure 5-8: Respiration index during the large-scale aerobic treatment in reactors 1 and 2.

According to the analysis on CGW (Figure 5-8), the input waste had a respiration index RI_7 value of $16mgO_2g^{-1}dm$, and decreased to $4mgO_2g^{-1}dm$ after 10 weeks of biological treatment, thus indicating a reduction of 75%. The respiratory indexes decreased gradually in CGW. The initial RI_7 value for the DGW was $116mgO_2g^{-1}dm$ while the output material displayed a RI_7 of $7mgO_2g^{-1}dm$ indicating a reduction of 36%. According to Gomez et al, (2006), RI_7 are useful for monitoring biological activity, since they directly provide information about the metabolic activity of the aerobic microbial population. 10 weeks aerobic treatment was necessary to reach $3.9mgO_2g^{-1}dm$ for CGW and $6.6mgO_2g^{-1}dm$ for DGW.

5.3.4 Carbon to Nitrogen ratio on dry matter.

The initial carbon to nitrogen ratio was 56:1 for DGW and 113:1 for CGW.

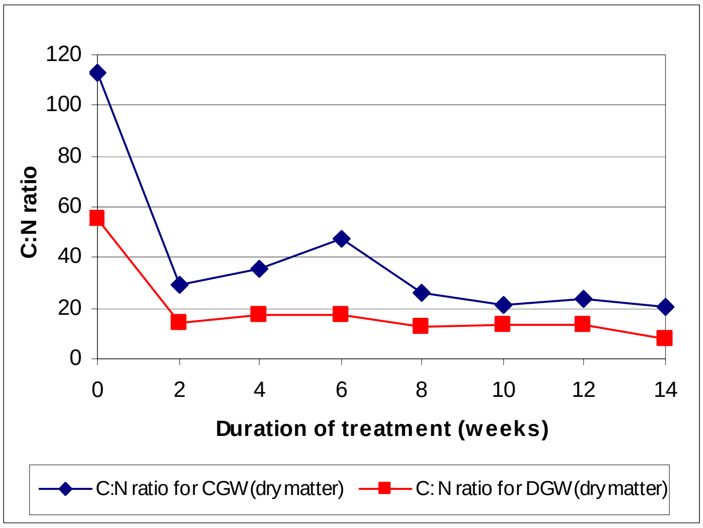

Figure 5-9: Variations in Carbon to Nitrogen ratio (dry solid) for CGW and DGW during the large-scale aerobic treatment in reactors 1 and 2.

From figure 5-9, the C/N ratios for both samples are seen to decrease sharply after 2 weeks. This reduction could be due to the fast degradation of organic matter by the microorganisms, the degradation of cellulose and other readily available carbon and consequent volatilisation of organic matter during the thermophilic phase (Norbu et al, 2005). After 10weeks of treatment the values were 13:1 for DGW and 21:1 for CGW and at 14 weeks the values were 7:1 for DGW and 20:1 for CGW. According to Ham and Komilis, (2003) and Brinton (2000) a mature compost type displays a C/N ratio of 25:1. In 10 weeks of treatment, both substrates have reached a similar level of maturity.

It is noted that there is a variance in the values of C/N ratios of the initial samples for both the small scale and large scale experiments. The C/N ratios of the small scale experiments refer to analysis done on dry matter, while the C/N ratios for the large scale experiment refer to fresh material at natural moisture content. The two samples were derived from two lots of garden waste at slightly different levels of maturity, stability and moisture content. These differences are responsible for the variation in C/N ratio detected and measured.

5.4 Eluate Tests Results.

5.4.1 pH

Figure 5-10 show pH values variation with time during the experiments.

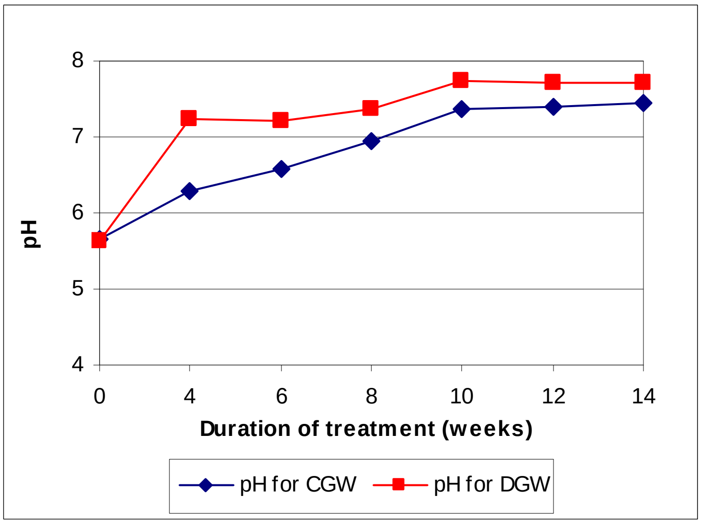

Figure 5-10: Variations in pH for CGW and DGW during the large-scale aerobic treatment, in reactors 1 and 2.

Figure 5-10 shows that the initial acidic pH is buffered during the process to levels that are acceptable for biodegradation.

5.4.2 Conductivity

The changes in conductivity are presented in Figure 5-11.

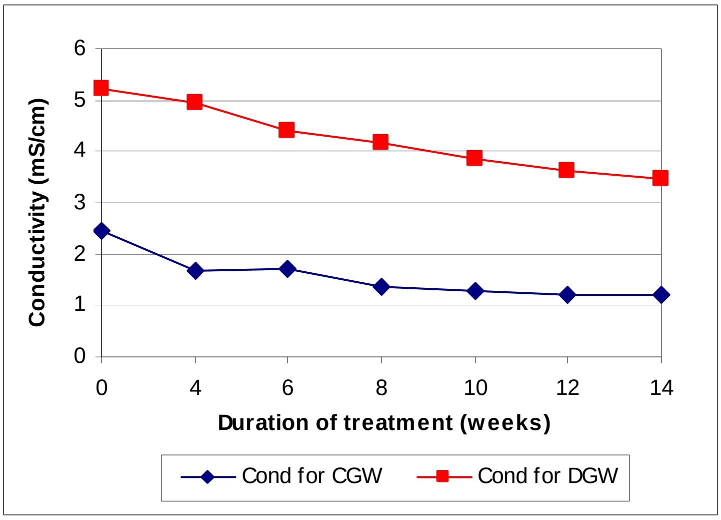

Figure 5-11: Variations in conductivity for CGW and DGW during the large-scale aerobic treatment process in reactors 1 and 2.

The initial high conductivity levels decreased for both substrates continuously during composting to 1.3mS/cm and 3.8mS/cm for CGW and DGW respectively. This decrease in conductivity is coupled with the reduction in TS and VS and must be associated with the degradation process.

5.4.3 BOD_5 & COD

The evolution of in COD and BOD_5 concentrations are presented in Figures 5-12 and 5-13 respectively.

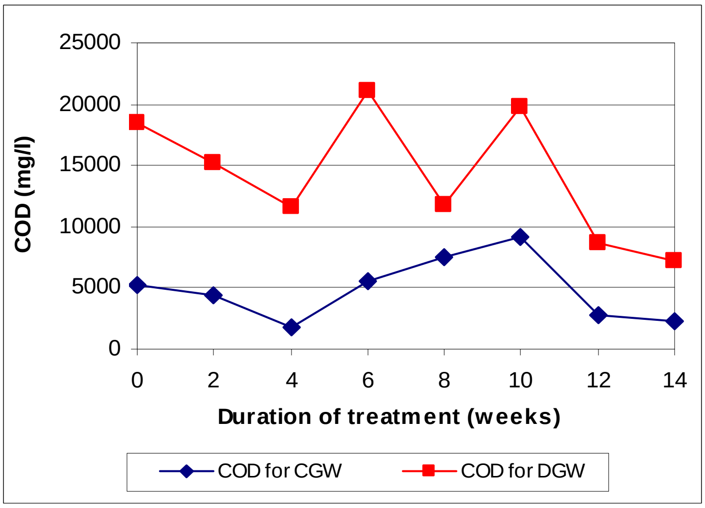

Figure 5-12: Variations in COD concentrations for CGW and DGW during the large-scale aerobic treatment in reactors 1 and 2.

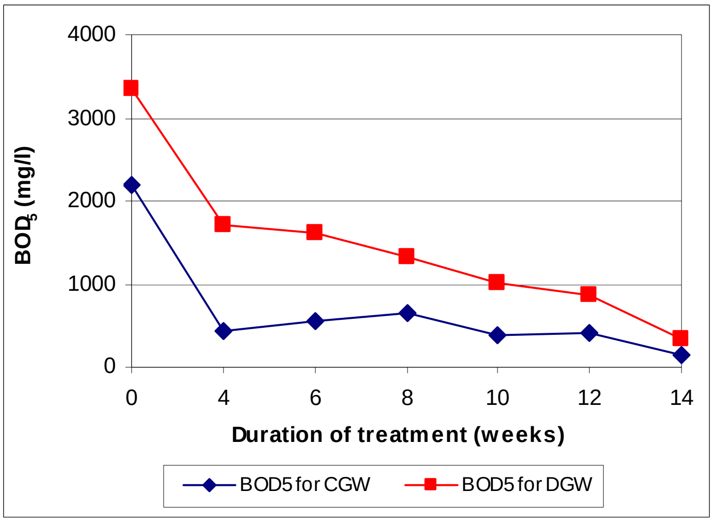

Figure 5-13: Variations in BOD_5 for CGW and DGW during the large-scale aerobic treatment, in reactors 1 and 2.

As expected, the initial high COD and BOD_5 levels decreased during the process as a result of stabilization (Cossu and Raga, 2007; Godley et al, 2004). The fluctuations in the COD values might be due to the difficulty in collecting representative samples from the reactors as the material tends to settle and compact on its own weight during composting.

5.4.4 Ammonia (NH_3-N) & Nitrate (NO_3-N) Nitrogen

Variations in nitrogenous compounds, ammonia and nitrates in reactors 1 and 2 during the 14 weeks period are presented in Figures 5-14 and 5-15.

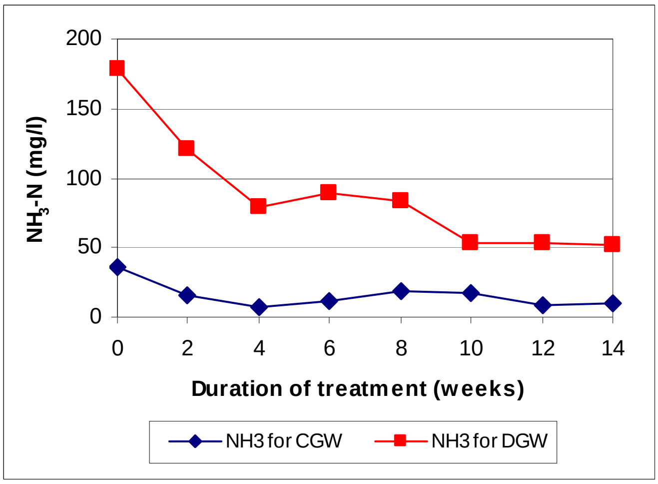

Figure 5-14: Evolution of Ammonia at different stages of the large-scale aerobic treatment process, for CGW and DGW in reactors 1 and 2.

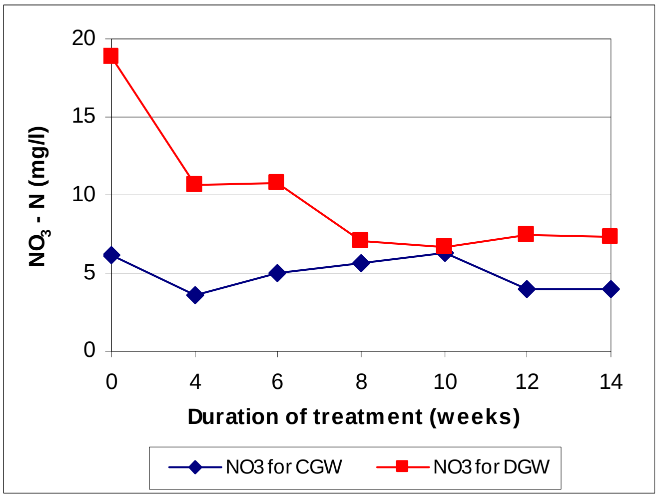

Figure 5-15: Evolution of Nitrate at different stages of the large-scale aerobic treatment process, for CGW and DGW in reactors 1 and 2.

The concentrations can be seen to reduce sharply from the initial values. According to figure 5-14, after 14weeks of treatment, NH_3 concentration of CGW decreased from 36.40mg/l to 9.80mg/l and from 178.92mg/l to 52.08mg/l for DGW, indicating a reduction of 73% and 71% respectively. The initial NO_3 value for the CGW was 6.16mg/l while the output material displayed a NO_3 value of 3.92mg/l indicating a reduction of 36%. Also the initial NO_3 value for the DGW was 18.90mg/l while the output value was 7.28mg/l indicating a reduction of 61%

5.5 Biogas production

The production of biogas during anaerobic decomposition was studied by simulating a landfill at different time frame, as shown in figure 5-16.

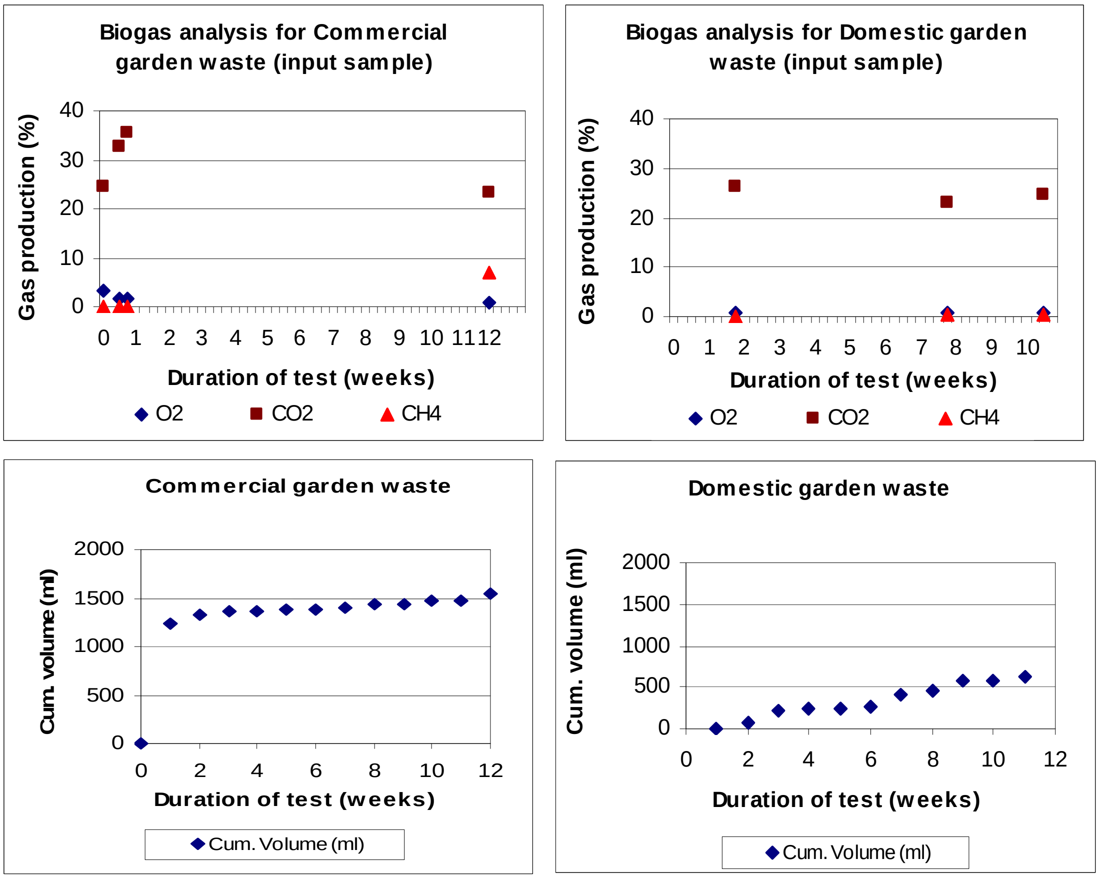

Figure 5-16: Biogas production rates and cumulative volumes for the input CGW and DGW samples.

No methane was produced during the 12 weeks of the experiment. This suggests that the waste in the anaerobic reactors is still in its acidogenic stage of decomposition (Bockreis and Steinberg, 2005).

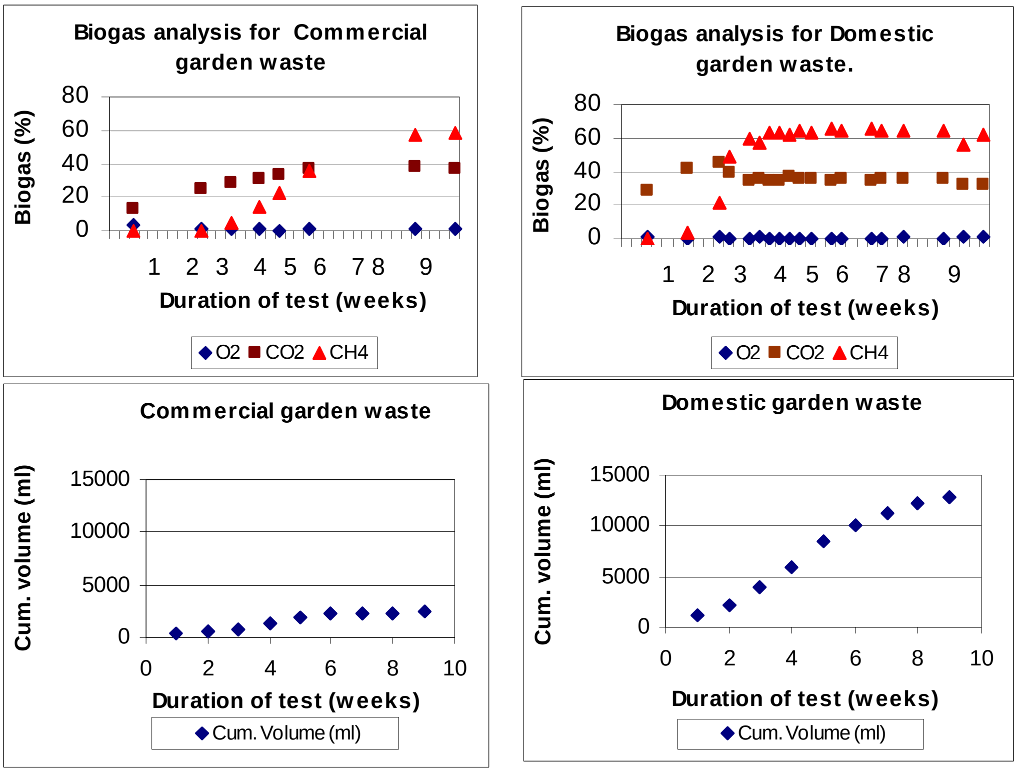

Figure 5-17: Biogas production rate and cumulative volume for 2-week pretreated samples of CGW and DGW from reactors 1 and 2.

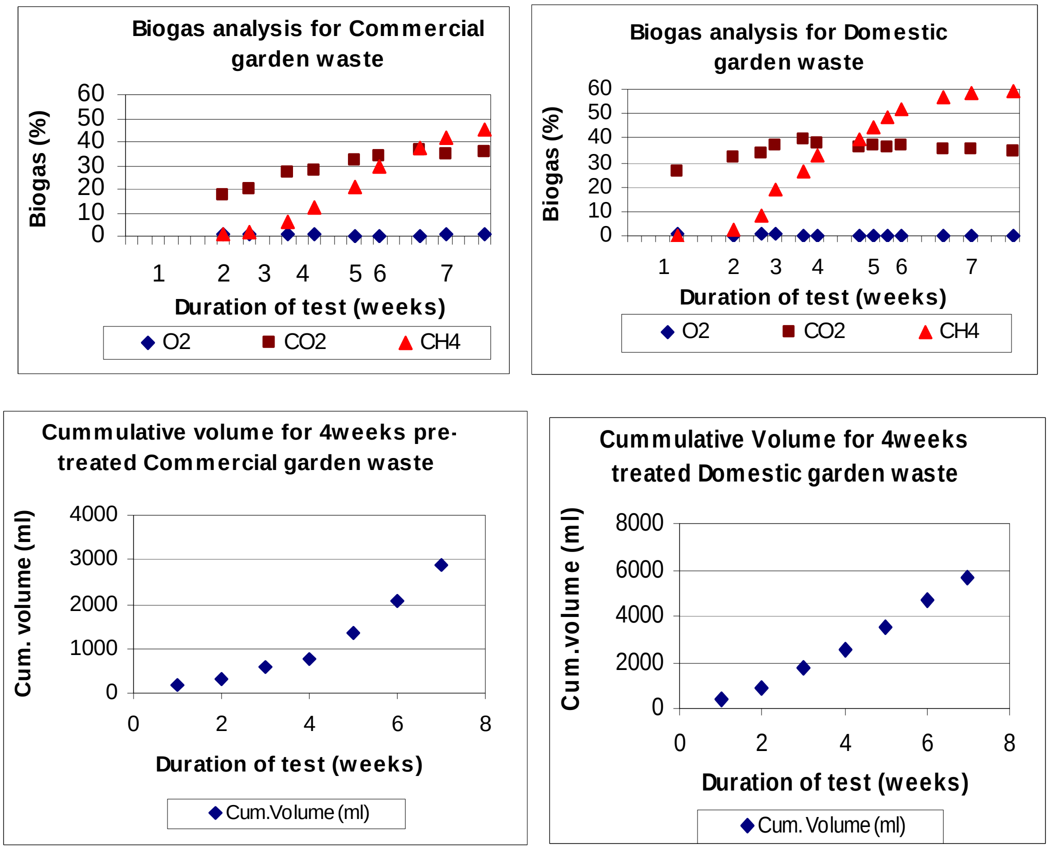

Figure 5-18: Biogas production and cumulative volume for 4-week pretreated samples of CGW and DGW from reactors 1 and 2.

Figures 5-17 and 5-18 show that 2 and 4 weeks samples of composting are not sufficient to stabilize the waste as the samples reached methanogenesis quickly producing over 60% of methane gas (expressed as volume/volume in air).

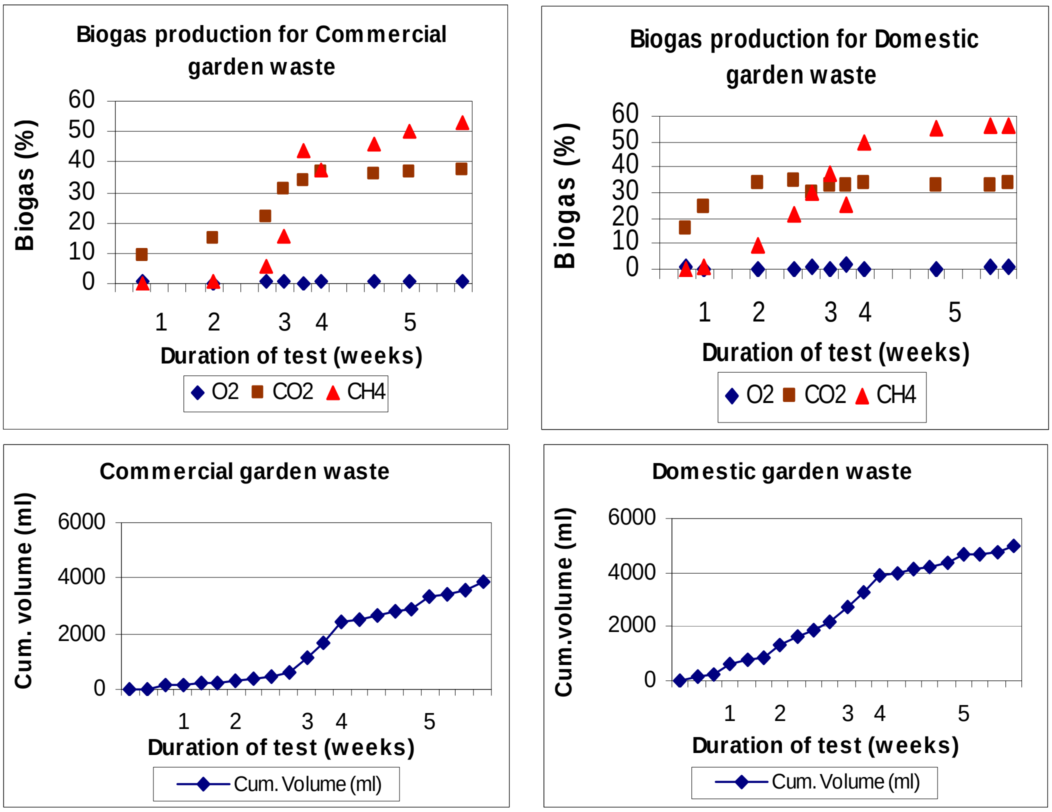

Figure 5-19: Biogas production and cumulative volume for 6-week pretreated sample of CGW and DGW in reactors 1 and 2.

In the 6-week and 8-week samples, methane production started after only 4 days from commencement of the experiment with concentrations staying around 60%.

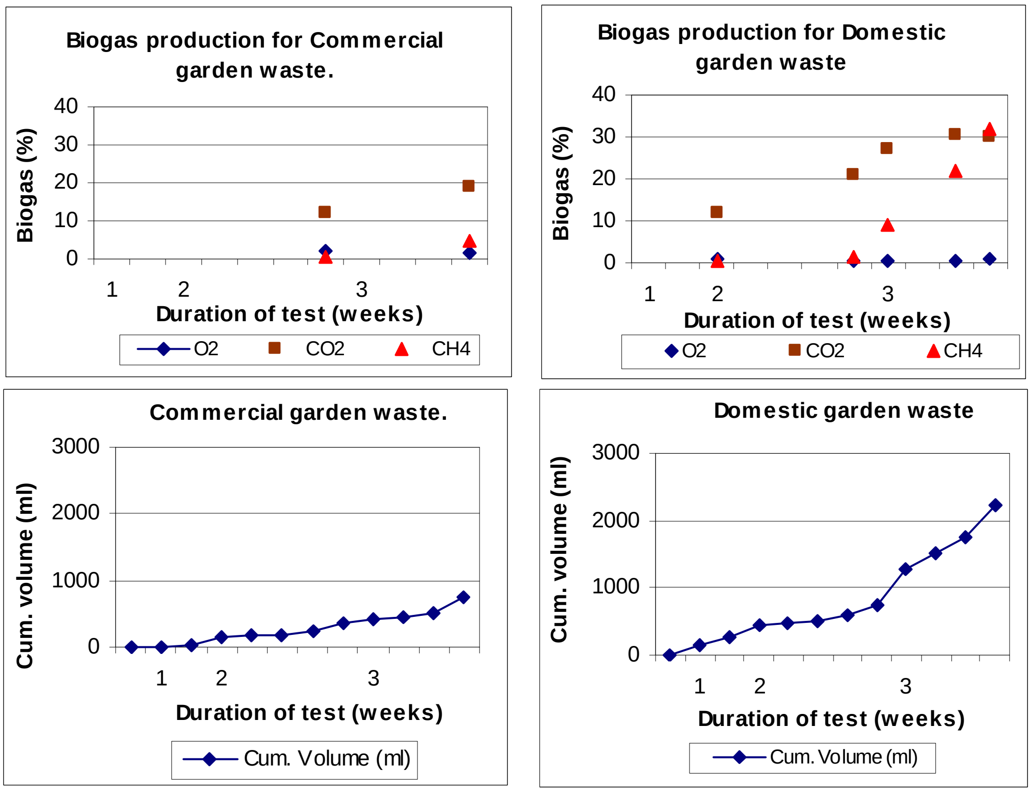

Figure 5-20: Biogas production and cumulative volume for 8-week pretreated sample of CGW and DGW in reactors 1 and 2.

An evident reduction in the methane concentrations and production is observed as expected in the 8-week treated samples as a result of the composting process.

5.6 Quality of compost.

Many EU countries have guidelines and standards for compost quality, indicating the required level or concentration of toxic elements. International compost standards are used to evaluate this study since there are no present standards relating to Green waste compost in South Africa. The two most important parameters that indicate compost maturity are the carbon to nitrogen (C/N) ratio and pH (Norbu et al, 2005). At the end of the composting process, the two products showed the values in Table 5-1.

Table 5-1: End–Use test values recommended for compost (Source: Brinton 2000)

Test parameter	Italy	Austria	USA	Output samples					
				CGW sample			DGW sample		
				8wks	10wks	14wks	8wks	10wks	14wks
pH	6- 8.5	5.5 - 7	6 - 7	6.95	7.38	7.44	7.36	7.75	7.72
C:N ratio	≤ 30	≤ 25	≤ 25	25.7	21.0	20.4	12.7	13.3	7.74

The evaluation of the compost revealed that the finished products provide stable compost with a C/N ratio < 25 (Brinton, 2000). The compost can be classified as *matured and cured compost*, *with no likely odour production, a limited toxicity potential and a minimal impact of plant available soil nitrogen.* Potential uses include general field use, vineyards and substitute for low analysis organic fertilizers in some cases (CCQC, 2001 page A3).

CHAPTER SIX

CONCLUSION

The disposal of garden waste directly into landfills without pretreatment poses a major challenge to the environment, which may lead to global warming. One main aim of this study was to evaluate the use of forced aeration during the Mechanical Biological Pretreatment of garden waste and its influence on carbon emissions. The objectives were: to study the biogas formation in anaerobic reactors, to investigate the steps needed in achieving a good compost quality and to estimate the carbon emission reduction potential. The study started by collecting and pretreating two substrates of garden waste, commercial and domestic garden wastes, on a small and a large scale. Representative samples of the two waste substrates were characterised every two weeks and collected in anaerobic reactors for assessing the biogas production potential. The process lasted for 14 weeks in both experimental campaigns.

6.1 Performance of the process

The large-scale experimental campaign has demonstrated excellent performance for aerobic decomposition of commercial and domestic garden waste. The results of this study support and confirm some actual operating practices in forced aeration composting plants. The temperature was seen as an important process control parameter for monitoring and evaluating the progress of degradation of the organic waste. Temperatures were as high as 70^{o}C in the large-scale experiments, and remained above 50^{o}C for the first three weeks. The gradual drop in temperature indicated a decrease in the degradation rate. By monitoring the temperature it was observed that the temperature readings at the bottom of the pile were lower than the readings at the middle of the pile, indicating a non uniform distribution of air and the possible formation of preferential pathways. This resulted in an unequal aeration rates and different temperature gradients within the waste material, hence implying that the aeration system design is very important.

The biological activity, decreased gradually during the 14 weeks of aerobic treatment. High values of BOD_5, COD, TS and VS found in the input samples of both experiments decreased significantly during the treatment (Table 4.1 & 4.2). A reduction in the volatile solids of between 30 and 60% were achieved in both experiments for a treatment time of 14 weeks. The efficiency of the stabilization process might have been influenced by different parameters: the characteristics of the input waste, the design of the reactors and the duration of treatment. The biogas tests of the treated waste from the large-scale reactors confirm the success of the treatment in reducing the potential for carbon production and concentration.

6.2 Difference among substrates and the effect of shredding.

Commercial garden waste was constituted of trees, big branches and leaves, produced by the activities of community parks and industrial garden services. The domestic garden waste was constituted of grass cuttings, leaves, small branches, cut flowers and weeds from private gardens and yards. The commercial garden waste was shredded to a particle size distribution of 30 to 60mm, while the Domestic garden waste was not shredded as it was collected directly from households, with a size distribution of 50 to 60mm. The aeration efficiency in reactor 2 of the large-scale experiment was affected by the presence of large leaves and particle size of the DGW resulting in a low porosity and water logging of the waste. The shredding of CGW might have contributed in mobilising carbon-rich fine material making it more readily available for degradation as suggested by the higher biodegradability of the CGW in relation to the DGW.

6.3 Influence of the Forced Aeration System

The poor results of the small scale experiment suggest that the aeration supply in the drums was in excess, lowering the temperatures and increasing the moisture contents. On the other hand the results of the large scale experiment indicated that the biological process was effective. The measurement of oxygen concentrations confirms that the process satisfied aerobic conditions, thus avoiding undesirable fermentation. The evaluation of the compost quality revealed a matured and cured compost, with no likely odour production, a limited toxicity potential and a minimal impact of plant available soil nitrogen that can be used in vineyards, fields and substituted for low analysis organic fertilizers in some cases. Based on the results above a Forced Aeration System proves to be a successful technique for the Mechanical Biological Pretreatment of garden waste. The three major conditions for an effective degradation by forced aeration are a well shredded input material, an adequate supply of moisture and an efficient and uniform air flow system. The success of forced aeration relies on the initial material having a sufficient degree of porosity which allows proper air penetration to the entire volume of the waste pile. It also requires a great amount of monitoring and control to be able to achieve the desired purpose, of removing readily decomposable matter prior to deposition in a landfill.

6.4 Summary

This study highlighted the significance of the Mechanical Biological Treatment of garden waste using forced aeration as an appropriate treatment process in South Africa. The process transformed and stabilised the garden waste substrates, and also reduced the carbon emission potential. This research shows that aerobic stabilisation of garden waste using forced aeration causes a marked reduction in carbon emissions after only 10 weeks of treatment before landfilling and this contributes to resource recovery as the compost can be reused in the revegetation of closed landfills or be sold to the public as soil amendment. According to the evolution of the different monitoring parameters most of the degradation took place during the first 10 weeks. The phase of intensive biological degradation was seen to have terminated after about 8 to 10 weeks, thereafter only a minor reduction in the parameters was found. This technology can directly reduce carbon emissions or avoid significant greenhouse gas generation through controlled aerobic degradation of organic matter and in the long run provide public health, environmental protection, prevent water and soil contamination, conserve natural resources and provide renewable energy benefits.

The advantage of this process is that it can be controlled and designed to achieve specified temperatures that can facilitate bacteria destruction. The research is also of important relevance to municipalities, in most developed and developing countries with increasing population, prosperity and urbanization, because waste management decisions are often made locally and it remains a major challenge to collect, recycle, treat and dispose of increasing quantities of solid waste. Finally, the carbon emissions from garden waste degradation can be significant in the aspect of global warming hence the results of this study could be applied to full-scale pretreatment projects.

6.5 Recommendations for future research

Continued investigations to further improve the process performance and to minimise the remaining environmental impacts should be considered. A representative data on the composition of garden waste is important in the design of forced aeration systems and for identifying the influence of the different garden waste fractions on the rate of decomposition. This research should be repeated for a longer treatment time, to develop a greater base of information and understanding of the forced aeration system, the degradation of garden waste as well as the energy requirements that were not considered in this study.

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APPENDIX A

Calculations for Respiratory Index (RI_7)

The ideal gas law predicts how the pressure, volume, and temperature of a gas depend upon the number of moles of the gas.

$$P\ V = n\ R\ T$$

The number of moles, *n*, is the total moles of all of the gas-phase species and R is the gas constant 83.1441(mbar/mol.k).

Air, is composed primarily of nitrogen and oxygen. In a given sample of air, the total number of moles is approximated as

$$n = n_{nitrogen} + n_{oxygen}$$

This expression for *n* can be substituted into the ideal gas law to give

$$P\ V = (\ n_{nitrogen} + n_{oxygen}\ )\ R\ T$$

All molecules in the gas have access to the entire volume of the system, thus *V* is the same for both nitrogen and oxygen. Similarly, both compounds experience the same temperature. One can therefore split this expression of the ideal gas law into two terms, one for nitrogen and one for oxygen.

$$P = n_{nitrogen}\ R\ T/V + n_{oxygen}\ R\ T/V$$

Dalton's Law of Partial Pressure states that the total pressure of a mixture of non reacting gases is equal to the sum of the partial pressures of the individual gases. The equation is given as $P_{tot} = P_{nitrogen} + P_{oxygen}$

Where $P_{nitrogen}$ is the partial pressure of Nitrogen

P_{oxygen} is the partial pressure of Oxygen.

$$P_{nitrogen} = n_{nitrogen}\ R\ T/V$$

$$P_{oxygen} = n_{oxygen}\ R\ T/V$$
$$P_{oxygen} = P_{atm}\ 0.21 \quad = 101.3(kpa)*\ 0.21=21.273$$
$$P_{nitrogen} = P_{atm}\ 0.79 \quad = 101.3(kpa)*\ 0.79=80.027$$

To obtain the oxygen uptake rate from the Oxy-top system, we assume that *nitrogen molecules do not make a contribution to the pressure and is constant and the carbondioxide produced by aerobic microorganisms is absorbed by the sodium hydroxide.* The number of moles of oxygen consumed is calculated using the above values and the ideal gas law.

$n_{oxygen\ (1)} = 21.273 * V/RT$

$n_{oxygen\ (tot)} = \Delta P * V/RT$

$n_{oxygen\ (2)} = n_{oxygen\ (tot)} - n_{oxygen\ (1)}$

The number of grams of oxygen is obtained from

$m = n * M.$

where m is mass of oxygen (g)

n is number of moles and (mol)

M is molar mass of oxygen (32g/mol)

The respiration index after seven days (RI_7) was then obtained by dividing the amount of oxygen (mg) consumed by the amount of dry matter (g) multiplied by the number of days.

APPENDIX B

Small-scale experimental results.

Temperature readings from drums (measurement in ^{o}C)

Commercial garden waste (CGW)					Domestic garden waste (DGW)			
Date analysed	Day	at middle of pile	at bottom of pile	Average reading	Ambient temperature	at middle of pile	at bottom of pile	Average reading
9-Sep-08	1	26.0	25.0	25.5	25.0	25.0	24.5	24.8
10-Sep-08	2	26.0	25.0	25.5	25.0	25.0	24.0	24.5
11-Sep-08	3	20.0	21.0	20.5	19.0	22.0	23.0	22.5
12-Sep-08	4	24.0	23.0	23.5	21.0	28.0	28.0	28.0
15-Sep-08	7	31.0	30.0	30.5	32.0	29.0	28.0	28.5
16-Sep-08	8	34.5	30.7	32.6	23.5	34.0	32.1	33.1
17-Sep-08	9	23.0	21.0	22.0	22.0	22.0	21.0	21.5
18-Sep-08	10	24.0	24.0	24.0	21.0	28.0	28.0	28.0
19-Sep-08	11	27.0	26.3	26.7	21.8	28.8	28.9	28.9
22-Sep-08	14	32.8	30.1	31.5	18.2	26.6	26.3	26.5
23-Sep-08	15	28.5	28.1	28.3	21.5	27.0	27.0	27.0
25-Sep-08	17	26.3	26.4	26.4	23.7	26.5	26.9	26.7
26-Sep-08	18	34.7	34.1	34.4	26.7	30.9	30.4	30.7
29-Sep-08	21	33.4	32.9	33.2	26.7	28.3	27.6	28.0
30-Sep-08	22	32.2	22.6	27.4	22.3	31.2	31.0	31.1
1-Oct-08	23	34.9	34.5	34.7	21.1	32.1	31.2	31.7
2-Oct-08	24	31.1	31.2	31.2	23.4	30.5	31.3	30.9
3-Oct-08	25	33.1	33.3	33.2	19.1	30.0	30.1	30.1
6-Oct-08	28	29.1	29.0	29.1	20.4	25.2	25.3	25.3
7-Oct-08	29	28.4	28.1	28.3	24.1	26.8	26.9	26.9
8-Oct-08	30	27.3	26.6	27.0	21.3	26.7	25.7	26.2
9-Oct-08	31	27.7	27.9	27.8	22.2	26.2	26.1	26.2
10-Oct-08	32	30.1	30.6	30.4	21.2	28.9	29.3	29.1
13-Oct-08	35	30.3	28.4	29.4	25.4	29.0	30.3	29.7
14-Oct-08	36	28.6	28.1	28.4	24.1	25.8	29.4	27.6
16-Oct-08	38	28.9	29.2	29.1	23.1	25.6	27.7	26.7
17-Oct-08	39	29.4	28.7	29.1	23.0	27.7	27.8	27.8
21-Oct-08	43	29.2	28.5	28.9	24.0	29.8	28.7	29.3
23-Oct-08	45	24.9	25.9	25.4	21.5	23.9	25.8	24.9
24-Oct-08	46	22.1	23.1	22.6	24.1	24.1	25.2	24.7
27-Oct-08	49	23.3	24.5	23.9	22.2	22.8	23.4	23.1
28-Oct-08	50	24.9	25.0	25.0	23.4	25.9	26.2	26.1
30-Oct-08	52	25.2	26.3	25.8	22.3	24.5	25.3	24.9
31-Oct-08	53	29.4	28.5	29.0	23.2	25.6	26.2	25.9
3-Nov-08	56	27.2	28.6	27.9	22.3	28.2	29.8	29.0
5-Nov-08	58	27.1	27.8	27.5	24.5	25.6	25.2	25.4
6-Nov-08	59	27.1	27.4	27.3	24.6	24.9	24.4	24.7
10-Nov-08	63	25.0	25.8	25.4	24.4	21.3	22.1	21.7

19-Nov-08	71	26.3	25.8	26.1	23.0	24.3	23.7	24.0
24-Nov-08	76	25.7	26.4	26.1	26.5	25.9	26.2	26.1
28-Nov-08	80	27.5	28.1	27.8	22.4	26.9	27.3	27.1
01-Dec-08	83	26.9	27.1	27.0	22.5	27.2	27.9	27.6
2-Dec-08	84	27.3	28.4	27.9	24.2	27.4	27.9	27.7
03-Dec-08	85	27.9	27.4	27.7	23.9	27.2	27.6	27.4
4-Dec-08	86	27.1	27.7	27.4	25.5	27.4	27.8	27.6
08-Dec-08	91	27.1	26.5	26.8	27.6	26.7	26.3	26.5
17-Dec-08	100	27.1	27.6	27.4	23.7	26.8	27.4	27.1

OFF-GAS ANALYSIS MONITORED FROM DRUMS (measurement in %)

Domestic garden waste				**Commercial garden waste**	
Date	**Day**	**CO_2**	**O_2**	**CO_2**	**O_2**
9-Sep-08	1	7.0	16.5	20.1	2.0
10-Sep-08	2	5.9	15.1	21.9	1.1
11-Sep-08	3	7.0	14.5	15.1	6.4
12-Sep-08	4	7.5	12.5	2.0	18.4
15-Sep-08	7	5.6	13.0	5.2	13.9
16-Sep-08	8	3.0	11.8	1.5	19.3
17-Sep-08	9	0.4	20.1	0.9	19.0
18-Sep-08	10	21.2	0.2	20.1	0.1
19-Sep-08	11	20.5	3.9	23.9	0.0
22-Sep-08	14	1.2	19.0	3.2	16.8
23-Sep-08	15	9.5	10.7	14.4	6.5
25-Sep-08	17	5.1	15.4	14.5	6.9
26-Sep-08	18	2.0	17.8	5.0	15.0
29-Sep-08	21	0.8	19.5	5.1	15.3
30-Sep-08	22	7.7	11.7	11.4	9.1
1-Oct-08	23	2.8	17.0	9.5	9.2
2-Oct-08	24	4.9	14.4	12.4	7.8
3-Oct-08	25	8.8	10.9	6.7	13.5
6-Oct-08	27	5.6	14.7	13.1	5.5
7-Oct-08	28	4.4	15.3	8.8	10.3
8-Oct-08	29	9.8	10.1	11.0	9.8
9-Oct-08	30	2.5	16.5	3.9	15.8
10-Oct-08	32	3.0	15.9	4.6	15.0
13-Oct-08	35	11.5	5.9	18.0	1.3
14-Oct-08	36	2.7	16.4	4.2	15.1
16-Oct-08	38	0.9	19.3	2.2	17.9
17-Oct-08	39	2.0	17.2	3.0	17.2
23-Oct-08	45	1.8	17.5	2.9	16.8
24-Oct-08	46	4.5	14.6	7.7	12.1
27-Oct-08	49	19.3	0.0	20.4	0.0
28-Oct-08	50	16.9	2.3	19.5	1.0

30-Oct-08	52	0.9	19.0	2.9	17.4
31-Oct-08	53	0.9	19.5	7.4	11.6
3-Nov-08	56	2.8	16.2	4.5	15.3
5-Nov-08	58	4.3	14.1	7.0	11.3
6-Nov-08	59	1.1	17.9	2.3	17.1
10-Nov-08	63	0.9	18.3	2.1	17.4
19-Nov-08	71	0.1	18.6	1.5	18.1
24-Nov-08	76	16.4	4.3	17.1	5.8
28-Nov-08	80	7.7	12.3	5.2	14.1
01-Dec-08	83	16.4	1.8	17.7	1.2
2-Dec-08	84	0.9	10.4	14.0	5.2
03-Dec-08	85	5.4	11.9	8.1	10.2
4-Dec-08	86	6.7	10.8	7.5	12.5
08-Dec-08	91	11.7	10.2	11.4	9.3
17-Dec-08	100	9.7	10.2	11.4	9.5

LIQUID DISPLACEMENT (BIOGAS TEST)

Fresh Domestic garden waste									*Fresh Commercial garden waste*								
Date sampled	**Date analysed**	**Day**	**O_2 (%)**	**CO_2 (%)**	**CH_4 (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**	**Date Prepared**	**Date analysed**	**Day**	**O_2 (%)**	**CO_2 (%)**	**CH_4 (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**
04-Sep-08								0	28-Sep-08								0
	29-Sep-08	1				8	19	19		29-Sep-08	1				13	32	32
	30-Sep-08	2				0	0	19		30-Sep-08	2				0	0	32
	2-Oct-08	4				0	0	19		2-Oct-08	4				0	0	32
	3-Oct-08	5				0	0	19		3-Oct-08	5				0	0	32
	6-Oct-08	8				0	0	19		6-Oct-08	8				0	0	32
	8-Oct-08	10				0	0	19		8-Oct-08	10				0	0	32
	9-Oct-08	11				0	0	19		9-Oct-08	11				0	0	32
	10-Oct-08	12				0	0	19		10-Oct-08	12				0	0	32
	13-Oct-08	14				0	0	19		13-Oct-08	14				0	0	32
	14-Oct-08	15				0	0	19		14-Oct-08	15				0	0	32
	16-Oct-08	17				0	0	19		16-Oct-08	17				0	0	32
	17-Oct-08	18				0	0	19		17-Oct-08	18				0	0	32
	21-Oct-08	22				0	0	19		21-Oct-08	22				0	0	32
	23-Oct-08	24				0	0	19		23-Oct-08	24				0	0	32
	24-Oct-08	25				0	0	19		24-Oct-08	25				0	0	32
	27-Oct-08	28				0	0	19		27-Oct-08	28				0	0	32
	28-Oct-08	29				0	0	19		28-Oct-08	29				0	0	32
	29-Oct-08	30				0	0	19		29-Oct-08	30				0	0	32
	30-Oct-08	31				0	0	19		30-Oct-08	31				0	0	32
	31-Oct-08	32				0	0	19		31-Oct-08	32				0	0	32

	3-Nov-08	35				0	0	19		3-Nov-08	35				0	0	32
	5-Nov-08	37				0	0	19		5-Nov-08	37				0	0	32
	11-Nov-08	43				0	0	19		11-Nov-08	43				0	0	32
	13-Nov-08	45				0	0	19		13-Nov-08	45				0	0	32
	18-Nov-08	50				0	0	19		18-Nov-08	50				0	0	32
	24-Nov-08	56				0	0	19		24-Nov-08	56				0	0	32
	27-Nov-08	59				0	0	19		27-Nov-08	59				0	0	32
	2-Dec-08	64				0	0	19		2-Dec-08	64				0	0	32
	8-Dec-08	70				0	0	19		8-Dec-08	70				0	0	32
	17-Dec-08	79				0	0	19		17-Dec-08	79				0	0	32

2-week pretreated Domestic garden waste										***2-week pretreated Commercial garden waste***							
Date sampled	**Date analysed**	**Day**	**O$_2$ (%)**	**CO$_2$ (%)**	**CH$_4$ (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**	**Date Prepared**	**Date analysed**	**Day**	**O$_2$ (%)**	**CO$_2$ (%)**	**CH$_4$ (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**
26-Sep-08								0	1-Oct-08								0
	2-Oct-08	1				14	34	34		2-Oct-08	1				6	15	15
	3-Oct-08	2				12	29	63		3-Oct-08	2				9	7	22
	6-Oct-08	5				5	12	75		6-Oct-08	5				18	22	44
	8-Oct-08	7				0	0	75		8-Oct-08	7				25	17	61
	9-Oct-08	8				1	2	78		9-Oct-08	8				31	15	75
	10-Oct-08	9				19	46	124		10-Oct-08	9				40	22	97
	13-Oct-08	11	1.1	29.4	22.7	74	134	258		13-Oct-08	11	1.4	25.9	8.8	49	22	119
	14-Oct-08	12				38	92	350		14-Oct-08	12				23	56	175
	16-Oct-08	14				43	12	362		16-Oct-08	14				84	148	324
	17-Oct-08	15				48	34	397		17-Oct-08	15				117	80	404
	21-Oct-08	19	1.1	30.8	52.4	75	78	474		21-Oct-08	19	1.1	28.9	37.0	135	44	448

	23-Oct-08	21				16	39	513		23-Oct-08	21				0	0	448
	24-Oct-08	22				23	17	530		24-Oct-08	22				0	0	448
	27-Oct-08	25	1.0	21.4	60.2	45	54	584		27-Oct-08	25				4	10	457
	28-Oct-08	26				9	22	606		28-Oct-08	26				0	0	457
	29-Oct-08	27				13	10	616		29-Oct-08	27				0	0	457
	30-Oct-08	28				18	12	628		30-Oct-08	28				0	0	457
	31-Oct-08	29				25	17	645		31-Oct-08	29				0	0	457
	3-Nov-08	32				30	12	657		3-Nov-08	32				0	0	457
	5-Nov-08	34				64	83	740		5-Nov-08	34				0	0	457
	11-Nov-08	41				158	302	1041		11-Nov-08	41				0	0	457
	13-Nov-08	43	0.6	31.0	63.8	168	24	1066		13-Nov-08	43				0	0	457
	18-Nov-08	48				46	112	1178		18-Nov-08	48				0	0	457
	24-Nov-08	54	0.9	28.0	65.0	104	141	1319		24-Nov-08	54				0	0	457
	27-Nov-08	57				18	44	1362		27-Nov-08	57				21	51	509
	2-Dec-08	62	1.2	24.5	64.6	50	78	1440		2-Dec-08	62	2.8	18.7	56.6	53	78	586
	8-Dec-08	68				39	95	1535		8-Dec-08	68				41	100	686
	17-Dec-08	77	1.4	29.2	60.8	62	56	1591		17-Dec-08	77	0.9	25.3	59.5	74	80	766

4-week pretreated Domestic garden waste									***4-week pretreated Commercial garden waste***								
Date	**Date**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading**	**Vol.**	**Cum. Vol.**	**Date**	**Date**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading**	**Vol.**	**Cum. Vol.**
sampled	**analysed**		**(%)**	**(%)**	**(%)**	**(mm)**	**(ml)**	**(ml)**	**Prepared**	**analysed**		**(%)**	**(%)**	**(%)**	**(mm)**	**(ml)**	**(ml)**
6-Oct-08								0	8-Oct-08								0
	9-Oct-08	1				6	15	15		9-Oct-08	1				5	12	12
	10-Oct-08	2				12	15	29		10-Oct-08	2				11	15	27
	13-Oct-08	4				23	27	56		13-Oct-08	4				23	29	56
	14-Oct-08	5				43	49	105		14-Oct-08	5				46	56	112

	16-Oct-08	7				87	107	212		16-Oct-08	7				51	12	124
	17-Oct-08	8				142	134	345		17-Oct-08	8				66	36	161
	21-Oct-08	12	0.1	23.8	28.7	240	372	584		21-Oct-08	12	1.6	13.6	21.5	78	29	190
	23-Oct-08	14				43	105	689		23-Oct-08	14				19	46	236
	24-Oct-08	15				43	41	689		24-Oct-08	15				12	29	265
	27-Oct-08	18	1.2	24.4	51.8	70	129	754		27-Oct-08	18	1.4	15.1	36.1	25	32	297
	28-Oct-08	19				27	66	820		28-Oct-08	19				8	19	316
	29-Oct-08	51				52	61	881		29-Oct-08	51				12	10	326
	30-Oct-08	20				74	54	934		30-Oct-08	20				35	56	382
	31-Oct-08	21				91	41	976		31-Oct-08	21				48	32	414
	3-Nov-08	24				133	102	1078		3-Nov-08	24				54	15	428
	5-Nov-08	26				157	58	1136		5-Nov-08	26				56	5	433
	11-Nov-08	32				217	146	1282		11-Nov-08	32	2.2	13.3	45.8	62	15	448
	13-Nov-08	34	1.1	24.5	62.4	224	17	1299		13-Nov-08	34				62	151	599
	18-Nov-08	39				9	22	1321		18-Nov-08	39				37	90	689
	24-Nov-08	45	1.9	40.6	61.4	47	92	1414		24-Nov-08	45	1.7	15.5	49.1	79	102	791
	27-Nov-08	48				10	24	1438		27-Nov-08	48				5	12	803
	2-Dec-08	53	1.9	37.5	61.8	24	34	1472		2-Dec-08	53				9	10	813
	8-Dec-08	59				25	2	1474		08-Dec-08	59				15	15	827
	17-Dec-08	68	0.9	34.2	61.9	33	19	1494		17-Dec-08	68	0.4	25.6	51.4	21	15	842

6-week pretreated Domestic garden waste										*6-week pretreated Commercial garden waste*							
Date sampled	**Date analysed**	**Day**	**O_2 (%)**	**CO_2 (%)**	**CH_4 (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**	**Date Prepared**	**Date analysed**	**Day**	**O_2 (%)**	**CO_2 (%)**	**CH_4 (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**
21-Oct-08								0	29-Oct-08								0
	30-Oct-08	1				5	12	12		31-Oct-08	1				0	0	0
	31-Oct-08	2				7	5	17		3-Nov-08	2				0	0	0
	3-Nov-08	5				27	49	66		5-Nov-08	5				0	0	0
	5-Nov-08	7				43	39	105		11-Nov-08	7				17	41	41
	11-Nov-08	13				126	202	307		13-Nov-08	13	2.8	10.4	7.1	21	10	51
	13-Nov-08	15	2.7	13	18.2	135	22	328		18-Nov-08	18				19	46	97
	18-Nov-08	20				51	124	453		24-Nov-08	24	1.4	13.2	17.4	36	41	139
	24-Nov-08	26	1.2	21.7	42.5	104	129	582		27-Nov-08	27				8	19	158
	27-Nov-08	29				15	36	618		2-Dec-08	33	0.4	10.5	17.7	23	36	195
	2-Dec-08	34	1.6	22.6	50.3	46	75	693		8-Dec-08	39				11	27	221
	8-Dec-08	40				37	90	783		17-Dec-08	47	0.7	17.5	34.2	17	17	238
	17-Dec-08	49	1.1	35.1	59.4	46	22	805									

8-week pretreated Domestic garden waste										*8-week pretreated Commercial garden waste*							
Date sampled	**Date analysed**	**Day**	**O_2 (%)**	**CO_2 (%)**	**CH_4 (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**	**Date Prepared**	**Date analysed**	**Day**	**O_2 (%)**	**CO_2 (%)**	**CH_4 (%)**	**Reading (mm)**	**Vol. (ml)**	**Cum. Vol. (ml)**
3-Nov-08								0	14-Nov-08								0
	18-Nov-08	1				19	46	46		18-Nov-08	1				21	51	51
	24-Nov-08	7	1.7	8.6	12.2	26	17	63		24-Nov-08	7	1.3	4.7	20.8	31	24	75
	27-Nov-08	10				24	58	63		27-Nov-08	10				4	10	85
	2-Dec-08	15	0.6	15.1	25.1	42	44	102		2-Dec-08	15	0.5	5.1	12.8	9	12	97
	8-Dec-08	21				5	12	114		8-Dec-08	21				5	12	109
	17-Dec-08	30	1.2	10.5	20.4	18	32	146		17-Dec-08	30	0.8	7.2	12.4	17	29	139

Domestic garden waste (Output sample from drum)										***Commercial garden waste (Output sample from drum)***							
Weight of input = 644g			**Volume of water added = 360ml**							**Weight of input = 698g**			**Volume of water added = 350ml**				
Date	**Date**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading**	**Vol.**	**Cum. Vol.**	**Date**	**Date**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading**	**Vol.**	**Cum. Vol.**
sampled	**analysed**					**mm**	**ml**	**ml**	**prepared**	**analysed**					**mm**	**ml**	**ml**
02-Mar-09								0	03-Mar-09								0
	4-Mar-09	1				31	75	75		4-Mar-09	1				19	46	46
	5-Mar-09	2				39	19	95		5-Mar-09	2				25	15	61
	6-Mar-09	3				49	24	119		6-Mar-09	3				30	12	73
	9-Mar-09	6				68	46	165		9-Mar-09	6				77	114	187
	10-Mar-09	7	2.6	6.1	0.2	72	10	175		10-Mar-09	7	2.4	9.2	0.5	85	19	207
	11-Mar-09	8				32	78	253		11-Mar-09	8				44	107	314
	12-Mar-09	9				41	22	275		12-Mar-09	9				69	61	375
	13-Mar-09	10	1.9	9.3	0.2	54	32	307		13-Mar-09	10	1.5	14.4	3.2	105	88	462
	16-Mar-09	13				20	49	355		16-Mar-09	13				52	127	589
	17-Mar-09	14				24	10	365		17-Mar-09	14				94	102	691
	18-Mar-09	15				31	19	384		18-Mar-09	15				132	92	783
	19-Mar-09	16				44	32	416		19-Mar-09	16				161	71	854
	20-Mar-09	17				52	19	436		20-Mar-09	17				215	131	985
	23-Mar-09	20				76	58	494		23-Mar-09	20	0.6	24.6	32.6	332	285	1270
	24-Mar-09	21				86	24	518		24-Mar-09	21				49	119	1389
	25-Mar-09	22				103	41	560		25-Mar-09	22				111	151	1540
	26-Mar-09	23				128	61	620		26-Mar-09	23				157	112	1652
	27-Mar-09	24				185	139	759		27-Mar-09	24				208	124	1776
	30-Mar-09	27	0.9	22.7	11	283	238	998		30-Mar-09	27	0.7	27.6	44.5	317	265	2041
	31-Mar-09	28				59	144	1141		31-Mar-09	28				45	109	2151
	1-Apr-09	29				114	134	1275		1-Apr-09	29				87	102	2253

	3-Apr-09	31				194	195	1470		3-Apr-09	31				159	175	2428
	6-Apr-09	34	0.7	24.7	31.4	304	268	1737		6-Apr-09	34	0.6	29.9	52.2	268	265	2693
	7-Apr-09	35				25	61	1798		7-Apr-09	35				35	85	2779
	8-Apr-09	36				52	66	1864		8-Apr-09	36				67	78	2856
	9-Apr-09	37	0.6	21.9	40.3	87	85	1949		9-Apr-09	37	0.5	30.2	54.3	106	95	2951
	14-Apr-09	42				83	202	2151		14-Apr-09	42				127	51	3002
	15-Apr-09	43				102	46	2197		15-Apr-09	43	1.2	27.2	48.4	162	85	3088
	16-Apr-09	44	1.6	22.3	46.6	113	27	2224		16-Apr-09	44				27	66	3153
	17-Apr-09	45				29	71	2294		17-Apr-09	45				55	68	3221
	20-Apr-09	48				64	85	2380		20-Apr-09	48				127	175	3397
	21-Apr-09	49				73	22	2401		21-Apr-09	49	1.2	30.9	54.1	146	46	3443
	23-Apr-09	51				126	129	2530		23-Apr-09	51				81	197	3640
	24-Apr-09	52	0.6	25.6	49.8	138	29	2560		24-Apr-09	52	0.7	33.7	54.6	105	58	3698
	28-Apr-09	56				75	182	2742		28-Apr-09	56				122	297	3995
	29-Apr-09	57				94	46	2788		29-Apr-09	57				155	80	4075
	30-Apr-09	58	0.7	30.8	51.8	114	49	2837		30-Apr-09	58	0.5	34.8	56.1	187	78	4153
	4-May-09	62				92	224	3061		4-May-09	62				97	236	4389
	5-May-09	63	0.8	26.4	49.2	128	88	3148		5-May-09	63				118	51	4440
	6-May-09	64				9	22	3170		6-May-09	64				137	46	4487
	8-May-09	66				26	41	3212		8-May-09	66	0.8	33.7	59.1	173	88	4574
	11-May-09	69				53	66	3277		11-May-09	69				75	182	4757
	14-May-09	72				83	73	3350		14-May-09	72				135	146	4903
	18-May-09	76				111	68	3418		18-May-09	76				128	7	4910
	19-May-09	77				122	27	3445		19-May-09	77	1.2	29.6	62.3	139	2	4912
	20-May-09	78				127	12	3457		20-May-09	78				44	107	5019
	21-May-09	79	0.6	26.1	52.8	137	24	3482		21-May-09	79				69	61	5080

	22-May-09	80				25	61	3543		22-May-09	80				81	29	5109
	25-May-09	83				43	44	3586		25-May-09	83				137	136	5246
	26-May-09	84				54	27	3613		26-May-09	84	0.7	34.9	60.8	158	51	5297
	27-May-09	85				68	34	3647		27-May-09	85				33	80	5377
	29-May-09	87	0.9	26.8	53.2	79	27	3674		29-May-09	87	0.8	34.6	60.2	68	85	5462

TS and VS ANALYSIS ON SOLID

Date analysed	**Sample**	**Cruc. No**	**Cruc.dry**	**Cruc + wet waste**	**Cruc + dried waste**	**Cruc + Fired waste**	**Mass of wet waste**	**TS (%)**	**VS (%)**	**TS (%) Average**	**VS (%) Average**
08/09/18	CGW(Input)	c	43.3772	50.1654	47.8144	43.5967	6.7882	**65.3664**	**62.1328**		
		16	52.8900	58.8929	56.8583	53.1325	6.0029	**66.1064**	**62.0667**		
		15	47.1572	53.28	51.2194	47.3933	6.1228	**66.3455**	**62.4894**	**65.9394**	**62.2296**
08/09/18	DGW(Input)	20	54.4830	58.7561	56.7369	54.9376	4.2731	**52.7462**	**42.1076**		
		19	49.3366	52.6714	51.1398	49.8326	3.3348	**54.0722**	**39.1988**		
		23	53.8358	57.1859	55.6219	54.3016	3.3501	**53.3148**	**39.4108**	**53.3778**	**40.2390**
08/09/25	CGW(2weeks)	61	48.8669	53.4751	50.5871	49.0630	4.6082	**37.3291**	**33.0737**		
		53	42.924	49.4649	45.3410	43.1806	6.5410	**36.9531**	**33.0286**		
		55	44.7063	51.9331	47.2653	45.1257	7.2268	**35.4099**	**29.6065**	**36.5640**	**31.9029**
08/09/25	DGW(2weeks)	58	46.1203	50.2629	48.2607	47.0802	4.1426	**51.6680**	**28.4966**		
		56	48.5501	53.9025	51.3080	49.7108	5.3524	**51.5264**	**29.8408**		
		54	45.0326	49.8429	47.5699	46.0448	4.8103	**52.7472**	**31.7049**	**51.9806**	**30.0141**
08/10/06	CGW(4weeks)	9	54.5801	64.9336	58.1335	55.2010	10.3535	**34.3208**	**28.3238**		
		29	56.4235	66.1559	59.8779	56.9670	9.7324	**35.4938**	**29.9094**		
		w	41.2222	51.985	45.2872	41.7603	10.7628	**37.7690**	**32.7694**	**35.8612**	**30.3342**
08/10/06	DGW(4weeks)	B	43.8606	48.0745	45.9557	44.8118	4.2139	**49.7188**	**27.1459**		
		25	57.1803	63.9278	60.6147	58.7276	6.7475	**50.8989**	**27.9674**		
		6	54.2647	61.3102	57.7281	55.7223	7.0455	**49.1576**	**28.4692**	**49.9251**	**27.8608**
08/10/22	CGW(6weeks)	25	57.1799	68.4886	60.6885	57.8520	11.3087	**31.0257**	**25.0825**		
		16	52.8962	64.4478	56.5698	53.6428	11.5516	**31.8017**	**25.3385**		

		w	41.2304	53.2132	45.0754	41.9772	11.9828	**32.0877**	**25.8554**	**31.6383**	**25.4254**
08/10/22	DGW(6weeks)	23	53.8411	58.5893	56.0893	54.9849	4.7482	**47.3485**	**23.2593**		
		6	54.2639	58.9758	56.4758	55.3850	4.7119	**46.9428**	**23.1499**		
		c	43.3839	51.2575	47.1335	45.3287	7.8736	**47.6224**	**22.9222**	**47.3046**	**23.1105**
08/11/04	CGW(8weeks)	B	43.8583	62.0889	49.7462	45.2184	18.2306	**32.2968**	**24.8363**		
		M	45.5420	61.6616	50.9929	47.2464	16.1196	**33.8154**	**23.2419**		
		29	56.4317	68.75	60.533	57.5749	12.3183	**33.2944**	**24.0139**	**33.1355**	**24.0307**
08/11/04	DGW(8weeks)	Z	40.5669	50.0844	44.7046	42.8299	9.5175	**43.4747**	**19.6974**		
		20	54.4882	60.6611	57.2459	55.8882	6.1729	**44.6743**	**21.9945**		
		W	41.2323	47.5409	43.9868	42.7283	6.3086	**43.6626**	**19.9490**	**43.9372**	**20.5470**
08/11/19	CGW(10weeks)	19	49.3417	61.9131	52.9745	49.9320	12.5714	**28.8973**	**24.2018**		
		23	53.8414	66.5965	57.7997	54.7365	12.7551	**31.0331**	**24.0155**		
		25	57.1790	69.3824	60.5875	57.6122	12.2034	**27.9307**	**24.3809**	**29.2871**	**24.1994**
08/11/19	DGW(10weeks)	15	47.1639	56.4280	50.6560	48.5328	9.2641	**37.6950**	**22.9186**		
		c	43.3848	52.0677	46.6639	44.8324	8.6829	**37.7650**	**21.0932**		
		p	40.7617	50.4988	44.4592	42.1919	9.7371	**37.9733**	**23.2852**	**37.8111**	**22.4323**
08/12/03	CGW(12weeks)	6	54.2638	69.2351	59.2320	54.8754	14.9713	**33.1848**	**29.0997**		
		1	53.9064	67.0980	58.2985	54.4409	13.1916	**33.2947**	**29.2429**		
		21	52.4778	66.691	56.9609	53.0225	14.2132	**31.5418**	**27.7095**	**32.6738**	**28.6840**
08/12/03	DGW(12weeks)	16	52.8970	67.2480	57.6300	54.9943	14.3510	**32.9803**	**18.3660**		
		32	62.2667	73.7133	66.4422	64.2055	11.4466	**36.4781**	**19.5403**		
		blank	44.4208	60.6204	50.058	46.9829	16.1996	**34.7984**	**18.9826**	**34.7523**	**18.9629**
08/12/16	CGW(14weeks)	53	42.9305	48.7516	44.7703	43.4146	5.8211	**31.6057**	**23.2894**		
		59	45.5264	52.4852	47.6643	46.0223	6.9588	**30.7223**	**23.5960**		
		56	48.5555	56.4577	51.0677	49.1656	7.9022	**31.7911**	**24.0705**	**31.3730**	**23.6520**
08/12/16	DGW(14weeks)	58	46.1246	52.5919	48.5242	47.1109	6.4673	**37.1036**	**21.8530**		
		57	48.1897	54.1268	50.3562	49.1566	5.9371	**36.4909**	**20.2052**		
		60	45.5091	51.4759	47.7705	46.6155	5.9668	**37.8997**	**19.3571**	**37.1647**	**20.4718**
09/03/03	CGW(Output sample)	M	45.5449	59.5363	50.4907	46.5107	13.9914	**35.3489**	**28.4460**		
		32	62.2697	73.4408	66.0117	62.9504	11.1711	**33.4971**	**27.4037**		
		blank	44.4232	58.3625	49.4135	45.3077	13.9393	**35.8002**	**29.4549**	**34.8821**	**28.4349**

09/03/03	DGW(Output sample)	9	54.5806	64.1043	58.8667	57.0115	9.5237	**45.0046**	**19.4798**		
		1	53.9088	65.2960	59.2963	57.2975	11.3872	**47.3119**	**17.5530**		
		25	57.1812	67.9049	62.1141	60.2333	10.7237	**46.0000**	**17.5387**	**46.1055**	**18.1905**

TS & VS ANALYSIS ON ELUATE

Date analysed	**Sample**	**Cruc No**	**Dry initial**	**After drying**	**After firing**	**TS g/l**	**VS g/l**	**TS (g/l)**	**VS (g/l)**
								Average	**Average**
14-Sep-08	CGW(Input)	32	62.2558	62.5417	62.3351	**11.436**	**8.264**		
		z	40.5561	40.8372	40.6502	**11.244**	**7.480**		
		blank	44.414	44.6911	44.492	**11.084**	**7.964**	**11.255**	**7.903**
14-Sep-08	DGW(Input)	6	54.2626	54.4361	54.3080	**6.940**	**5.124**		
		b	43.8589	44.0311	43.9128	**6.888**	**4.732**		
		16	52.8952	53.0676	52.9525	**6.896**	**4.604**	**6.908**	**4.820**
30-Sep-08	CGW(2weeks)	21	52.4791	52.6175	52.4978	**5.536**	**4.788**		
		25	57.1785	57.3158	57.2057	**5.492**	**4.404**		
		23	53.8410	53.9791	53.8668	**5.524**	**4.492**	**5.517**	**4.561**
30-Sep-08	DGW(2weeks)	1	53.9009	54.0851	53.9800	**7.368**	**4.204**		
		21	52.4721	52.6460	52.5481	**6.956**	**3.916**		
		m	45.5356	45.7072	45.6012	**6.864**	**4.240**	**7.063**	**4.120**
14-Oct-08	CGW(4weeks)	p	40.7601	40.8355	40.7980	**3.016**	**1.500**		
		1	53.9080	53.9767	53.9443	**2.748**	**1.296**		
		blank	44.421	44.4927	44.4575	**2.868**	**1.408**	**2.877**	**1.401**
14-Oct-08	DGW(4weeks)	16	52.8965	53.0462	52.9630	**5.988**	**3.328**		
		blank	44.4228	44.5728	44.4886	**6.000**	**3.368**		
		6	54.2629	54.4116	54.3287	**5.948**	**3.316**	**5.979**	**3.337**
24-Oct-08	CGW(6weeks)	21	52.4792	52.5977	52.5236	**4.740**	**2.964**		
		6	54.2633	54.3808	54.3069	**4.700**	**2.956**		
		b	43.8585	43.9742	43.9015	**4.628**	**2.908**	**4.689**	**2.943**
24-Oct-08	DGW(6weeks)	p	40.7607	40.8204	40.7969	**2.388**	**0.940**		
		15	47.1627	47.2210	47.1987	**2.332**	**0.892**		
		23	53.8409	53.8984	53.8778	**2.300**	**0.824**	**2.340**	**0.885**

5-Nov-08	CGW(8weeks)	25	57.1806	57.3135	57.2640	**5.316**	**1.980**		
		19	49.3423	49.4774	49.4293	**5.404**	**1.924**		
		z	40.566	40.6933	40.6431	**5.092**	**2.008**	**5.271**	**1.971**
5-Nov-08	DGW(8weeks)	32	62.2706	62.3521	62.3110	**3.260**	**1.644**		
		z	40.5637	40.6469	40.6038	**3.328**	**1.724**		
		21	52.477	52.5754	52.5198	**3.936**	**2.224**	**3.508**	**1.864**
20-Nov-08	CGW(10weeks)	c	43.3856	43.4636	43.4179	**3.120**	**1.828**		
		23	53.8431	53.9253	53.8821	**3.288**	**1.728**		
		p	40.7618	40.8384	40.7990	**3.064**	**1.576**	**3.157**	**1.711**
20-Nov-08	DGW(10weeks)	15	47.1650	47.2603	47.2309	**3.812**	**1.176**		
		w	41.2326	41.3215	41.2922	**3.556**	**1.172**		
		m	45.5422	45.6292	45.5985	**3.480**	**1.228**	**3.616**	**1.192**
3-Dec-08	CGW(12weeks)	21	52.4781	52.5727	52.5142	**3.784**	**2.340**		
		32	62.2737	62.3687	62.3098	**3.800**	**2.356**		
		9	54.5802	54.6757	54.6172	**3.820**	**2.340**	**3.801**	**2.345**
3-Dec-08	DGW(12weeks)	29	56.4319	56.5135	56.4782	**3.264**	**1.412**		
		20	54.4884	54.5713	54.5361	**3.316**	**1.408**		
		b	43.8590	43.9427	43.9056	**3.348**	**1.484**	**3.309**	**1.435**
22-Dec-08	CGW(14weeks)	16	52.8965	52.9865	52.9415	**3.598**	**1.798**		
		blank	44.4228	44.5228	44.4697	**4.000**	**2.124**		
		6	54.263	54.3530	54.3180	**3.600**	**1.400**	**3.733**	**1.774**
22-Dec-08	DGW(14weeks)	21	52.4781	52.5381	52.5071	**2.400**	**1.240**		
		32	62.2732	62.3283	62.2972	**2.204**	**1.244**		
		9	54.5808	54.6412	54.6108	**2.416**	**1.216**	**2.340**	**1.233**
3-Mar-09	CGW(Output sample)	B	43.8594	44.0650	43.9319	**8.224**	**5.324**		
		Z	40.5666	40.7729	40.6392	**8.252**	**5.348**		
		15	47.1648	47.3713	47.2354	**8.260**	**5.436**	**8.245**	**5.369**
3-Mar-09	DGW(Output sample)	29	56.4322	57.0537	56.7292	**24.860**	**12.980**		
		16	52.8987	53.5146	53.1924	**24.636**	**12.888**		
		C	43.3856	43.9799	43.6697	**23.772**	**12.408**	**24.423**	**12.759**

Respiratory Index, (RI_7 (mgO_2/gdm))

Date	Sample	Mass of	Vol. of	Vol. of	Vol. of	Vol. of	Δ in pressure	Final Pressure	O_2 initial	O_2 consumed	O_2 produced	Mass of	Total solid	dry matter	RI7
analysed	(dry solid)	sample(g)	bottle (l)	water (l)	sample (l)	gas (l)	(kpa)	(kpa)	N1(mol)	Ntotal(mol)	N2(mol)	O_2(mgO_2)	%	(gdm)	(mgO_2/gdm*7d)
14-Sep-08	CGW(Input)	25	1.5	0.014	0.14	1.4	5.75	95.55	0.012	0.053	0.042	1709.5	65.94	0.02	**14.81**
14-Sep-08	DGW(Input)	25	1.5	0.020	0.20	1.3	14.75	86.55	0.011	0.046	0.035	1481.7	53.38	0.01	**15.86**
26-Sep-08	CGW(2wks)	50	1.5	0.018	0.18	1.3	10.68	90.62	0.012	0.049	0.038	1574.7	36.56	0.02	**12.31**
26-Sep-08	DGW(2wks)	50	1.5	0.024	0.24	1.3	9.07	92.23	0.011	0.048	0.037	1531.4	51.98	0.03	**8.42**
6-Oct-08	CGW(4wks)	75	1.5	0.025	0.25	1.3	13.98	87.32	0.011	0.045	0.034	1438.6	35.86	0.03	**7.64**
6-Oct-08	DGW(4wks)	75	1.5	0.029	0.28	1.2	40.26	61.04	0.011	0.030	0.020	974.2	49.93	0.04	**3.72**
21-Oct-08	CGW(6wks)	75	1.5	0.022	0.22	1.3	50.90	50.40	0.011	0.027	0.015	849.8	31.64	0.02	**5.12**
21-Oct-08	DGW(6wks)	75	1.5	0.035	0.34	1.2	63.23	38.07	0.010	0.018	0.008	578.2	47.36	0.04	**2.33**
11-Nov-08	CGW(8wks)	75	1.5	0.029	0.28	1.2	63.65	37.65	0.011	0.019	0.008	600.9	33.14	0.02	**3.45**
11-Nov-08	DGW(8wks)	75	1.5	0.061	0.60	0.9	81.28	20.02	0.008	0.007	0.000	237.0	43.94	0.03	**1.03**
20-Nov-08	CGW(10wks)	75	1.5	0.012	0.12	1.4	51.74	49.56	0.012	0.028	0.016	899.5	29.29	0.02	**5.85**
20-Nov-08	DGW(10wks)	75	1.5	0.025	0.25	1.3	85.78	15.52	0.011	0.008	-0.003	255.7	37.81	0.03	**1.29**
3-Nov-08	CGW(12wks)	75	1.5	0.024	0.24	1.3	43.52	57.78	0.011	0.030	0.019	959.4	32.64	0.02	**5.60**
3-Nov-08	DGW(12wks)	75	1.5	0.053	0.52	1.0	88.70	12.60	0.009	0.005	-0.003	162.2	34.75	0.03	**0.89**
15-Dec-08	CGW(14wks)	75	1.5	0.016	0.16	1.3	51.71	49.59	0.012	0.027	0.016	874.5	31.37	0.02	**5.31**
15-Dec-08	DGW(14wks)	75	1.5	0.023	0.23	1.3	78.83	22.47	0.011	0.012	0.001	376.0	37.16	0.03	**1.93**
3-Mar-09	CGW(OS)	75	1.5	0.020	0.20	1.3	66.23	35.07	0.011	0.019	0.007	600.4	34.88	0.03	**3.28**
3-Mar-09	DGW(OS)	75	1.5	0.028	0.27	1.2	75.98	25.32	0.011	0.013	0.002	407.4	46.11	0.03	**1.68**

COD CONCERNTRATION (mg/L)

Sample	Date	Volume	Blank	Reading			Average	Result	Std	Var
	analysed	(ml)	Average	1	2	3	reading	(mg/l)	Dev	
Standard	2008/09/15	1	0.0000	0.092	0.097	0.100	0.096	**596.21**	0.004	0.000
CGR(Input)	2008/09/30	0.03	-0.0023	0.076	0.073	0.071	0.073	**15603.16**	0.003	0.000
DGR(Input)	2008/09/15	0.1	0.0000	0.333	0.329	0.329	0.330	**20444.33**	0.002	0.000
Standard	2008/09/30	1	-0.0023	0.079	0.087	0.075	0.080	**511.42**	0.006	0.000
CGR (2weeks)	2008/09/30	0.05	-0.0023	0.080	0.088	0.085	0.084	**10723.47**	0.004	0.000
DGR (2weeks)	2008/09/30	0.05	-0.0023	0.031	0.036	0.040	0.036	**4699.51**	0.005	0.000
Standard	2008/10/24	1	-0.0003	0.079	0.078	0.073	0.077	**476.19**	0.003	0.000
CGR(4weeks)	2008/10/24	0.5	-0.0003	0.084	0.089	0.090	0.088	**1088.54**	0.003	0.000
DGR(4weeks)	2008/10/24	0.5	-0.0003	0.138	0.140	0.147	0.142	**1756.95**	0.005	0.000
Standard	2008/10/14	1	0.0005	0.084	0.083	0.084	0.084	**514.72**	0.001	0.000
CGR(6weeks)	2008/10/24	0.5	-0.0003	0.133	0.142	0.138	0.138	**1707.44**	0.005	0.000
DGR(6weeks)	2008/10/24	0.5	-0.0003	0.061	0.064	0.064	0.063	**783.22**	0.002	0.000
Standard	2008/11/11	1	0.0003	0.079	0.078	0.081	0.079	**489.45**	0.002	0.000
CGR(8weeks)	2008/11/11	0.1	0.0003	0.033	0.033	0.035	0.034	**2068.16**	0.001	0.000
DGR(8weeks)	2008/11/11	0.1	0.0003	0.093	0.092	0.089	0.091	**5637.15**	0.002	0.000
Standard	2008/12/03	1	-0.0013	0.086	0.086	0.084	0.085	**535.86**	0.001	0.000
CGR(10weeks)	2008/12/03	0.2	-0.0013	0.048	0.047	0.050	0.048	**1534.36**	0.002	0.000
DGR(10weeks)	2008/12/03	0.1	-0.0013	0.029	0.022	0.024	0.025	**1624.61**	0.004	0.000
Standard	2008/12/22	1	0.0008	0.078	0.079	0.078	0.078	**480.16**	0.001	0.000
CGR(12weeks)	2008/12/22	0.05	0.0008	0.061	0.060	0.060	0.060	**7375.23**	0.001	0.000
DGR(12weeks)	2008/12/22	0.05	0.0008	0.058	0.061	0.055	0.058	**7086.41**	0.003	0.000
CGR(14weeks)	2008/12/22	0.1	0.0008	0.034	0.034	0.036	0.035	**2099.10**	0.001	0.000
DGR(14weeks)	2008/12/22	0.1	0.0008	0.083	0.082	0.079	0.081	**4987.30**	0.002	0.000
Standard	2009/03/03	1	-0.0008	0.078	0.082	0.081	0.080	**501.82**	0.002	0.000
CGR(output sample)	2009/03/03	0.1	-0.0008	0.095	0.093	0.090	0.093	**5781.56**	0.003	0.000
DGR(output sample)	2009/03/03	0.1	-0.0008	0.094	0.097	0.098	0.096	**6008.49**	0.002	0.000

BOD$_5$ (mg/l)

Date	Date	Sample	Volume of	BOD$_5$	Average reading (mg/l)
sampled	analysed		sample (ml)	(mg/l)	
8-Sep-08	14-Sep-08	CGW Input (1)	157	1657	
		CGW Input (2)	157	1657	**1657**
8-Sep-08	14-Sep-08	DGW Input (1)	157	1283	
		DGW Input (2)	157	1298	**1290.5**
25-Sep-08	6-Oct-08	CGW 2weeks (1)	94	1019	
		CGW 2weeks (2)	94	995	**1007**
25-Sep-08	6-Oct-08	DGW 2weeks (1)	94	802	
		DGW 2weeks (2)	94	808	**805**

6-Oct-08	14-Oct-08	CGW 4weeks (1)	94	417	
		CGW 4weeks (2)	94	406	**411.5**
6-Oct-08	14-Oct-08	DGW 4weeks (1)	94	705	
		DGW 4weeks (2)	94	684	**694.5**
20-Oct-08	29-Oct-08	CGW 6weeks (1)	94	417	
		CGW 6weeks (2)	94	395	**406**
20-Oct-08	29-Oct-08	DGW 6weeks (1)	94	192	
		DGW 6weeks (2)	94	182	**187**
3-Nov-08	11-Nov-08	CGW 8weeks (1)	56	310	
		CGW 8weeks (2)	56	289	**299.5**
3-Nov-08	11-Nov-08	DGW 8weeks (1)	56	844	
		DGW 8weeks (2)	56	823	**833.5**
18-Nov-08	20-Nov-08	CGW 10weeks (1)	56	224	
		CGW 10weeks (2)	56	224	**224**
18-Nov-08	20-Nov-08	DGW 10weeks (1)	56	385	
		DGW 10weeks (2)	56	353	**369**
1-Dec-08	3-Nov-08	CGW 12weeks (1)	56	577	
		CGW 12weeks (2)	56	577	**577**
1-Dec-08	3-Nov-08	DGW 12weeks (1)	56	855	
		DGW 12weeks (2)	56	855	**855**
15-Dec-08	16-Dec-09	CGW 14weeks (1)	56	364	
		CGW 14weeks (2)	56	360	**362**
15-Dec-08	16-Dec-09	DGW 14weeks (1)	56	594	
		DGW 14weeks (2)	56	622	**608**
2-Mar-09	3-Mar-09	CGW output sample(1)	56	1116	
		CGW output sample(2)	56	1229	**1172.5**
2-Mar-09	3-Mar-09	DGW output sample (1)	56	819	
		DGW output sample (2)	56	805	**812**

Moisture Content (%)

Date sampled	**Date analysed**	**Sample**	**Weight of wet waste (g)**	**Weight of dry waste(g)**	**Result (%)**
8-Sep-08	8-Sep-08	CGW(Input)	308	192	**37.66**
8-Sep-08	8-Sep-08	DGW(Input)	150	68	**54.67**
25-Sep-08	25-Sep-08	CGW(2weeks)	6.9	2.6	**64.75**
25-Sep-08	25-Sep-08	DGW(2weeks)	5.2	2.8	**45.97**
6-Oct-08	6-Oct-08	CGW(4weeks)	10.3	3.7	**64.11**
6-Oct-08	6-Oct-08	DGW(4weeks)	6.0	3.1	**52.16**
20-Oct-08	21-Oct-08	CGW(6weeks)	11.6	3.7	**68.35**
20-Oct-08	21-Oct-08	DGW(6weeks)	5.8	2.7	**52.64**
3-Nov-08	3-Nov-08	CGW(8weeks)	15.6	6.1	**60.89**
3-Nov-08	3-Nov-08	DGW(8weeks)	7.3	3.2	**56.06**
18-Nov-08	18-Nov-08	CGW(10weeks)	12.5	3.7	**70.71**
18-Nov-08	18-Nov-08	DGW(10weeks)	9.2	3.5	**62.19**
1-Dec-08	1-Dec-08	CGW(12weeks)	14.1	4.6	**67.33**

1-Dec-08	1-Dec-08	DGW(12weeks)	14.0	4.8	**65.25**
15-Dec-08	15-Dec-08	CGW(14weeks)	6.9	2.2	**67.88**
15-Dec-08	15-Dec-08	DGW(14weeks)	6.5	2.0	**65.62**
2-Mar-09	2-Mar-09	CGW(output sample)	364	128	**64.84**
2-Mar-09	2-Mar-09	DGW(output sample)	308	136	**55.84**

C:N ratio

Date sampled	Date analysed	Sample (dry solid)	C %	N %	C:N Ratio
8-Sep-08	2-Oct-08	CGW(Input)	35.39	0.88	**40.22**
8-Sep-08	2-Oct-08	DGW(Input)	32.40	1.45	**22.34**
25-Sep-08	29-Oct-08	CGW(2weeks)	36.50	0.73	**50.00**
25-Sep-08	29-Oct-08	DGW(2weeks)	20.90	0.98	**21.33**
6-Oct-08	29-Oct-08	CGW(4weeks)	37.40	0.90	**41.56**
6-Oct-08	29-Oct-08	DGW(4weeks)	25.30	1.18	**21.44**
20-Oct-08	29-Oct-08	CGW(6weeks)	35.80	0.85	**42.12**
20-Oct-08	29-Oct-08	DGW(6weeks)	20.30	1.15	**17.65**
3-Nov-08	17-Dec-08	CGW(8weeks)	10.60	0.98	**10.82**
3-Nov-08	17-Dec-08	DGW(8weeks)	6.33	1.15	**5.50**
18-Nov-08	17-Dec-08	CGW(10weeks)	11.03	1.11	**9.94**
18-Nov-08	17-Dec-08	DGW(10weeks)	5.68	1.17	**4.85**
1-Dec-08	17-Dec-08	CGW(12weeks)	8.34	1.21	**6.89**
1-Dec-08	17-Dec-08	DGW(12weeks)	2.67	1.21	**2.21**

Field Capacity (%)

Date sampled	Date analysed	Sample	Weight of wet waste(g)	Water retained(ml)	Result (ml/100g)
8-Sep-08	8-Sep-08	CGW(Input)	64	36	**56.25**
8-Sep-08	8-Sep-08	DGW(Input)	82	64	**78.05**
25-Sep-08	25-Sep-08	CGW(2weeks)	22	8	**64.75**
25-Sep-08	25-Sep-08	DGW(2weeks)	21	10	**48.18**
6-Oct-08	6-Oct-08	CGW(4weeks)	36	12	**33.33**
6-Oct-08	6-Oct-08	DGW(4weeks)	26	10	**38.46**
20-Oct-08	21-Oct-08	CGW(6weeks)	34	10	**27.78**
20-Oct-08	21-Oct-08	DGW(6weeks)	34	16	**47.06**
3-Nov-08	3-Nov-08	CGW(8weeks)	36	14	**38.89**
3-Nov-08	3-Nov-08	DGW(8weeks)	22	18	**81.82**
18-Nov-08	18-Nov-08	CGW(10weeks)	252	40	**15.87**
18-Nov-08	18-Nov-08	DGW(10weeks)	126	42	**33.33**
1-Dec-08	1-Dec-08	CGW(12weeks)	38	12	**31.58**
1-Dec-08	1-Dec-08	DGW(12weeks)	34	24	**70.59**
15-Dec-08	15-Dec-08	CGW(14weeks)	266	56	**21.05**
15-Dec-08	15-Dec-08	DGW(14weeks)	186	56	**30.12**
2-Mar-09	2-Mar-09	CGW(output sample)	492	128	**26.02**
2-Mar-09	2-Mar-09	DGW(output sample)	488	182	**37.29**

Dry solid analysis for CGW and DGW in drums 1 and 2 during the small-scale degradation process.

SAMPLE	TS	VS	Moisture	Field capacity	RI_7	C:N ratio
	(%)	(%)	Content (%)	ml/100g	mgO_2/gdm	
CGW (Input)	65.94	62.23	37.66	56.25	14.80	40.22
CGW(2weeks)	36.56	31.90	64.75	64.75	12.29	50.00
CGW(4weeks)	35.86	30.33	64.11	33.33	7.64	41.55
CGW(6weeks)	31.64	25.43	68.35	27.78	5.11	42.12
CGW(8weeks)	33.14	24.03	60.89	38.89	3.45	10.82
CGW(10weeks)	29.29	24.20	70.71	15.87	5.85	9.94
CGW(12weeks)	32.67	28.68	67.33	31.58	5.61	6.89
CGW(14weeks)	31.37	23.65	67.88	21.05	5.32	-
DGW(Input)	53.38	40.24	54.67	78.05	15.92	22.34
DGW(2weeks)	51.98	30.01	45.97	48.18	8.43	21.33
DGW(4weeks)	49.93	27.86	52.16	38.46	3.72	21.44
DGW(6weeks)	47.30	23.11	52.64	47.06	2.32	17.65
DGW(8weeks)	43.94	20.55	56.06	81.82	1.02	5.50
DGW(10weeks)	37.81	22.43	62.19	33.33	1.29	4.86
DGW(12weeks)	34.75	18.96	65.25	70.59	0.89	2.21
DGW(14weeks)	37.16	20.47	65.62	30.12	1.93	-

Eluate tests results for input, output and intermediate samples during the small-scale experiment.

SAMPLE	TS	VS	PH	COND.	COD	BOD	N-NH_3	N-NO_3
	(g/l)	(g/l)		(mS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
CGW (Input)	11.25	7.90	5.46	2.40	15603.16	1657.0	63.7	14.0
CGW(2weeks)	5.52	4.56	6.46	2.37	10723.47	1007.0	41.9	25.9
CGW(4weeks)	2.88	1.40	6.62	2.35	1088.54	411.5	7.1	3.5
CGW(6weeks)	4.69	2.94	6.83	2.02	1707.44	406.0	12.7	3.2
CGW(8weeks)	5.27	1.97	7.02	1.67	2068.16	299.5	7.8	3.9
CGW(10weeks)	3.16	1.71	7.26	2.09	1534.36	224.0	4.3	8.5
CGW(12weeks)	3.80	2.35	7.02	2.29	7375.23	577.0	5.3	5.9
CGW(14weeks)	3.73	1.77	7.21	2.20	2099.10	362.0	3.9	4.5
DGW(Input)	6.91	4.82	5.94	3.82	5631.99	1290.5	131.6	18.5
DGW(2weeks)	7.06	4.12	7.11	2.63	4699.51	805.0	22.3	21.6
DGW(4weeks)	5.98	3.34	6.40	2.88	1756.95	694.5	40.5	10.4
DGW(6weeks)	2.34	0.89	6.90	2.55	783.22	187.0	12.3	4.1
DGW(8weeks)	3.51	1.86	7.13	2.92	5637.15	833.5	15.7	5.7
DGW(10weeks)	3.62	1.19	7.18	2.98	1624.61	369.0	14.6	4.2
DGW(12weeks)	3.31	1.43	7.12	3.20	7086.41	855.0	10.5	5.9
DGW(14weeks)	2.34	1.23	7.24	3.22	4987.30	608.0	10.1	3.5

APPENDIX C

Large-scale experimental results.

TEMPERATURE READING (°C) at middle of pile

Sample (Commercial garden waste)														Average reading (°C)			
			POSITION OF PROBES.														
Date	Weeks	Days	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	C4	Section A	Section B	Section C	Ambient
10-Mar-09	0	1					52.0	53.0	49.0						51.3		
11-Mar-09		2					66.2	73.1	63.5						67.6		
12-Mar-09		3	52.4			64.3	51.0	49.4	58.4	53.3	52.7			58.4	52.9	53.0	
13-Mar-09		4	55.2	61.9	56.3	57.8	59.3	67.6	64.4	53.3	58.3	53.2	58.4	57.8	63.8	55.8	
16-Mar-09	1	7	45.5	51.4	49.5	50.4	59.4	62.3	57.8	45.9	51.3	45.5	50.7	49.2	59.8	48.4	26.7
17-Mar-09		8	38.7	45.8	44.2	46.2	51.9	53.8	48.3	42.7	44.4	49.6	47.1	43.7	51.3	46.0	17.9
18-Mar-09		9	39.2	46.6	48.3	42.3	53.7	54.3	53.5	44.8	47.5	48.7	44.6	44.1	53.8	46.4	20.5
19-Mar-09		10	37.8	44.5	46.5	39.4	52.7	53.4	51.7	37.5	46.7	48.4	42.4	42.1	52.6	43.8	23.9
20-Mar-09		11	41.3	39.6	45.1	43.7	53.6	58.1	54.5	40.7	42.4	45.1	48.5	42.4	55.4	44.2	21.1
23-Mar-09	2	14	31.9	42.1	45.7	38.9	49.8	54.8	52.3	39.8	48.5	47.8	41.6	39.7	52.3	44.4	28.1
24-Mar-09		15	32.4	43.7	40.8	32.8	55.6	50.3	52.7	36.4	48.2	47.5	36.3	37.4	52.9	42.1	28.6
25-Mar-09		16	35.2	40.1	39.6	32.7	48.5	55.3	51.6	39.6	48.1	47.6	45.9	36.9	51.8	45.3	29.1
26-Mar-09		17	36.7	45.8	43.8	40.2	49.5	55.6	52.9	42.0	44.2	45.6	43.1	41.6	52.7	43.7	29.0
27-Mar-09		18	35.1	44.3	42.9	41.2	54.3	50.9	51.0	40.2	43.1	45.5	43.8	40.9	52.1	43.2	30.2
30-Mar-09	3	21	36.7	43.5	46.1	37.5	51.2	53.9	49.3	37.8	48.7	44.2	39.9	41.0	51.5	42.7	24.7
31-Mar-09		22	36.4	43.5	42.8	33.6	48.7	53.1	48.6	37.5	44.8	36.9	41.5	39.1	50.1	40.2	26.7
1-Apr-09		23	37.4	41.7	40.6	35.8	48.3	52.6	46.2	37.3	44.2	43.5	38.5	38.9	49.0	40.9	27.4
3-Apr-09		25	35.1	41.5	39.3	34.2	46.8	50.2	45.9	37.6	41.5	41.2	33.8	37.5	47.6	38.5	23.7
6-Apr-09	4	28	34.3	36.7	33.8	30.1	44.8	47.3	42.4	34.7	38.7	37.6	30.9	33.7	44.8	35.5	28.6
8-Apr-09		30	28.4	38.2	33.6	31.4	43.2	45.4	42.9	35.1	33.7	34.6	33.8	32.9	43.8	34.3	26.2
14-Apr-09	5	36	32.9	31.4	31.2	28.5	36.9	37.5	33.4	29.9	32.1	31.4	32.2	31.0	35.9	31.4	23.2
15-Apr-09		37	30.9	30.4	32.6	28.7	37.8	38.3	33.4	30.4	31.8	30.7	31.9	30.7	36.5	31.2	23.7

16-Apr-09		38	31.8	32.1	31.8	29.2	37.1	37.3	3.7	30.2	32.2	31.8	31.5	31.2	26.0	31.4	26.8
17-Apr-09		39	29.8	31.6	32.8	30.5	35.6	37.4	36.8	31.7	32.3	32.8	31.7	31.2	36.6	32.1	26.2
20-Apr-09	6	42	32.7	31.9	30.8	30.5	35.5	36.9	38.2	30.7	34.7	33.8	33.7	31.5	36.9	33.2	23.1
21-Apr-09		43	33.1	31.4	32.1	29.7	36.9	37.5	34.2	29.2	32.5	33.6	31.8	31.6	36.2	31.8	18.3
23-Apr-09		45	29.4	28.9	28.6	28.2	37.8	35.7	34.9	26.7	29.8	29.4	28.7	28.8	36.1	28.7	21.3
24-Apr-09		46	30.8	32.5	32.4	31.6	37.5	36	36.1	31.7	30.9	32.8	31.7	31.8	36.7	31.8	24.5
28-Apr-09	7	50	28.4	29.2	28.7	28.3	35.8	37	34.2	27.5	31.5	31.3	30.9	28.7	35.5	30.3	23.8
29-Apr-09		51	28.9	29.5	29.2	28.3	33.8	35	33.8	28.7	30.3	31.2	30.8	29.0	34.1	30.3	23.1
30-Apr-09		52	29.3		29.5		32.7	35			31.2		32.4	29.4	33.8	31.8	25.7
4-May-09	8	56	29.7	29.1	30.1	29.5	33.4	35	34.9	28.8	31.2	30.7	31.9	29.6	34.5	30.7	24.6
5-May-09		57	30.7	32	30.4	30.5	34.9	36	36.7	29.3	33.2	33.9	33.4	30.9	35.8	32.5	25.5
6-May-09		58	30.1	31.9	30.9	31.3	35.7	36	37.1	28.2	31.4	32.3	31.6	31.1	36.3	30.9	25.2
7-May-09		59	31.7	31.2	31.3	30.4	34.7	35	36.5	29.5	31.2	31.8	31.5	31.2	35.5	31.0	23.2
8-May-09		60	31.8	32.2	31.5	32.3	35.7	37	36.2	29.6	32.5	32.3	31.8	32.0	36.1	31.6	24.6
11-May-09	9	63	27.8	28.7	28.5	27.3	32.9	34	34.5	26.9	27.8	30.6	27.6	28.1	33.7	28.2	22.6
14-May-09		67	28.1	27.9	27.8	26.9	32.4	34	33.9	26.3	27.5	29.6	26.5	27.7	33.3	27.5	23.1
18-May-09	10	71	28.7	28.4	29.3	28.6	30.6	32.3	33.6	27.7	28.3	29.7	28.3	28.8	32.2	28.5	24.5
19-May-09		72	28.5	28.9	27.6	25.7	32.4	32.1	31.7	27.3	29.4	30.1	28.4	27.7	32.1	28.8	25.1
20-May-09		73	28.3	28.4	27.9	27.8	31.2	32.5	32.6	28.1	28.3	28.5	28.7	28.1	32.1	28.4	24.8
22-May-09		75	28.7	28.5	28.2	27.9	32.5	33.1	31.7	28.6	28.5	28.7	28.2	28.3	32.4	28.5	23.6
25-May-09	11	78	28.4	28.4	29.1	28.0	30.6	33.0	32.6	27.5	28.1	29.4	28.7	28.5	32.1	28.4	22.2
26-May-09		79	29.8	28.1	27.6	27.4	30.9	32.8	32.9	27.5	29.8	30.5	29.5	28.2	32.2	29.3	24.3
27-May-09		80	27.8	29.3	29.2	28.6	31.2	34.1	34.3	28.4	29.4	30.6	30.3	28.7	33.2	29.7	23.4
29-May-09		82	28.3	29.2	26.3	26.4	31.9	33.1	30.6	27.5	29.2	29.3	27.8	27.6	31.9	28.5	23.8

TEMPERATURE READING (°C) at bottom of pile

		Sample (Commercial garden waste)												Average reading (°C)		
			POSITION OF PROBES.													
Date	**Weeks**	**Days**	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	**Section A**	**Section B**	**Section C**
10-Mar-09	0	1					48.0	47.0	42.0						45.7	
11-Mar-09		2					54.0	67.0	55.0						58.7	
12-Mar-09		3	56.6			63.7	52.3	48.1	56.5	59.3			60.3	60.2	52.3	59.8
13-Mar-09		4	43.2	49.7	44.5	43.9	46.3	58.1	52.9	46.0	42.1	42.4	47.2	45.3	52.4	44.4
16-Mar-09	1	7	39.7	49.7	45.6	39.7	46.4	56.6	49.1	41.0	42.5	40.6	41.6	43.7	50.7	41.4
17-Mar-09		8	37.1	41.6	41.9	36.8	46.3	50.1	44.0	38.5	37.9	39.2	37.8	39.4	46.8	38.4
18-Mar-09		9	34.7	42.4	41.6	34.5	44.4	50.8	43.1	37.4	37.1	38.7	37.2	38.3	46.1	37.6
19-Mar-09		10	34.3	37.9	39.5	32.4	40.9	48.2	40.8	32.1	38.9	33.5	53.4	36.0	43.3	39.5
20-Mar-09		11	37.8	34.5	39.2	37.6	47.1	42.3	44.2	34.3	38.2	36.8	52.8	37.3	44.5	40.5
23-Mar-09	2	14	30.8	37.3	39.4	33.3	42.7	50.1	43.5	35.6	38.2	38.6	36.2	35.2	45.4	37.2
24-Mar-09		15	30.8	38.2	37.6	29.8	49.8	42.9	46.5	33.1	39.4	36.7	33.8	34.1	46.4	35.8
25-Mar-09		16	31.6	35.6	35.4	30.2	39.6	48.2	43.3	34.1	39.8	37.9	35.7	33.2	43.7	36.9
26-Mar-09		17	30.5	37.2	38.4	35.6	37.9	47.8	42.5	35.3	37.6	40.1	38.9	35.4	42.7	38.0
27-Mar-09		18	32.4	36.2	39.5	37.7	46.2	48.5	43.7	32.4	36.3	39.9	37.2	36.5	46.1	36.5
30-Mar-09	3	21	32.1	38.9	42.6	31.3	41.7	49.5	40.2	33.2	36.5	35.2	33.2	36.2	43.8	34.5
31-Mar-09		22	31.3	40.2	36.9	30.8	40.3	47.9	40.2	35.7	36.0	33.5	31.8	34.8	42.8	34.3
1-Apr-09		23	32.6	38.1	36.7	31.9	40.9	47.8	40.1	34.2	36.1	35.6	33.4	34.8	42.9	34.8
3-Apr-09		25	32.8	37.3	35.2	31.2	40.8	46.5	37.2	34.8	34.2	35.6	31.4	34.1	41.5	34.0
6-Apr-09	4	28	30.7	31.5	31.2	28.0	37.3	42.1	36.9	33.8	32.6	31.9	28.7	30.4	38.8	31.8
8-Apr-09		30	30.1	33.1	31.2	29.4	38.5	39.2	37.4	33.0	30.1	29.5	30.3	31.0	38.4	30.7
14-Apr-09	5	36	30.1	29.9	29.3	27.8	33.2	34.9	30.4	28.6	28.9	28.6	30.3	29.3	32.8	29.1
15-Apr-09		37	27.5	29.2	30.2	27.4	33.4	34.2	30.2	27.8	28.7	28.6	30.2	28.6	32.6	28.8

16-Apr-09		38	30.1	30.5	29.5	27.5	32.6	34.2	30.1	28.3	28.6	28.1	29.8	29.4	32.3	28.7
17-Apr-09		39	27.7	28.9	29.2	27.6	32.8	32.3	30.2	29.8	28.5	29.5	28.2	28.4	31.8	29.0
20-Apr-09	6	42	29.9	29.2	28.7	28.1	30.8	34.2	33.1	28.3	30.2	29.4	30.3	29.0	32.7	29.6
21-Apr-09		43	29.1	28.8	27.8	27.1	32.7	34.3	30.4	26.7	28.7	28.6	28.9	28.2	32.5	28.2
23-Apr-09		45	26.8	26.4	26.7	26.1	30.1	26	31.7	30.5	25.1	26.4	26.8	26.5	29.3	27.2
24-Apr-09		46	27.6	28.2	28.5	27.6	31.5	30.8	30.2	29.5	28.7	28.2	27.5	28.0	30.8	28.5
28-Apr-09	7	50	25.5	27.1	26.5	25.2	31.8	32	30.1	24.9	27.5	27.8	27.5	26.1	31.4	26.9
29-Apr-09		51	26.3	26.2	27.1	26.7	29.5	31	29.8	26.2	27.2	27.6	28.7	26.6	30.2	27.4
30-Apr-09		52	26.7		27.6		29.7	33			27.2		27.8	27.2	31.1	27.5
4-May-09	8	56	27.5	27.3	28.2	26.9	29.8	33	30.2	26.4	27.5	27.5	28.3	27.5	30.9	27.4
5-May-09		57	28.2	28.6	27.7	28.1	31.3	33	31.4	27.6	28.8	29.8	29.7	28.2	32.0	29.0
6-May-09		58	27.8	27.8	28.6	28.2	31.8	33	32.6	26.7	28.1	28.7	29.6	28.1	32.4	28.3
7-May-09		59	29.4	28.4	28.7	27.2	30.5	33	33.2	27.1	28.7	28.5	27.8	28.4	32.3	28.0
8-May-09		60	29.4	28.5	28.3	28.7	32.5	33	32.1	26.5	28.2	28.5	27.9	28.7	32.5	27.8
11-May-09	9	63	25.4	27.5	26.1	25.2	29.1	32	30.8	25.2	25.6	26.5	25.8	26.1	30.7	25.8
14-May-09		67	25.9	25.8	26.1	23.8	28.2	31	29.6	23.7	25.1	25.8	24.9	25.4	29.6	24.9
18-May-09	10	71	26.4	26.2	27.2	25.9	27.6	30	30.4	25.8	25.9	26.3	26.4	26.4	29.3	26.1
19-May-09		72	26.5	26.4	24.7	22.6	29.1	30	28.6	25.7	26.3	26.2	25.4	25.1	29.3	25.9
20-May-09		73	25.7	26.1	25.2	25.4	28.7	30	29.7	25.9	26.2	26.4	26.7	25.6	29.6	26.3
22-May-09		75	26.2	26.8	26.4	25.2	28.9	30	27.6	25.9	26.7	26.4	26.2	26.2	28.9	26.3
25-May-09	11	78	25.7	25.8	26.4	25.7	27.6	31	29.3	25.5	25.6	26.2	26.6	25.9	29.1	26.0
26-May-09		79	26.3	27	25.2	25.5	28.1	30	28.6	25.2	26.7	27.2	26.8	26.0	28.8	26.5
27-May-09		80	26.1	26.7	27.2	26.6	28.3	31	30.2	26.3	26.8	27.2	27.4	26.7	29.9	26.9
29-May-09		82	26.2	26.8	24.8	24.4	29.1	30	27.2	26.1	26.5	26.1	26.2	25.6	28.7	26.2

TEMPERATURE READING (^{o}C) at middle of pile

Sample (Domestic garden waste)														Average reading (^{o}C)			
			POSITION OF PROBES.														
Date	**Weeks**	**Days**	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	**Section A**	**Section B**	**Section C**	**Ambient**
13-Mar-09	0	1	51.8	53.5	52.4	48.6	56.3	62.5	59.9	44.6	53.5	51.8	57.3	51.6	59.6	51.8	25.3
16-Mar-09		4	26.3	31.6	26.3	31.7	53.8	50.6	45.1	47.2	37.8	39.4	41.2	29.0	49.8	41.4	26.7
17-Mar-09	1	5	21.5	29.7	22.9	26.7	47.9	43.2	40.2	34.5	25.2	31.2	43.5	25.2	43.8	33.6	17.9
18-Mar-09		6	22.8	27.9	30.4	25.3	47.3	45.4	44.6	32.7	27.1	32.3	35.3	26.6	45.8	31.9	20.5
19-Mar-09		7	26.1	29.5	31.8	25.6	48.5	42.9	47.4	31.2	27.8	32.9	33.6	28.3	46.3	31.4	23.9
20-Mar-09		8	27.8	31.2	32.4	29.1	40.7	38.7	42.4	30.3	29.1	33.9	32.8	30.1	40.6	31.5	21.1
23-Mar-09	2	11	29.3	28.2	31.7	31.5	37.5	35.7	46.8	30.2	29.5	32.6	37.8	30.2	40.0	32.5	28.1
24-Mar-09		12	31.3	26.1	28.7	29.1	45.9	47.6	42.8	29.8	30.1	31.6	34.7	28.8	45.4	31.6	28.6
25-Mar-09		13	27.5	26.7	26.5	28.6	40.1	36.8	42.0	28.6	31.4	29.8	36.2	27.3	39.6	31.5	29.0
26-Mar-09		14	32.3	34.8	30.4	29.6	38.1	34.2	34.8	31.9	32.1	33.1	34.6	31.8	35.7	32.9	28.5
27-Mar-09		15	31.8	30.6	32.5	35.2	39.3	46.5	40.1	33.5	34.4	37.2	33.7	32.5	42.0	34.7	29.8
30-Mar-09	3	18	27.6	28.9	29.1	28.7	33.5	32.3	36.1	33.8	29.7	39.2	29.6	28.6	34.0	33.1	24.7
31-Mar-09		19	26.4	27.6	25.9	27.2	37.1	36.2	40.2	28.9	31.2	28.1	28.5	26.8	37.8	29.2	26.7
1-Apr-09		20	26.2	26.5	25.1	27.6	31.3	37.5	40.2	33.6	25.4	27.6	26.7	26.4	36.3	28.3	27.4
3-Apr-09		22	25.4	27.2	28.3	26.3	32.4	29.8	31.2	26.2	25.5	25.8	28.7	26.8	31.1	26.6	23.7
6-Apr-09	4	25	28.1	28.3	27.2	27.5	33.6	34.2	32.5	29.8	29.3	29.5	30.7	27.8	33.4	29.8	28.6
8-Apr-09		27	33.5	38.2	32.3	31.8	35.4	35.2	39.5	30.9	31.8	34.9	31.4	34.0	36.7	32.3	22.3
14-Apr-09	5	33	28.6	32.3	31.2	29.7	32.8	34.6	35.9	27.5	29.7	32.3	29.2	30.5	34.4	29.7	23.2
15-Apr-09		34	28.4	33.1	31.4	30.2	32.3	32.8	33.6	27.6	28.9	30.1	27.5	30.8	32.9	28.5	23.7
16-Apr-09		35	30.3	34.9	31.8	29.2	32.1	33.2	34.5	28.9	29.1	30.9	28.7	31.6	33.3	29.4	26.8
17-Apr-09		36	31.2	34.8	31.9	31.6	34.2	35.7	34.9	28.5	30.4	32.8	30.9	32.4	34.9	30.7	26.2
20-Apr-09	6	39	29.8	34.3	30.9	31.2	32.8	33.4	35.2	29.7	31.3	31.7	30.5	31.6	33.8	30.8	23.1

21-Apr-09		40	28.3	26.2	24.8	29.7	32.9	32.5	33.8	28.4	27.6	30.2	28.2	27.3	33.1	28.6	18.3
23-Apr-09		42	25.8	24.2	24.1	27.2	30.2	31.3	29.2	25.7	25.9	26.5	26.1	25.3	30.2	26.1	21.3
24-Apr-09		43	30.2	32.8	31.9	30.6	31.4	32.5	31.8	29.6	29.7	30.4	30.9	31.4	31.9	30.2	24.5
28-Apr-09	7	47	27.8	28.9	26.8	27.5	28.7	30	29.8	27.5	27.6	27.8	27.6	27.8	29.6	27.6	23.2
29-Apr-09		48	27.6	27.8	26.9	28.2	28.7	30	28.6	27.2	27.1	26.9	26.3	27.6	28.9	26.9	23.1
30-Apr-09		49	28.1		27.9		28.7	29			28.3		27.6	28.0	28.9	28.0	25.7
4-May-09	8	53	27.2	26.3	26.8	28.1	28.5	29	29.7	27.2	27.9	28.2	28.6	27.1	28.9	28.0	24.6
5-May-09		54	25.9	25.8			25.1	26		25.9	26.1			25.9	25.5	26.0	24.5
6-May-09		55	28.6	27.6			30.3			27.8	29.3			28.1	30.3	28.6	23.4
7-May-09		56	34.1				34.8	35		33.6				34.1	34.8	33.6	24.3
8-May-09		57	34.5	33.6			35.7	36		34.8	33.2			34.1	35.9	34.0	25.3
11-May-09	9	60	39.2				35.9	40		35.5				39.2	37.7	35.5	22.6
14-May-09		63	32.4	31.9			34.5	40		29.2	32.3			32.2	37.0	30.8	20.9
18-May-09	10	67	32.4				36.5	35		36.2				32.4	35.9	36.2	24.5
19-May-09		68	31.4	30.1			35.3	35		28.3	31.6			30.8	35.1	30.0	20.5
20-May-09		69	34.5				33.4	35		32.6				34.5	34.0	32.6	20.8
22-May-09		71	34.3	33.9			34.8	35		29.3	32.1			34.1	35.1	30.7	21.3
25-May-09	11	74	31.2				31.6	31		30.7				31.2	31.2	30.7	20.2
26-May-09		75	29.5	29.6			34.2	33		28.5	30.8			29.6	33.4	29.7	20.2
27-May-09		76	32.3				32.1	32		32.5				32.3	32.2	32.5	21.9
29-May-09		78	28.2	27.3			30.2	31		27.2	28.4			27.8	30.4	27.8	19.6

TEMPERATURE READING (°C) at bottom of pile

Sample (Domestic garden waste)														Average reading (°C)		
			POSITION OF PROBES.													
Date	Weeks	Days	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	C4	Section A	Section B	Section C
13-Mar-09	0	1	44.5	45.0	47.5	43.7	48.1	49.6	52.1	37.2	46.5	44.2	46.2	45.2	49.9	43.5
16-Mar-09		4	36.1	45.6	46.5	49.1	55.6	53.7	61.4	34.2	37.9	42.1	38.2	44.3	56.9	38.1
17-Mar-09	1	5	32.6	40.7	42.8	45.1	51.5	46.4	57.5	32.0	32.5	40.2	40.3	40.3	51.8	36.3
18-Mar-09		6	32.8	39.4	42.3	41.8	46.5	43.5	54.2	29.9	32.2	37.3	35.1	39.1	48.1	33.6
19-Mar-09		7	30.3	37.8	40.2	42.6	47.4	41.7	52.3	33.7	32.6	37.3	36.7	37.7	47.1	35.1
20-Mar-09		8	32.5	38.3	39.7	40.6	45.7	42.4	52.1	32.8	35.1	38.6	35.9	37.8	46.7	35.6
23-Mar-09	2	11	36.4	35.7	37.2	36.4	42.9	40.1	49.3	34.5	31.2	35.8	34.2	36.4	44.1	33.9
24-Mar-09		12	27.4	33.6	32.8	33.5	56.8	52.5	50.2	32.7	34.2	34.5	31.9	31.8	53.2	33.3
25-Mar-09		13	32.4	31.7	33.9	35.2	35.3	39.8	49.6	26.2	28.5	31.6	30.1	33.3	41.6	29.1
26-Mar-09		14	30.2	39.6	37.2	34.7	36.7	38.5	39.9	29.0	30.4	32.2	30.7	35.4	38.4	30.6
27-Mar-09		15	30.3	35.9	37.1	30.2	49.5	38.2	46.7	29.7	30.8	35.4	31.2	33.4	44.8	31.8
30-Mar-09	3	18	28.9	37.4	33.1	31.2	38.2	37.5	40.4	28.2	32.4	31.5	28.7	32.7	38.7	30.2
31-Mar-09		19	28.7	34.1	29.2	29.8	26.9	32.3	35.9	31.6	28.1	29.6	27.6	30.5	31.7	29.2
1-Apr-09		20	29.5	32.4	29.8	30.3	38.5	31.2	35.6	27.3	27.9	29.4	29.3	30.5	35.1	28.5
3-Apr-09		22	27.9	29.8	30.1	28.4	36.7	33.5	34.6	28.7	27.8	28.2	26.4	29.1	34.9	27.8
6-Apr-09	4	25	27.8	30.5	28.4	29.8	31.2	31.5	34.7	27.3	28.5	28.7	27.8	29.1	32.5	28.1
8-Apr-09		27	29.2	32.1	28.6	29.3	31.2	32.2	29.5	28.3	29.4	29.5	26.8	29.8	31.0	28.5
14-Apr-09	5	33	26.1	30.5	29.1	27.4	30.5	32.1	29.5	26.1	27.5	28.5	25.6	28.3	30.7	26.9
15-Apr-09		34	26.2	30.5	29.1	27.3	27.8	30.8	26.9	25.2	27.1	26.7	24.5	28.3	28.5	25.9
16-Apr-09		35	27.2	30.8	27.1	26.5	28.2	31.3	28.4	26.4	27.5	28.2	25.4	27.9	29.3	26.9
17-Apr-09		36	28.3	31.2	27.4	27.2	30.2	30.5	28.7	25.7	28.9	29.3	28.7	28.5	29.8	28.2

20-Apr-09	6	39	26.4	30.4	28.6	27.4	28.7	31.6	28.7	26.4	27.7	28.9	26.4	28.2	29.7	27.4
21-Apr-09		40	25.6	29.8	27.3	26.9	27.8	29.7	28.9	26.9	25.8	26.7	24.5	27.4	28.8	26.0
23-Apr-09		42	23.9	26.5	25.8	24.5	28.7	28.7	25.1	24.9	24.2	25.2	23.4	25.2	27.5	24.4
24-Apr-09		43	28.6	27.2	27.6	26.5	29.2	28.7	28.5	26.2	25.6	26.7	27.3	27.5	28.8	26.5
28-Apr-09	7	47	24.7	26.2	24.7	24.6	26.5	27.3	25.8	24.7	25.2	25.8	24.9	25.1	26.5	25.2
29-Apr-09		48	24.9	26.5	24.4	25.1	26.1	27	25.9	25.9	24.7	24.2	24.7	25.2	26.4	24.9
30-Apr-09		49	25.4		25.3	27.2	27.6			26.2		24.3		26.0	27.6	25.3
4-May-09	8	53	25.7	28.6	25.5	26.1	26.9	27	26.6	25.4	26.5	25.8	25.1	26.5	26.9	25.7
5-May-09		54	24.7	24.5			24.6	25		24.8	24.8			24.6	24.7	24.8
6-May-09		55	25.5	24.8			26.2			25.1	25.9			25.2	26.2	25.5
7-May-09		56	28.5				28.9	29		27.6				28.5	29.1	27.6
8-May-09		57	28.5	28.3			30.2	32		29.1	28.7			28.4	30.9	28.9
11-May-09	9	60	26.8				26.1	34		25.6				26.8	29.9	25.6
14-May-09		63	25.5	25.3			27.4	28		24.6	24.5			25.4	27.5	24.6
18-May-09	10	67	27.6				27.8	27		27.2				27.6	27.2	27.2
19-May-09		68	25.6	24.7			27.2	28		24.9	25.5			25.2	27.4	25.2
20-May-09		69	29.7				27.1	27		26.8				29.7	27.0	26.8
22-May-09		71	28.6	27.2			27.6	30		26.3	27.7			27.9	28.6	27.0
25-May-09	11	74	26.1				26.5	26		26.1				26.1	26.4	26.1
26-May-09		75	24.9	24.2			33.5	26		24.8	24.7			24.6	29.8	24.8
27-May-09		76	25.5				26.4	26		25.3				25.5	26.0	25.3
29-May-09		78	23.7	22.6			25.6	25		24.1	23.1			23.2	25.3	23.6

LIQUID DISPLACEMENT TEST (BIOGAS TEST)

Fresh Commercial garden waste (input)

Weight of input = 518g				Volume of water added = 250ml					
Date	**Weeks**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading (mm)**	**Volume (ml)**	**Cum. Vol. (ml)**	**Date Prepared**
analysed								0	10-Mar-09
11-Mar-09		1	3.1	24.4	0.1	335	815	815	
11-Mar-09						94	229	1044	
12-Mar-09		2	1.8	32.6	0.1	95	2	1046	
13-Mar-09		3	1.7	35.5	0.1	173	190	1236	
16-Mar-09		6				12	29	1265	
17-Mar-09	1	7				20	19	1285	
18-Mar-09		8				27	17	1302	
19-Mar-09		9				0	0	1302	
20-Mar-09		10				14	34	1336	
23-Mar-09		13				29	2	1372	
24-Mar-09	2	14				0	0	1372	
25-Mar-09		15				0	0	1372	
26-Mar-09		16				0	0	1372	
27-Mar-09		17				0	0	1372	
30-Mar-09		20				0	0	1372	
31-Mar-09	3	21				0	0	1372	
1-Apr-09		22				0	0	1372	
3-Apr-09		24				0	0	1372	
6-Apr-09		27				0	0	1372	
7-Apr-09	4	28				0	0	1372	
8-Apr-09		29				0	0	1372	
9-Apr-09		30				0	0	1372	checked for leaks
14-Apr-09	5	35				0	0	1372	
15-Apr-09		36				2	5	1377	
16-Apr-09		37				4	10	1382	
17-Apr-09		38				7	17	1389	
20-Apr-09		41				0	0	1389	
21-Apr-09	6	42				0	0	1389	
23-Apr-09		44				12	29	1418	
24-Apr-09		45				3	7	1397	
28-Apr-09	7	49				6	15	1404	
29-Apr-09		50				12	29	1418	
30-Apr-09		51				17	12	1431	
4-May-09	8	55				19	46	1436	
5-May-09		56				13	32	1421	
6-May-09		57				8	19	1440	
8-May-09		59				0	0	1440	
11-May-09	9	62				11	27	1467	
14-May-09		65				11	2	1467	

18-May-09	10	69				11	2	1467	
19-May-09		70				12	5	1470	
20-May-09		71				12	5	1470	
21-May-09		72				17	12	1482	
22-May-09		73				15	5	1487	
25-May-09	11	76				19	10	1496	
26-May-09		77				22	10	1504	
27-May-09		78				30	27	1523	
29-May-09		80	0.9	23.2	6.9	36	10	1538	

Fresh Domestic garden waste (input)

Weight of input = 318g

Volume of water added = 200ml

Date	**Weeks**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading (mm)**	**Volume (ml)**	**Cum. Vol. (ml)**	**Date Prepared**
analysed								0	16-Mar-09
17-Mar-09	1	1				0	0	0	
18-Mar-09		2				8	19	19	
19-Mar-09		3				16	19	39	
20-Mar-09		4				19	7	46	
23-Mar-09	2	7				33	34	80	
24-Mar-09		8				41	19	100	
25-Mar-09		9				55	34	134	
26-Mar-09		10	0.8	26.2	0.1	68	32	165	
27-Mar-09		11				15	36	202	
30-Mar-09	3	14				22	17	219	
31-Mar-09		15				28	15	234	
01-Apr-09		16				0	0	234	
3-Apr-09		18				0	0	234	
6-Apr-09		21				0	0	234	
7-Apr-09	4	22				0	0	234	
8-Apr-09		23				0	0	234	
9-Apr-09		30				0	0	234	checked for leaks
14-Apr-09		35				0	0	234	
15-Apr-09	5	36				3	7	241	
16-Apr-09		37				5	5	246	
17-Apr-09		38				10	12	258	
20-Apr-09	6	41				14	10	268	
21-Apr-09		42				12	5	273	
23-Apr-09		44				43	75	348	
24-Apr-09		45				36	17	365	
28-Apr-09		47				51	36	401	
29-Apr-09	7	48				57	15	416	
30-Apr-09		49				69	29	445	
4-May-09	8	53				72	7	453	
5-May-09		54				62	24	477	

6-May-09		55				64	5	482	
8-May-09		57	0.7	23.1	0.5	68	10	491	
11-May-09	9	62				31	75	567	
14-May-09		65				26	10	577	
18-May-09	10	69				28	10	586	
19-May-09		70				25	7	594	
20-May-09		71				17	7	601	
21-May-09		72				27	10	611	
22-May-09		73				22	2	613	
25-May-09	11	76				22	2	616	
26-May-09		77				21	2	618	
27-May-09		78				29	10	628	
29-May-09		79	0.8	24.6	0.5	31	5	633	

2-week pretreated Domestic garden waste

Weight of input = 444g

Volume of water added = 300ml

Date analysed	Weeks	Day	O_2	CO_2	CH_4	Reading (mm)	Volume (ml)	Cum. Volume (ml)	Date Prepared
								0	25-Mar-09
26-Mar-09		1				41	100	100	
27-Mar-09		2				140	241	341	
30-Mar-09		5	0.6	28.3	0.0	393	613	956	
31-Mar-09		6				39	95	1051	
1-Apr-09	1	7				67	68	1119	
3-Apr-09		9				112	109	1229	
6-Apr-09		12	0.5	42.2	4.1	282	414	1642	
7-Apr-09		13				126	307	1949	
8-Apr-09	2	14				251	304	2253	
9-Apr-09		15	0.6	45.0	21.6	386	328	2582	
14-Apr-09		20	0.5	39.7	48.4	450	1095	3676	
15-Apr-09	3	21				135	328	4005	
16-Apr-09		22	0.3	34.4	60.0	294	387	4392	
17-Apr-09		23	0.9	35.3	56.8	132	321	4713	
20-Apr-09		26	0.3	34.9	62.7	382	929	5642	
21-Apr-09	4	27	0.2	35.1	62.9	139	338	5981	
23-Apr-09		29	0.3	37.5	62.0	355	864	6844	
24-Apr-09		30	0.2	35.4	64.5	172	418	7263	
28-Apr-09	5	34	0.5	36.4	63.6	537	1307	8569	
29-Apr-09		35				121	294	8864	
30-Apr-09		36	0.3	35.0	65.4	248	309	9173	
4-May-09	6	40	0.4	35.9	64.8	381	927	10100	
5-May-09		41				83	202	10302	
6-May-09		42				142	144	10445	
8-May-09		44	0.4	34.4	65.8	263	294	10740	
11-May-09	7	47	0.4	36.4	64.9	247	601	11341	

14-May-09		50				157	382	11723	
18-May-09	8	54	0.7	35.9	64.5	372	523	12246	
19-May-09		55				38	92	12338	
20-May-09		56				86	117	12455	
21-May-09		57				142	136	12591	
22-May-09		58	0.4	36.1	64.2	153	27	12618	
25-May-09	9	61				123	299	12917	
26-May-09		62	0.9	31.7	56.2	161	92	13010	
27-May-09		63				52	127	13136	
29-May-09		65	0.9	32.7	62.0	116	156	13292	

2-week pretreated Commercial garden waste

Weight of input = 664g **Volume of water added = 350ml**

Date analysed	Weeks	Day	O_2	CO_2	CH_4	Reading (mm)	Volume (ml)	Cum. Volume (ml)	Date Prepared
								0	25-Mar-09
26-Mar-09		1				47	114	114	
27-Mar-09		2				132	207	321	
30-Mar-09		5	3.6	13.5	0.0	153	51	372	
31-Mar-09		6				16	39	411	
1-Apr-09	1	7				27	27	438	
3-Apr-09		9				46	46	484	
6-Apr-09		12				71	61	545	
7-Apr-09		13				74	7	552	
8-Apr-09	2	14				79	12	564	
9-Apr-09		15	1.2	24.7	0.4	92	32	596	
14-Apr-09		20				51	124	720	
15-Apr-09	3	21				83	78	798	
16-Apr-09		22	1.2	28.6	5.0	112	71	869	
17-Apr-09		23				35	85	954	
20-Apr-09		26				139	253	1207	
21-Apr-09	4	27	1.2	31.4	14.0	181	102	1309	
23-Apr-09		29				121	294	1603	
24-Apr-09		30	0.5	33.2	23.0	178	139	1742	
28-Apr-09	5	34				97	236	1978	
29-Apr-09		35				104	17	1995	
30-Apr-09		36	0.6	36.9	36.1	117	32	2027	
4-May-09	6	40				91	221	2248	
5-May-09		41				98	17	2265	
6-May-09		42				105	17	2282	
8-May-09		44				132	66	2287	
11-May-09	7	47				68	165	2292	
14-May-09		50				101	80	2297	
18-May-09	8	54				113	29	2302	
19-May-09		55				115	5	2307	

20-May-09		56				121	15	2321	
21-May-09		57				126	12	2333	
22-May-09		58	0.8	38.7	56.8	134	19	2353	
25-May-09	9	61				17	41	2394	
26-May-09		62				25	19	2414	
27-May-09		63				33	19	2433	
29-May-09		65	0.8	36.5	58.9	25	17	2450	

4-week pretreated Commercial garden waste

Weight of input = 730g				**Volume of water added = 50ml**					
Date analysed	**Weeks**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading (mm)**	**Volume (ml)**	**Cum. Volume (ml)**	**Date Prepared**
								0	07-Apr-09
8-Apr-09		1				0	0	0	
9-Apr-09		2				5	12	12	
14-Apr-09	1	7				67	151	163	
15-Apr-09		8				76	22	185	
16-Apr-09		9				85	22	207	
17-Apr-09		10				88	7	214	
20-Apr-09		13				103	36	251	
21-Apr-09	2	14	0.8	17.2	0.6	126	56	307	
23-Apr-09		16				42	102	409	
24-Apr-09		17	0.9	19.8	1.5	61	46	455	
28-Apr-09	3	21				56	136	591	
29-Apr-09		22				78	54	645	
30-Apr-09		23	0.6	27.2	6.3	98	49	693	
4-May-09	4	27				119	51	745	
5-May-09		28	0.5	28.2	12.0	149	73	818	
6-May-09		29				28	68	886	
8-May-09		31				89	148	1034	
11-May-09	5	34	0.4	32.0	21.2	213	302	1336	
14-May-09		37				130	316	1652	
18-May-09	6	41	0.4	33.7	29.9	307	431	2083	
19-May-09		42				47	114	2197	
20-May-09		43				89	102	2299	
21-May-09		44	0.3	36.1	37.5	153	156	2455	
22-May-09		45				54	131	2586	
25-May-09	7	48	0.5	34.6	41.8	177	299	2886	
26-May-09		49				45	109	2995	
27-May-09		50				99	131	3127	
29-May-09		52	0.5	35.7	45.1	183	204	3331	

4-week pretreated Domestic garden waste

Weight of input = 556g				**At water holding capacity**					
Date analysed	**Weeks**	**Day**	**O2**	**CO2**	**CH4**	**Reading (mm)**	**Volume (ml)**	**Cum. Volume (ml)**	**Date Prepared**
								0	07-Apr-09
8-Apr-09		1				31	75	75	
9-Apr-09		2				79	117	192	
14-Apr-09	1	7				162	202	394	
15-Apr-09		8	0.7	26.2	0.1	215	129	523	
16-Apr-09		9				34	83	606	
17-Apr-09		10				41	17	623	
20-Apr-09		13				110	168	791	
21-Apr-09	2	14	0.3	31.7	2.4	131	51	842	
23-Apr-09		16				87	212	1054	
24-Apr-09		17	0.9	33.9	8.3	149	151	1204	
28-Apr-09	3	21	0.6	37.2	18.8	222	540	1745	
29-Apr-09		22				58	141	1886	
30-Apr-09		23	0.3	39.1	26.4	111	129	2015	
4-May-09	4	27	0.3	37.5	33.2	212	516	2530	
5-May-09		28				66	161	2691	
6-May-09		29				121	134	2825	
8-May-09		31	0.3	35.9	39.5	193	175	3000	
11-May-09	5	34	0.2	36.7	44.4	224	545	3545	
14-May-09		37	0.4	36.5	48.8	200	487	4032	
18-May-09	6	41	0.2	36.6	52.0	272	662	4693	
19-May-09		42				41	100	4793	
20-May-09		43				96	134	4927	
21-May-09		44	0.4	35.1	56.8	178	200	5127	
22-May-09		45				47	114	5241	
25-May-09	7	48	0.3	35.3	58.4	223	428	5669	
26-May-09		49				46	112	5781	
27-May-09		50				97	124	5905	
29-May-09		52	0.3	34.6	59.4	216	290	6195	

6-week pretreated Commercial garden waste

Weight of input = 866g				**Volume of water added = 300ml**					
Date analysed	**Weeks**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading (mm)**	**Volume (ml)**	**Cum. Volume (ml)**	**Date Prepared**
								0	21-Apr-09
23-Apr-09		1				13	32	32	
24-Apr-09		2	0.4	9.3	0.1	52	95	127	
28-Apr-09	1	6				68	39	165	
29-Apr-09		7				79	27	192	
30-Apr-09		8				92	32	224	
4-May-09	2	12	0.3	15.1	0.6	134	102	326	
5-May-09		13				25	61	387	

6-May-09		14				54	71	457	
8-May-09		16	0.5	21.6	5.4	115	148	606	
11-May-09	3	19	0.4	31.1	15.7	226	550	1156	
14-May-09		22	0.3	33.7	43.8	217	528	1684	
18-May-09	4	26	0.5	36.5	37.5	293	713	2397	
19-May-09		27				45	109	2506	
20-May-09		28				98	129	2635	
21-May-09		29	0.8	36.1	45.7	165	163	2798	
22-May-09		30				49	119	2917	
25-May-09	5	33	0.5	36.5	49.8	219	414	3331	
26-May-09		34				49	119	3450	
27-May-09		35				104	134	3584	
29-May-09		37	0.6	37.1	52.9	224	292	3876	

6-week pretreated Domestic garden waste

Weight of input = 640g

Volume of water added = 150ml

Date analysed	Weeks	Day	O_2	CO_2	CH_4	Reading (mm)	Volume (ml)	Cum. Volume (ml)	Date Prepared
								0	21-Apr-09
23-Apr-09		1				72	175	175	
24-Apr-09		2	0.6	15.9	0.0	102	73	248	
28-Apr-09	1	6	0.2	24.8	0.6	170	414	662	
29-Apr-09		7				38	92	754	
30-Apr-09		8				72	83	837	
4-May-09	2	12	0.2	33.3	9.0	282	511	1348	
5-May-09		13				111	270	1618	
6-May-09		14	0.4	34.4	21.9	211	243	1861	
8-May-09		16	0.5	30.3	29.8	141	343	2204	
11-May-09	3	19	0.1	33.1	37.7	226	550	2754	
14-May-09		22	2.3	32.4	25.0	206	501	3255	
18-May-09	4	26	0.1	33.5	49.4	274	667	3922	
19-May-09		27				29	71	3993	
20-May-09		28				75	112	4105	
21-May-09		29				133	141	4246	
22-May-09		30	0.3	32.8	54.9	175	102	4348	
25-May-09	5	33				120	292	4640	
26-May-09		34				146	63	4703	
27-May-09		35	0.5	33.2	56.4	182	88	4791	
29-May-09		37	0.5	33.5	56.7	89	217	5007	

8weeks pre-treated Commercial garden waste

Weight of input = 866g				Volume of water added = 300ml					
Date analysed	**Weeks**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading (mm)**	**Volume (ml)**	**Cum. Volume (ml)**	**Date Prepared**
								0	**08-May-09**
11-May-09	1	1				0	0	0	Re-levelled
14-May-09		2				9	22	22	
18-May-09	2	6				64	134	156	
19-May-09		7				73	22	178	
20-May-09		8				75	5	182	
21-May-09		9				95	49	231	
22-May-09		10	2.1	11.9	0.3	142	114	345	
25-May-09	3	13				31	75	421	
26-May-09		14				39	19	440	
27-May-09		15				69	73	513	
29-May-09		17	1.4	18.8	4.8	172	251	764	

8-week pretreated Domestic garden waste

Weight of input = 640g				Volume of water added = 150ml					
Date analysed	**Weeks**	**Day**	**O_2**	**CO_2**	**CH_4**	**Reading (mm)**	**Volume (ml)**	**Cum. Volume (ml)**	**Date Prepared**
								0	08-May-09
11-May-09	1	1				57	139	139	
14-May-09		2				109	127	265	
18-May-09	2	6	1.1	12.1	0.3	182	178	443	
19-May-09		7				11	27	470	
20-May-09		8				23	29	499	
21-May-09		9				64	100	599	
22-May-09		10	0.7	21.1	1.2	128	156	754	
25-May-09	3	13	0.6	27.3	9.2	211	513	1268	
26-May-09		14				98	238	1506	
27-May-09		15	0.5	30.6	22.1	200	248	1754	
29-May-09		17	0.8	30.2	32.1	190	462	2217	

OFF-GAS ANALYSIS FOR COMMERCIAL GARDEN WASTE (%)

Date	Weeks	Days	Section A (%)			Section B (%)			Section C (%)		
			CH_4	CO_2	O_2	CH_4	CO_2	O_2	CH_4	CO_2	O_2
10-Mar-09	0	1				0.0	0.0	0.0			
11-Mar-09		2				0.0	0.0	0.0			
12-Mar-09		3	0.4	40.1	3.2	0.0	7.3	0.1	0.2	36.7	5.0
13-Mar-09		4	0.1	6.4	13.1	0.1	4.9	14.3	0.1	5.4	13.9
16-Mar-09	1	7	0.1	3.8	15.8	0.1	2.5	17.0	0.1	3.4	16.1
17-Mar-09		8	0.0	1.9	18.0	0.0	1.4	18.3	0.0	1.2	18.6
18-Mar-09		9	0.0	3.9	16.1	0.0	2.8	17.0	0.0	3.4	16.5
19-Mar-09		10	0.0	2.5	17.2	0.0	2.2	17.8	0.0	2.1	17.8
20-Mar-09		11	0.0	2.6	17.5	0.0	2.1	17.8	0.0	2.1	17.9
23-Mar-09	2	14	0.1	4.8	15.2	0.0	4.8	15.2	0.0	4.3	15.6
24-Mar-09		15	0.0	2.2	17.8	0.0	1.5	18.5	0.0	1.7	18.2
25-Mar-09		16	0.1	7.4	13.0	0.0	7.0	12.9	0.0	6.8	13.5
26-Mar-09		17	0.0	7.2	13.4	0.0	2.9	16.4	0.0	4.9	15.1
27-Mar-09		18	0.1	6.4	13.7	0.0	4.2	15.8	0.0	4.2	15.9
30-Mar-09	3	21	0.0	3.9	15.9	0.0	2.3	17.2	0.0	3.1	16.6
31-Mar-09		22	0.0	7.4	13.1	0.0	4.3	15.3	0.0	5.4	14.7
1-Apr-09		23	0.0	9.2	12.6	0.0	6.0	13.5	0.0	6.4	13.3
3-Apr-09		25	0.0	12.2	9.0	0.0	8.6	11.1	0.0	8.8	10.9
6-Apr-09	4	28	0.0	8.3	12.9	0.0	7.3	12.9	0.0	7.2	13.1
8-Apr-09		30	0.0	2.8	17.4	0.0	2.5	17.4	0.0	2.6	17.3
14-Apr-09	5	36	0.0	2.9	17.0	0.0	3.2	16.8	0.0	3.1	16.9
15-Apr-09		37	0.0	3.4	17.0	0.0	3.0	17.1	0.0	3.3	16.7
16-Apr-09		38	0.0	3.7	16.8	0.0	3.6	16.4	0.0	3.6	16.5
17-Apr-09		39	0.0	5.0	15.7	0.0	3.8	15.9	0.0	4.1	15.7
20-Apr-09	6	42	0.0	3.5	17.1	0.0	3.6	17.1	0.0	3.1	17.1
21-Apr-09		43	0.0	2.9	17.4	0.0	2.3	17.7	0.0	2.4	17.5
23-Apr-09		45	0.0	3.7	16.8	0.0	2.7	17.2	0.0	3.0	16.9
24-Apr-09		46	0.0	5.5	15.1	0.0	5.5	15.1	0.0	5.6	15.0
28-Apr-09	7	50	0.1	3.1	17.1	0.1	3.1	16.8	0.1	3.0	16.8

29-Apr-09		51	0.1	4.9	15.6	0.1	4.6	15.1	0.1	4.7	15.0
30-Apr-09		52	0.0	8.2	6.3	0.1	7.0	12.8	0.0	10.7	19.1
4-May-09	8	56	0.1	7.4	13.4	0.1	6.7	13.2	0.1	7.0	13.0
5-May-09		57	0.1	6.5	14.8	0.1	5.3	15.0	0.1	5.6	14.8
6-May-09		58	0.0	6.9	14.0	0.1	6.2	14.0	0.1	6.5	13.7
7-May-09		59	0.1	6.3	14.5	0.1	5.4	14.9	0.1	5.8	14.5
8-May-09		60	0.0	7.1	13.1	0.0	6.2	13.7	0.0	6.4	13.4
11-May-09	9	63	0.1	3.8	16.4	0.1	3.283	16.66	0.1	3.548	16.39
14-May-09		67	0.0	4.6	15.3	0.1	4.0	15.6	0.0	4.2	15.3
18-May-09	10	71	0.1	5.8	14.3	0.1	4.9	14.7	0.1	5.2	14.5
19-May-09		72	0.1	5.8	14.5	0.1	4.9	14.8	0.1	5.2	14.6
20-May-09		73	0.1	6.8	13.5	0.1	6.1	13.4	0.1	6.4	13.2
22-May-09		75	0.1	6.6	13.4	0.1	6.1	13.0	0.1	6.2	12.9
25-May-09	11	78	0.1	8.0	13.2	0.1	7.1	13.5	0.1	7.5	13.0
26-May-09		79	0.1	6.3	14.1	0.1	5.5	14.5	0.1	5.8	14.2
27-May-09		80	0.1	5.9	14.3	0.0	5.2	14.4	0.0	5.4	14.2
29-May-09		82	0.1	4.7	15.2	0.1	4.6	14.9	0.1	4.7	14.8

OFF-GAS ANALYSIS FOR DOMESTIC GARDEN WASTE (%)

Date	Weeks	Days	Section A (%)			Section B (%)			Section C (%)		
			CH_4	CO_2	O_2	CH_4	CO_2	O_2	CH_4	CO_2	O_2
13-Mar-09	0	1	0.0	1.0	18.5	0.0	2.5	17.4	0.0	1.8	18.1
16-Mar-09		4	0.1	1.4	17.7	0.1	3.7	15.8	0.1	2.6	17.1
17-Mar-09	1	5	0.0	0.6	19.2	0.0	3.1	16.8	0.0	2.6	17.3
18-Mar-09		6	0.0	1.8	18.2	0.0	3.0	17.2	0.0	1.8	18.2
19-Mar-09		7	0.0	1.7	18.3	0.0	3.4	16.8	0.0	1.7	18.3
20-Mar-09		8	0.0	1.8	18.3	0.0	3.1	16.9	0.0	1.9	18.2
23-Mar-09	2	11	0.0	1.5	18.6	0.0	2.2	17.9	0.0	1.6	18.4
24-Mar-09		12	0.0	1.4	18.5	0.0	3.0	17.0	0.0	2.8	17.1
25-Mar-09		13	0.0	1.8	18.0	0.0	4.1	16.0	0.0	3.0	16.8
26-Mar-09		14	0.0	1.3	18.4	0.0	2.6	17.2	0.0	1.6	18.3
27-Mar-09		15	0.0	2.2	17.9	0.0	3.1	16.9	0.0	1.7	18.4
30-Mar-09	3	18	0.0	0.6	18.8	0.0	0.7	18.6	0.0	1.0	18.6

31-Mar-09		19	0.0	0.6	19.0	0.0	2.2	17.6	0.0	1.6	18.1
1-Apr-09		20	0.0	2.3	17.5	0.0	4.4	15.5	0.0	2.7	17.4
3-Apr-09		22	0.0	1.2	18.5	0.0	2.8	16.9	0.0	2.2	17.7
6-Apr-09	4	25	0.0	1.3	18.2	0.1	2.3	17.4	0.0	1.6	18.1
8-Apr-09		27	0.0	2.1	17.8	0.1	3.0	17.1	0.0	2.4	17.5
14-Apr-09	5	33	0.0	1.3	18.6	0.0	1.8	18.2	0.0	1.1	18.8
15-Apr-09		34	0.1	1.7	17.9	0.1	2.2	17.6	0.0	1.4	18.3
16-Apr-09		35	0.1	1.7	17.9	0.1	2.2	17.6	0.0	1.4	18.3
17-Apr-09		36	0.1	1.5	18.1	0.1	2.1	17.4	0.1	1.8	17.6
20-Apr-09	6	39	0.0	1.0	18.4	0.0	1.6	18.2	0.0	1.3	18.4
21-Apr-09		40	0.1	1.5	18.3	0.1	2.0	17.9	0.1	1.6	18.3
23-Apr-09		42	0.1	0.9	18.6	0.1	1.7	18.1	0.1	1.2	18.4
24-Apr-09		43	0.1	2.3	17.3	0.1	2.6	16.7	0.1	1.9	17.5
28-Apr-09	7	47	0.0	1.3	18.4	0.0	2.2	18.0	0.0	1.4	18.5
29-Apr-09		48	0.1	1.3	18.4	0.1	2.1	17.5	0.1	1.3	18.0
30-Apr-09		49	0.1	2.6	16.8	0.1	4.0	15.6	0.1	3.7	15.9
4-May-09	8	53	0.1	1.5	17.7	0.1	2.9	17.0	0.1	2.4	17.3
5-May-09		54	0.1	4.6	10.7	0.1	4.2	12.1	0.1	4.0	12.4
6-May-09		55	0.1	13.5	5.4	0.1	13.8	4.5	0.1	12.4	6.1
7-May-09		56	0.0	13.8	7.2	0.0	10.9	9.7	0.0	9.6	11.1
8-May-09		57	0.0	13.1	7.9	0.0	10.4	10.2	0.0	10.9	9.5
11-May-09	9	60	0.0	5.5	12.4	0.0	4.5	14.2	0.0	5.4	12.5
14-May-09		63	0.0	4.8	13.4	0.1	4.8	13.7	0.1	4.2	14.8
18-May-09	10	67	0.1	5.4	12.9	0.1	5.5	14.0	0.1	6.9	12.6
19-May-09		68	0.1	5.6	14.2	0.1	5.8	14.5	0.1	6.5	13.7
20-May-09		69	0.1	9.0	10.3	0.1	7.8	11.7	0.0	5.7	13.6
22-May-09		71	0.1	6.7	12.3	0.1	7.1	11.0	0.1	6.1	13.2
25-May-09	11	74	0.1	7.8	13.9	0.1	6.9	14.0	0.1	6.2	14.2
26-May-09		75	0.1	4.2	14.6	0.1	5.8	14.5	0.1	6.4	14.0
27-May-09		76	0.0	6.4	12.2	0.0	5.2	13.5	0.0	4.4	14.2
29-May-09		78	0.1	3.6	14.8	0.1	5.5	13.5	0.1	3.5	14.9

MOISTURE CONTENT (%)

Date sampled	Date analysed	Sample	Weight of wet waste(g)	Weight of dry waste(g)	Result (%)
09-Mar-09	09-Mar-09	CGW (input)	314	162	**48.41**
12-Mar-09	12-Mar-09	DGW (input)	146	60	**58.90**
23-Mar-09	23-Mar-09	CGW (2weeks)	360	188	**47.80**
23-Mar-09	23-Mar-09	DGW (2weeks)	214	98	**54.21**
06-Apr-09	07-Apr-09	CGW (4weeks)	448	188	**58.04**
06-Apr-09	07-Apr-09	DGW (4weeks)	336	110	**67.26**
20-Apr-09	21-Apr-09	CGW (6weeks)	376	144	**61.70**
20-Apr-09	21-Apr-09	DGW (6weeks)	370	136	**63.24**
04-May-09	05-May-09	CGW (8weeks)	382	132	**65.40**
04-May-09	05-May-09	DGW (8weeks)	264	114	**56.80**
18-May-09	19-May-09	CGW (10weeks)	498	178	**64.20**
18-May-09	19-May-09	DGW (10weeks)	592	204	**65.50**

FIELD CAPACITY (ml/100g)

Date sampled	Date analysed	Sample	Weight of wet waste(g)	Water retained (ml)	Result (ml/100g)
09-Mar-09	09-Mar-09	CGW (input)	264	80	**30.30**
12-Mar-09	12-Mar-09	DGW (input)	134	62	**42.27**
23-Mar-09	23-Mar-09	CGW (2weeks)	386	86	**22.28**
23-Mar-09	23-Mar-09	DGW (2weeks)	144	64	**44.44**
06-Apr-09	07-Apr-09	CGW (4weeks)	320	90	**28.13**
06-Apr-09	07-Apr-09	DGW (4weeks)	224	80	**35.71**
20-Apr-09	21-Apr-09	CGW (6weeks)	470	112	**23.83**
20-Apr-09	21-Apr-09	DGW (6weeks)	270	82	**30.37**
04-May-09	05-May-09	CGW (8weeks)	412	110	**26.69**
04-May-09	05-May-09	DGW (8weeks)	402	96	**23.88**
18-May-09	19-May-09	CGW (10weeks)	490	128	**26.12**
8-May-09	19-May-09	DGW (10weeks)	560	106	**18.93**

BOD$_5$ (mg/l)

Date sampled	Date analysed	Sample	BOD$_5$ (mg/l)	Average (mg/l)
09-Mar-09	20-Mar-09	CGW input (1)	2117	
09-Mar-09	20-Mar-09	CGW input (2)	2315	**2202**
12-Mar-09	24-Mar-09	DGW input (1)	3528	
12-Mar-09	24-Mar-09	DGW input (2)	3161	**3344.5**
23-Mar-09	26-Mar-09	CGW 2weeks (1)	1087	
23-Mar-09	26-Mar-09	CGW 2weeks (2)	1116	**1101.5**
23-Mar-09	30-Mar-09	DGW 2weeks (1)	3161	
23-Mar-09	30-Mar-09	DGW 2weeks (2)	3161	**3161**
06-Apr-09	09-Apr-09	CGW 4weeks (1)	452	
06-Apr-09	09-Apr-09	CGW 4weeks (2)	424	**438**
06-Apr-09	09-Apr-09	DGW 4weeks (1)	1694	
06-Apr-09	09-Apr-09	DGW 4weeks (2)	1750	**1722**
20-Apr-09	24-Apr-09	CGW 6weeks (1)	537	

20-Apr-09	24-Apr-09	CGW 6weeks (2)	551	**544**
20-Apr-09	24-Apr-09	DGW 6weeks (1)	1610	
20-Apr-09	24-Apr-09	DGW 6weeks (2)	1624	**1617**
04-May-09	11-May-09	CGW 8weeks (1)	692	
04-May-09	11-May-09	CGW 8weeks (2)	593	**643**
04-May-09	11-May-09	DGW 8weeks (1)	1298	
04-May-09	11-May-09	DGW 8weeks (2)	1355	**1327**
18-May-09	21-May-09	CGW 10weeks (1)	381	
18-May-09	21-May-09	CGW 10weeks (2)	367	**374**
18-May-09	21-May-09	DGW 10weeks (1)	989	
18-May-09	21-May-09	DGW 10weeks (2)	1031	**1010**
1-June-09	6-June-09	CGW 12weeks (1)	416	**416**
1-June-09	6-June-09	DGW 12weeks (1)	878	**878**
15-June-09	20-June-09	CGW 14weeks (1)	155	**155**
15-June-09	20-June-09	DGW 14weeks (1)	331	**331**

C/N ratio (Dry solid)

Date	**Date**	**Sample**	**C**	**N**	**C/N Ratio**
sent	**tested**	**(dry solid)**	**%**	**%**	
16-Mar-09	26-Mar-09	CGW (input)	47.50	0.42	**113.10**
16-Mar-09	26-Mar-09	DGW (input)	41.70	0.75	**55.60**
26-Mar-09	15-Apr-09	CGW (2weeks)	34.00	1.17	**29.06**
26-Mar-09	15-Apr-09	DGW (2weeks)	19.90	1.39	**14.32**
10-Apr-09	30-Apr-09	CGW (4weeks)	46.40	1.32	**35.15**
10-Apr-09	30-Apr-09	DGW (4weeks)	27.00	1.53	**17.65**
29-Apr-09	11-May-09	CGW (6weeks)	44.60	0.94	**47.45**
29-Apr-09	11-May-09	DGW (6weeks)	24.30	1.43	**16.99**
7-Apr-09	19-Apr-09	CGW (8weeks)	38.05	1.48	**25.71**
7-Apr-09	19-Apr-09	DGW (8weeks)	20.46	1.61	**12.71**
21-May-09	27-May-09	CGW (10weeks)	21.63	1.03	**21.00**
21-May-09	27-May-09	DGW (10weeks)	22.08	1.66	**13.30**
2-June-09	9-June-09	CGW (12weeks)	28.69	1.20	**23.91**
2-June-09	9-June-09	DGW (12weeks)	21.66	1.62	**13.37**
16-June-09	29-June-09	CGW (14weeks)	25.52	1.25	**20.42**
16-June-09	29-June-09	DGW (14weeks)	12.93	1.67	**7.74**

C/N ratio (Eluate)

Date	**Date**	**Sample**	**C**	**N**	**C/N Ratio**
sent	**tested**	**(dry solid)**	**%**	**%**	
16-Mar-09	15-Apr-09	CGW (input)	0.07	0.02	**3.50**
2-Apr-09	15-Apr-09	DGW (input)	0.48	0.07	**6.86**
2-Apr-09	15-Apr-09	CGW (2weeks)	0.05	0.03	**1.67**
2-Apr-09	15-Apr-09	DGW (2weeks)	0.43	0.10	**4.30**
10-Apr-09	30-Apr-09	CGW (4weeks)	0.03	0.04	**0.75**
10-Apr-09	30-Apr-09	DGW (4weeks)	0.24	0.05	**4.80**
29-Apr-09	13-May-09	CGW (6weeks)	0.38	0.06	**6.33**
29-Apr-09	13-May-09	DGW (6weeks)	0.98	0.12	**8.17**
7-May-09	19-May-09	CGW (8weeks)	0.19	0.05	**3.80**
7-May-09	19-May-09	DGW (8weeks)	0.51	0.04	**12.75**

21-May-09	27-May-09	CGW (10weeks)	0.52	0.04	**13.00**
21-May-09	27-May-09	DGW (10weeks)	0.83	0.11	**7.55**
2-June-09	9-June-09	CGW (12weeks)	0.70	0.03	**23.33**
2-June-09	9-June-09	DGW (12weeks)	0.90	0.08	**11.25**
16-June-09	29-June-09	CGW (14weeks)	0.11	0.06	**1.83**
16-June-09	29-June-09	DGW (14weeks)	0.26	0.04	**6.50**

RI$_7$(mgO$_2$/gdm)

Date	Sample	Mass of	Volume of	Volume	Volume of	Δ in	Volume of	Final	O_2 initial	O_2 produced	O_2 consumed	Mass of	Total solids	RI$_7$
analysed	**(dry solid)**	**sample (g)**	**bottle (l)**	**of water (l)**	**sample (l)**	**Pressure (kpa)**	**gas (l)**	**Pressure (kpa)**	**N1(mol)**	**N(total)**	**N2(mol)**	**Oxygen (mgO$_2$)**	**%**	**(mgO$_2$/gdm*7d)**
20-Mar-09	CGW (input)	12	1.5	0.012	0.118	58.0	1.382	43.3	0.012	0.033	0.021	666.57	51.21	**15.50**
27-Mar-09	CGW (2weeks)	25	1.5	0.015	0.147	52.5	1.353	48.8	0.012	0.029	0.017	554.68	53.71	**5.90**
07-Apr-09	CGW (4weeks)	25	1.5	0.005	0.049	33.0	1.451	68.3	0.013	0.020	0.007	223.41	42.34	**3.02**
21-Apr-09	CGW (6weeks)	25	1.0	0.005	0.049	43.5	0.951	57.8	0.008	0.017	0.009	277.52	38.16	**4.16**
11-May-09	CGW (8weeks)	25	1.5	0.010	0.098	32.0	1.402	69.3	0.012	0.018	0.006	197.45	35.65	**3.16**
19-May-09	CGW (10weeks)	30	1.5	0.015	0.147	38.0	1.353	63.3	0.012	0.021	0.009	297.12	36.34	**3.89**
20-Mar-09	DGW (input)	12	1.5	0.015	0.147	43.5	1.353	57.8	0.012	0.024	0.012	394.82	43.10	**10.91**
27-Mar-09	DGW (2weeks)	25	1.5	0.030	0.294	63.0	1.206	38.3	0.011	0.031	0.021	660.60	47.44	**7.96**
19-May-09	DGW (10weeks)	26	1.5	0.006	0.059	44.0	1.441	57.3	0.013	0.026	0.013	430.03	35.66	**6.63**

COD (mg/l)

Sample	Date	Volume	Blank	Readings			Average	Result	Std	Var
	analysed		average	1	2	3	value	(mg/l)	Dev.	
Standard	26-Mar-09	1	-0.0003	0.079	0.081	0.083	0.081	**503.17**	0.002	0.000
CGW(input)	26-Mar-09	0.1	-0.0003	0.095	0.094	0.091	0.093	**5794.97**	0.002	0.000
DGW(input)	26-Mar-09	0.01	0.0005	0.035	0.034	0.030	0.033	**20114.25**	0.003	0.000
Standard	30-Mar-09	1	0.0005	0.082	0.083	0.082	0.082	**506.47**	0.001	0.000
CGW(2weeks)	30-Mar-09	0.1	-0.0003	0.065	0.071	0.077	0.071	**4412.76**	0.006	0.000
DGW(2weeks)	30-Mar-09	0.03	0.0005	0.086	0.079	0.073	0.079	**16263.32**	0.007	0.000
Standard	9-Apr-09	1	-0.0015	0.082	0.081	0.079	0.081	**508.53**	0.002	0.000
CGW(4weeks)	9-Apr-09	0.1	-0.0015	0.034	0.038	0.039	0.037	**2382.77**	0.003	0.000
DGW(4weeks)	9-Apr-09	0.05	-0.0015	0.091	0.089	0.097	0.092	**11614.69**	0.004	0.000
Standard	28-Apr-09	1	-0.0008	0.080	0.078	0.080	0.079	**495.64**	0.001	0.000
CGW(6weeks)	28-Apr-09	0.05	-0.0008	0.058	0.053	0.056	0.056	**6983.26**	0.004	0.000
DGW(6weeks)	7-May-09	0.03	0.0005	0.102	0.105	0.101	0.103	**21076.98**	0.002	0.000
Standard	7-May-09	1	0.0005	0.085	0.080	0.084	0.083	**510.59**	0.004	0.000
CGW(8weeks)	7-May-09	0.08	0.0005	0.101	0.098	0.097	0.099	**7594.42**	0.002	0.000
DGW(8weeks)	7-May-09	0.03	0.0005	0.058	0.059	0.055	0.057	**11724.72**	0.001	0.000
Standard	27-May-09	1	-0.0003	0.089	0.086	0.088	0.088	**544.12**	0.002	0.000
CGW(10weeks)	27-May-09	0.1	-0.0003	0.073	0.072	0.078	0.074	**4615.96**	0.001	0.000
DGW(10weeks)	27-May-09	0.05	-0.0003	0.096	0.094	0.096	0.095	**11831.31**	0.001	0.000
Standard	11-Jun-09	1	0.0003	0.082	0.078	0.081	0.080	**495.64**	0.003	0.000
CGW(12weeks)	11-Jun-09	0.1	0.0003	0.043	0.042	0.047	0.044	**2707.69**	0.001	0.000
DGW(12weeks)	11-Jun-09	0.03	0.0003	0.112	0.097	0	0.070	**8592.40**	0.011	0.000
Standard	26-Jun-09	1	0.0005	0.082	0.078	0.081	0.080	**494.09**	0.003	0.000
CGW(14weeks)	26-Jun-09	1	0.0005	0.390	0.383	0.336	0.370	**2284.77**	0.005	0.000
DGW(14weeks)	26-Jun-09	0.3	0.0005	0.356	0.346	0.350	0.351	**7223.94**	0.007	0.000

NH$_3$-N

Date	Date	Sample	Volume	Constant	Readings		Average	Result	Std	Var
sampled	analysed		of sample (ml)		1	2		(mg/l)	Dev	
9-Mar-09	19-Mar-09	CGW (input)	50	28	1.28	1.32	1.30	**36.40**	0.028	0.001
12-Mar-09	26-Mar-09	DGW (input)	50	28	6.42	6.36	6.39	**178.92**	0.042	0.002
23-Mar-09	26-Mar-09	CGW (2wks)	50	28	0.51	0.57	0.54	**15.12**	0.042	0.002
23-Mar-09	26-Mar-09	DGW (2wks)	50	28	4.31	4.35	4.33	**121.24**	0.028	0.001
6-Apr-09	14-Apr-09	CGW (4wks)	50	28	0.23	0.24	0.24	**6.58**	0.007	0.000
6-Apr-09	14-Apr-09	DGW (4wks)	50	28	2.83	2.78	2.81	**78.54**	0.035	0.001
20-Apr-09	29-Apr-09	CGW (6wks)	50	28	0.40	0.42	0.41	**11.48**	0.014	0.000
20-Apr-09	29-Apr-09	DGW (6wks)	50	28	3.18	3.21	3.20	**89.46**	0.021	0.000
4-May-09	14-May-09	CGW (8wks)	50	28	0.70	0.64	0.67	**18.76**	0.042	0.002
4-May-09	14-May-09	DGW (8wks)	50	28	3.03	2.98	3.01	**84.14**	0.035	0.001

18-May-09	22-May-09	CGW (10wks)	50	28	0.60	0.63	0.62	**17.22**	0.021	0.000
18-May-09	22-May-09	DGW (10wks)	50	28	1.90	1.86	1.88	**52.64**	0.028	0.001
01-Jun-09	06-Jun-09	CGW (12wks)	50	28	0.30	0.32	0.31	**8.68**	0.014	0.000
01-Jun-09	06-Jun-09	DGW (12wks)	50	28	1.95	1.87	1.91	**53.48**	0.057	0.003
15-Jun-09	20-Jun-09	CGW (14wks)	50	28	0.34	0.36	0.35	**9.80**	0.014	0.000
15-Jun-09	20-Jun-09	DGW (14wks)	50	28	1.88	1.84	1.86	**52.08**	0.028	0.001

NO_3-N

Date	Date	Sample	Volume	Constant	Readings			Result	Std	Var
sampled	analysed		of sample (ml)		1	2	Average	(mg/l)	Dev	
9-Mar-09	19-Mar-09	CGW (input)	50	28	0.26	0.18	0.22	**6.16**	0.057	0.003
12-Mar-09	26-Mar-09	DGW (input)	50	28	0.66	0.69	0.68	**18.90**	0.021	0.000
23-Mar-09	26-Mar-09	CGW (2wks)	50	28	0.23	0.24	0.24	**6.58**	0.007	0.000
23-Mar-09	26-Mar-09	DGW (2wks)	50	28	0.38	0.41	0.40	**11.06**	0.021	0.000
6-Apr-09	14-Apr-09	CGW (4wks)	50	28	0.10	0.16	0.13	**3.64**	0.042	0.002
6-Apr-09	14-Apr-09	DGW (4wks)	50	28	0.39	0.37	0.38	**10.64**	0.014	0.000
20-Apr-09	29-Apr-09	CGW (6wks)	50	28	0.17	0.19	0.18	**5.04**	0.014	0.000
20-Apr-09	29-Apr-09	DGW (6wks)	50	28	0.39	0.38	0.39	**10.78**	0.007	0.000
4-May-09	14-May-09	CGW (8wks)	50	28	0.18	0.22	0.20	**5.60**	0.028	0.001
4-May-09	14-May-09	DGW (8wks)	50	28	0.23	0.27	0.25	**7.00**	0.028	0.001
18-May-09	22-May-09	CGW (10wks)	50	28	0.24	0.21	0.23	**6.30**	0.021	0.000
18-May-09	22-May-09	DGW (10wks)	50	28	0.22	0.26	0.24	**6.72**	0.021	0.000
01-Jun-09	06-Jun-09	CGW (12wks)	50	28	0.12	0.16	0.14	**3.92**	0.028	0.001
01-Jun-09	06-Jun-09	DGW (12wks)	50	28	0.25	0.28	0.27	**7.42**	0.014	0.000
15-Jun-09	20-Jun-09	CGW (14wks)	50	28	0.14	0.14	0.14	**3.92**	0.000	0.000
15-Jun-09	20-Jun-09	DGW (14wks)	50	28	0.25	0.27	0.26	**7.28**	0.007	0.000

ANALYSIS ON ELUATE (TS and VS)

Date	Date	Sample	Cruc	Dry	After	After	TS	VS	Average	Average
sampled	analysed		No	initial	drying	firing	(g/l)	(g/l)	TS (g/l)	VS (g/l)
9-Mar-09	18-Mar-09	CGW (input)	32	62.2530	62.3845	62.3042	**5.260**	**3.212**		
			B	43.8517	43.9755	43.8945	**4.952**	**3.240**		
			C	43.3752	43.5002	43.4203	**5.000**	**3.196**	**5.071**	**3.216**
12-Mar-09	18-Mar-09	DGW (input)	29	56.4221	56.9238	56.5916	**20.068**	**13.288**		
			M	45.5433	46.0408	45.8049	**19.900**	**9.436**		
			16	52.8909	53.3979	53.0641	**20.280**	**13.352**	**20.083**	**12.025**
23-Mar-09	30-Mar-09	CGW (2weeks)	B	43.8612	43.9850	43.8970	**4.952**	**3.520**		
			6	54.2685	54.3936	54.3049	**5.004**	**3.548**		
			29	56.4333	56.5566	56.4689	**4.932**	**3.508**	**4.963**	**3.525**
23-Mar-09	30-Mar-09	DGW (2weeks)	C	43.3881	43.6612	43.4860	**10.924**	**7.008**		
			16	52.8994	53.1718	52.9983	**10.896**	**6.940**		
			32	62.2709	62.5436	62.3689	**10.908**	**6.988**	**10.909**	**6.979**
6-Apr-09	14-Apr-09	CGW (4weeks)	25	57.1801	57.2375	57.2033	**2.296**	**1.368**		
			29	56.4316	56.4894	56.4552	**2.312**	**1.368**		
			16	52.899	52.9564	52.9228	**2.296**	**1.344**	**2.301**	**1.360**
6-Apr-09	14-Apr-09	DGW (4weeks)	32	62.2686	62.5894	62.3842	**12.832**	**8.208**		
			21	52.4792	52.7991	52.5943	**12.796**	**8.192**		
			B	43.8585	44.179	43.9735	**12.820**	**8.220**	**12.816**	**8.207**
6-Apr-09	21-May-09	CGW (4weeks)	19	49.3379	49.3985	49.3625	**2.424**	**1.440**		
			20	54.4884	54.5495	54.5134	**2.444**	**1.444**		
			15	47.1632	47.2237	47.1869	**2.420**	**1.472**	**2.429**	**1.452**

6-Apr-09	21-May-09	DGW (4weeks)	6	54.2625	54.5716	54.3776	**12.364**	**7.760**		
			59	45.5247	45.8330	45.6415	**12.332**	**7.660**		
			57	48.188	48.5002	48.3067	**12.488**	**7.740**	**12.395**	**7.720**
20-Apr-09	28-Apr-09	CGW (6weeks)	W	41.2352	41.3968	41.2755	**6.464**	**4.852**		
			M	45.5454	45.6876	45.5827	**5.688**	**4.196**		
			20	54.4913	54.6419	54.5294	**6.024**	**4.500**	**6.059**	**4.516**
20-Apr-09	28-Apr-09	DGW (6weeks)	15	47.1666	47.8336	47.5662	**26.680**	**10.696**		
			19	49.3461	49.9590	49.5662	**24.516**	**15.712**		
			23	53.8447	54.4150	54.0524	**22.812**	**14.504**	**24.669**	**13.637**
20-Apr-09	21-May-09	CGW (6weeks)	60	45.4094	45.4810	45.4350	**2.864**	**1.840**		
			55	44.7137	44.7855	44.7393	**2.872**	**1.848**		
			56	48.5557	48.6277	48.5803	**2.880**	**1.896**	**2.872**	**1.861**
20-Apr-09	21-May-09	DGW (6weeks)	61	48.8735	49.4214	49.0765	**21.916**	**13.796**		
			58	46.1259	46.6767	46.3272	**22.032**	**13.980**		
			53	42.9311	43.4815	43.1357	**22.016**	**13.832**	**21.988**	**13.869**
4-May-09	7-May-09	CGW (8weeks)	21	52.4791	52.6485	52.5194	**6.776**	**5.164**		
			B	43.8593	44.0328	43.9001	**6.940**	**5.308**		
			32	62.2691	62.4336	62.3091	**6.580**	**4.980**	**6.765**	**5.151**
4-May-09	7-May-09	DGW (8weeks)	29	56.4320	56.9102	56.6187	**19.128**	**11.660**		
			P	40.7667	41.2388	40.9506	**18.884**	**11.528**		
			25	57.1805	57.6366	57.3591	**18.244**	**11.100**	**18.752**	**11.429**
18-May-09	21-May-09	CGW (10weeks)	M	45.5433	45.7279	45.5825	**7.384**	**5.816**		
			32	62.2670	62.4466	62.3061	**7.184**	**5.620**		
			W	41.2319	41.4092	41.2707	**7.092**	**5.540**	**7.220**	**5.659**
18-May-09	21-May-09	DGW (10weeks)	16	52.8989	53.4812	53.1516	**23.292**	**13.184**		
			29	56.4302	57.0163	56.6862	**23.444**	**13.204**		
			23	53.8425	54.4121	54.0886	**22.784**	**12.940**	**23.173**	**13.109**
1-Jun-09	5-Jun-09	CGW (12weeks)	B	43.8549	43.9791	43.8868	**4.968**	**3.692**		
			32	62.2670	62.3908	62.2947	**4.952**	**3.844**		
			25	57.1793	57.303	57.209	**4.948**	**3.760**	**4.956**	**3.765**
1-Jun-09	5-Jun-09	DGW (12weeks)	B	44.4216	44.9683	44.6558	**21.868**	**12.500**		
			9	54.5789	55.1290	54.8123	**22.004**	**12.668**		
			W	41.2314	41.7849	41.4708	**22.140**	**12.564**	**22.004**	**12.577**
17-Jun-09	21-Jun-09	CGW (14weeks)	32	62.2678	62.3303	62.2880	**2.500**	**1.692**		
			9	54.5792	54.6390	54.5983	**2.392**	**1.628**		
			19	49.3383	49.3959	49.3572	**2.304**	**1.548**	**2.399**	**1.623**
17-Jun-09	21-Jun-09	DGW (14weeks)	B	43.8563	44.0946	43.9517	**9.532**	**5.716**		
			29	56.4304	56.6749	56.5289	**9.780**	**5.840**		
			16	52.8987	53.1344	52.9941	**9.428**	**5.612**	**9.580**	**5.723**

ANALYSIS ON DRY SOLID

Date sampled	Date analysed	Sample	Cruc No	Cruc.dry	Cruc+ wet waste	Cruc+ dried waste	Cruc+ Fired waste	Mass of dry waste	TS (%)	VS (%)	Average TS (%)	Average VS (%)
9-Mar-09	16-Mar-09	CGW (input)	6	54.2660	63.9572	59.3282	54.5797	9.6912	**52.2350**	**48.9981**		
			W	41.2339	53.5998	47.4323	41.6056	12.3659	**50.1249**	**47.1191**		
			P	40.7639	51.6608	46.3506	41.0652	10.8969	**51.2687**	**48.5037**	**51.2096**	**48.2070**
12-Mar-09	16-Mar-09	DGW (input)	20	54.4903	59.5193	56.6717	54.9009	5.0290	**43.3764**	**35.2118**		
			19	49.3443	55.1364	52.0821	49.7907	5.7921	**47.2678**	**39.5608**		
			23	53.8441	59.3206	55.9606	54.2398	5.4765	**38.6469**	**31.4215**	**43.0971**	**35.3980**
23-Mar-09	25-Mar-09	CGW (2weeks)	blank	44.4237	56.6518	51.1538	45.2037	12.2281	**55.0380**	**48.6592**		
			Z	40.5685	53.7167	47.7309	41.1137	13.1482	**54.4744**	**50.3278**		
			9	54.5808	65.9907	60.4697	55.0654	11.4099	**51.6122**	**47.3650**	**53.7082**	**48.7840**
23-Mar-09	25-Mar-09	DGW (2weeks)	21	52.4807	58.6701	55.2712	53.6855	6.1894	**45.0851**	**25.6196**		
			1	53.910	61.3117	57.3034	55.3859	7.4020	**45.8484**	**25.9052**		
			25	57.1805	63.9071	60.6361	58.8516	6.7266	**51.3722**	**26.5290**	**47.4352**	**26.0179**
6-Apr-09	8-Apr-09	CGW (4weeks)	15	47.1660	59.5704	52.4140	47.4988	12.4044	**42.3076**	**39.6246**		
			M	45.5448	57.6019	51.0845	45.9066	12.0571	**45.9455**	**42.9448**		
			19	49.3453	59.2379	53.1801	49.6547	9.8926	**38.7643**	**35.6367**	**42.3391**	**39.4021**
6-Apr-09	8-Apr-09	DGW (4weeks)	W	41.2354	50.0936	44.9533	42.7642	8.8582	**41.9713**	**24.7127**		
			20	54.4906	61.8443	57.3417	55.4769	7.3537	**38.7710**	**25.3587**		
			23	53.8437	64.2560	57.6642	55.4762	10.4123	**36.6922**	**21.0136**	**39.1448**	**23.6950**
20-Apr-09	23-Apr-09	CGW (6weeks)	16	52.8976	65.8945	57.7275	53.3517	12.9969	**37.1619**	**33.6680**		
			C	43.3854	60.6080	49.8404	43.9358	17.2226	**37.4798**	**34.2840**		
			1	53.9090	70.9455	60.6952	54.4108	17.0365	**39.8333**	**36.8879**	**38.1584**	**34.9466**
20-Apr-09	23-Apr-09	DGW (6weeks)	6	54.2663	65.1974	57.9253	55.9065	10.9311	**33.4733**	**18.4684**		
			9	54.5823	71.1026	60.2726	57.0744	16.5203	**34.4443**	**19.3592**		
			Z	40.5687	57.4062	46.4533	42.8344	16.8375	**34.9494**	**21.4931**	**34.2890**	**19.7736**
4-May-09	6-May-09	CGW (8weeks)	9	54.5818	70.5186	60.2682	55.0933	15.9368	**35.6809**	**32.4714**		
			23	53.8437	67.7668	58.9778	54.2193	13.9231	**36.8747**	**34.1770**		

			C	43.3862	62.5930	49.9927	43.9311	19.2068	**34.3967**	**31.5597**	**35.6508**	**32.7360**
4-May-09	6-May-09	DGW (8weeks)	P	40.7627	54.2397	45.3934	42.7727	13.4770	**34.3600**	**19.4457**		
			blank	44.4224	60.3233	50.1094	46.9851	15.9009	**35.7653**	**19.6486**		
			9	54.5807	70.6100	60.2839	57.2618	16.0293	**35.5798**	**18.8536**	**35.2350**	**19.3160**
18-May-09	20-May-09	CGW (10weeks)	21	52.4774	63.7324	56.5361	52.8345	11.2550	**36.0613**	**32.8885**		
			1	53.9074	67.8403	59.1296	54.3878	13.9329	**37.4811**	**34.0331**		
			Z	40.5664	54.8057	45.6181	41.0894	14.2393	**35.4772**	**31.8042**	**36.3398**	**32.9086**
18-May-09	20-May-09	DGW (10weeks)	C	43.3865	59.6717	49.2568	46.8118	16.2852	**36.0468**	**15.0136**		
			25	57.1795	74.6285	63.4822	60.5112	17.4490	**36.1207**	**17.0268**		
			B	43.8582	65.7023	51.4639	47.8284	21.8441	**34.8181**	**16.6429**	**35.6619**	**16.2278**
1-Jun-09	2-Jun-09	CGW (12weeks)	21	52.4775	66.7229	57.0186	52.9150	14.2454	**31.8777**	**28.8065**		
			M	45.5428	61.1809	51.1533	46.0991	15.6381	**35.8771**	**32.3198**		
			16	52.8978	69.8033	59.1242	53.3975	16.9055	**36.8306**	**33.8748**	**34.8618**	**31.6670**
1-Jun-09	2-Jun-09	DGW (12weeks)	C	43.3856	59.0556	48.6222	45.7965	15.6700	**33.4180**	**18.0325**		
			Z	40.5649	61.6156	47.5227	43.9985	21.0507	**33.0526**	**16.7415**		
			15	47.1616	68.2079	54.3949	50.9091	16.9543	**32.3995**	**26.4930**	**32.9567**	**20.4223**
17-Jun-09	18-Jun-09	CGW (14weeks)	15	47.1623	64.1166	52.6554	48.1637	18.1213	**33.1709**	**27.6879**		
			M	45.5437	63.6650	51.5547	46.5373	18.1213	**33.1709**	**27.6879**		
			21	52.4776	74.2212	59.7273	55.2356	21.7436	**33.3418**	**20.6576**	**33.2279**	**25.3444**
17-Jun-09	18-Jun-09	DGW (14weeks)	P	40.7614	57.4091	46.0858	42.5616	16.6477	**31.9828**	**21.1693**		
			W	41.2307	57.7295	46.7260	43.2402	16.4988	**33.3073**	**21.1276**		
			25	57.1791	74.9592	63.1354	59.6112	17.7801	**33.4998**	**19.8210**	**32.9300**	**20.7060**

SUMMARY OF CHARACTERIZATION

ANALYSIS ON ELUATE

SAMPLE	TS	VS	PH	Cond.	COD	NH_3-N	NO_3-N	BOD_5	C/N	BOD_5/COD
	(g/l)	(g/l)		(mS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	ratio	ratio
CGW (input)	5.07	3.22	5.65	2.47	5177.10	36.40	6.16	2202.0	3.50	0.43
CGW (2weeks)	4.96	3.53	6.07	1.88	4412.76	15.12	6.58	1101.5	1.67	0.25
CGW (4weeks)	2.30	1.36	6.28	1.69	1727.76	6.58	3.64	438.0	0.75	0.25
CGW (6weeks)	6.06	4.52	6.59	1.73	5624.25	11.48	5.04	544.0	6.33	0.10
CGW (8weeks)	6.77	5.15	6.95	1.38	7594.42	18.76	5.60	643.0	3.80	0.08
CGW (10weeks)	7.22	5.66	7.38	1.29	9231.93	17.22	6.30	374.0	13.00	0.04
CGW (12weeks)	4.96	3.77	7.40	1.21	2707.69	8.68	3.92	416.0	23.33	0.15
CGW (14weeks)	2.40	1.62	7.44	1.22	2284.77	9.80	3.92	155.0	1.83	0.07
DGW (input)	20.08	12.03	5.63	5.21	18412.28	178.92	18.90	3344.5	6.86	0.18
DGW (2weeks)	10.91	6.98	7.01	5.05	15214.63	121.24	11.06	3161.0	4.30	0.21
DGW (4weeks)	12.82	8.21	7.25	4.94	11614.69	78.54	10.64	1722.0	4.80	0.15
DGW (6weeks)	21.99	13.87	7.21	4.40	21076.98	89.46	10.78	1617.0	8.17	0.08
DGW (8weeks)	18.75	11.43	7.36	4.18	11707.53	84.14	7.00	1327.0	12.75	0.11
DGW (10weeks)	23.17	13.11	7.75	3.84	19718.84	52.64	6.72	1010.0	7.55	0.05
DGW (12weeks)	22.00	12.58	7.70	3.62	8592.40	53.48	7.42	878.0	11.25	0.10
DGW (14weeks)	9.58	5.72	7.72	3.46	7223.94	52.08	7.28	331.0	6.50	0.05

ANALYSIS ON DRY SOLID

SAMPLE	Total Solid (%)	Volatile Solid (%)	Moisture Content (%)	Field Capacity (ml/100g)	Respiratory Index (RI_7) (mgO2/gdm)	Carbon to Nitrogen Ratio
CGW (input)	51.21	48.21	48.41	30.30	15.50	113.10
CGW (2weeks)	53.71	48.78	47.80	22.28	5.90	29.06
CGW (4weeks)	42.34	39.40	58.04	28.13	3.02	35.15
CGW (6weeks)	38.16	34.95	61.70	23.83	4.16	47.45
CGW (8weeks)	35.65	32.74	65.40	26.69	3.16	25.71
CGW (10weeks)	36.34	32.91	64.20	18.93	3.89	21.00
CGW (12weeks)	34.86	31.67	63.65	-	-	23.91
CGW (14weeks)	33.23	25.34	66.75	-	-	20.42
DGW (input)	43.10	35.40	58.90	42.27	10.91	55.60
DGW (2weeks)	47.44	26.02	54.21	44.44	7.96	14.32
DGW (4weeks)	39.14	23.69	67.26	35.71	-	17.65
DGW (6weeks)	34.29	19.77	63.24	30.37	-	16.99
DGW (8weeks)	35.24	19.32	56.80	23.88	-	12.71
DGW (10weeks)	35.66	16.23	65.50	26.12	6.63	13.30
DGW (12weeks)	32.96	20.42	66.30	-	-	13.37
DGW (14weeks)	32.93	20.71	66.59	-	-	7.74