Title of Dissertation:

A Study of the Biological Treatment of Biodegradable Waste from mixed Municipal Solid Waste and the use of Compost-Like Outputs in Ireland

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This dissertation is submitted as part fulfilment of the M.Sc. in Environmental Protection, Institute of Technology, Sligo.

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ABSTRACT

Ireland is seeking to eliminate the landfilling of municipal waste, and to achieve maximum recovery of resources from waste, including from mixed municipal solid waste. This dissertation tries to investigate how biodegradable waste from mixed municipal solid waste is biologically treated to produce compost-like outputs in Ireland. The dissertation examines the quantity and quality of compost-like outputs produced in Ireland and what they are used for.

The amount of compost-like outputs produced in 2011 was slightly below 20 000 tonnes, indicating that the treatment of biodegradable waste from mixed municipal solid waste is still low in Ireland.

The study revealed that compost-like outputs cannot be used as a resource in Ireland. Waste regulations in Ireland do not permit compost-like outputs to be used for any other purpose other than disposal by landfill. The results of the analysis of compost-like outputs produced in Ireland indicate that their quality would meet the quality requirements of the United Kingdom standard for the end-use of compost-like outputs for land restoration. The analytical results show that compost-like outputs are a source of plant nutrients and organic matter. The results also show that compost-like outputs are a source of harmful substances that can cause a risk to the environment and human health.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Introduction

This dissertation has been written to fulfil the requirements of the Master of Science degree in Environmental Protection at the Institute of Technology Sligo, Sligo, Ireland. The title of the dissertation is '*A Study of the Biological Treatment of Biodegradable Waste from mixed Municipal Solid Waste and the use of Compost-Like Outputs in Ireland*.' This dissertation attempts to investigate how residual biodegradable waste separated from mixed municipal solid waste is biologically treated in Ireland, and what the resultant compost-like outputs are used for.

Municipal Solid Waste (MSW) means household waste as well as commercial and other waste which, because of its nature and composition, is similar to household waste. It excludes municipal sludges and effluents (Environmental Protection Agency, 2008). Mixed means that it is unsorted. It includes paper, cardboard, plastics, textiles, glass, metal, garden and other wastes that are discarded in grey or black bins.

Biodegradable Waste is any waste that is capable of undergoing aerobic or anaerobic decomposition, such as food and garden waste, and paper and cardboard.

Biological Treatment means composting, anaerobic digestion, mechanical-biological treatment or any other biological treatment process for the stabilising and sanitising of biodegradable waste including pre-treatment processes (Environmental Protection Agency, 2008).

The term *Compost-Like Output*, CLO for short refers to biologically treated and stabilised biodegradable waste derived from mixed municipal solid waste (Environmental Agency, 2009). Compost-like outputs are also referred to as stabilised biowaste, biocompost, separated organic material outputs from mixed resources (SOMs), grey compost, MBT organic output, stabilised organic fraction (SOF), and organic matter amendment (OMA). Compost-like outputs are soil forming material. They are given the name compost-like outputs to distinguish them from compost that is derived from source segregated organic municipal waste.

1.2 Background Problem

In July 2012, the Irish Department of the Environment, Community and Local Government published a document entitled '*A Resource Opportunity, Waste Management Policy in Ireland*'. The document is a policy statement covering the period 2011 to 2020. In this DECLG, 2012 document the Government is committed to achieving some of the following during that period:

- 'When waste is generated we must extract the maximum value from it by ensuring that it is reused , recycled or recovered, including by appropriate treatment of mixed municipal waste or residual waste collected in our black bins.'
- ' Disposal of municipal waste to the landfill must be a last resort – in fact , we must now work to effectively eliminate our use of landfill for this purpose within the next decade, in line with the 2011 EU Roadmap to a Resource Efficient Europe.'
- 'Make Ireland become a recycling society, with a clear focus on resource efficiency and the virtual elimination of landfilling of municipal waste.'

At present all compost-like outputs produced in Ireland are disposed of by landfill. This dissertation attempts to investigate why this is the case in Ireland. Organic biodegradable fines separated from mixed municipal solid waste and their product, compost-like outputs are a resource. They are source of plant nutrients and organic matter. The research study tries to examine beneficial uses of compost-like outputs that can assist in diverting them from landfills in Ireland.

1.3 Significance of the Study

The following are the significance of research study in Ireland:

(i) The study will be useful in finding ways of diverting compost-like outputs from landfills and this will assist in the elimination of landfilling municipal waste in Ireland.

The number of landfills and landfill space is getting less in Ireland. According to DECLG, 2012 there were 126 operational landfills in Ireland in 1998, this number had reduced to 28 by 2010. The number of landfills accepting municipal waste for disposal is continuing to decrease, as is the remaining licensed landfill disposal capacity (EPA National Waste Report for 2011). The same report states that 'the remaining national landfill capacity for municipal waste was approx.14.5Mt. (Circa years remaining life expectancy) at the end of 2011.' There is therefore need to research ways using compost-like outputs so that biodegradable wastes from mixed municipal waste can be diverted from landfills in Ireland. 'We must also now plan more fundamentally for alternative approaches that will allow us effectively to eliminate our use of landfill within the next decade (DECLG, 2012).'

(ii) *The study will be useful in finding ways of recovering and recycling resources from residual biodegradable waste from mixed municipal solid waste.*

Landfilling of compost-like outputs means that resources are being buried and wasted without the possibility of recovery. According to the EPA National Waste Report for 2010, 47 % of biodegradable municipal waste was disposed of to landfill in 2010. 'There is clearly a need to address this situation, to ensure that this material is used for more sustainable and profitable purposes. This is material which could be turned into products such as composts (DECLG, 2012).'

(iii) The findings of the study will be useful to companies that are composting biodegradable mixed municipal waste to produce compos-like outputs.

The composting of waste is a business. There might be opportunities for financial benefits creation of employment if compost-like outputs are allowed to be diverted from landfills.

(iv) The findings of the study will add new information and knowledge to the existing information on compost-like outputs.

2. LITERATURE REVIEW

2.1 Objectives of the Literature Review

The aim of the literature review was to establish what is known and has been published by other scholars on the study topic. The main goal was to establish why compost-like outputs are permitted to be used on land, including agricultural land in other European Union Member States and while it is prohibited in Ireland.

The objectives of the literature review were:

i. *To investigate the impacts on the environment of landfilling untreated biodegradable waste, and to understand the benefits of treating biodegradable waste.*

ii. *To gain an understanding of how biodegradable waste from mixed municipal solid waste is mechanically-biologically treated to produce compost-like outputs.*

iii. *To understand the hazards associated with the use of compost-like outputs on agricultural and non-agricultural land.*

iv. *To examine the regulatory regimes controlling the use of compost-like outputs, and also to investigate what compost- like outputs can legally be used for in other European Union Member States. Countries that were researched were France, Ireland, Italy, Spain and the United Kingdom.*

2.2 Sources of Information and Data

Sources of information used for this literature review were published books, Irish government waste policy reports, Irish EPA national waste reports and guidance reports, United Kingdom Environmental Agency waste guidance and research reports, journals articles on environment and waste, European Union waste research reports, and newspaper articles on waste treatment.

2.3 Reasons for Biological Treatment of Biodegradable Municipal Waste

When landfilled and compacted, untreated biodegradable wastes decompose to produce landfill gases and leachates. According to (Ewall, 2008) 'The main gases produced are methane and carbon dioxide. These gases contribute to global warming and have an influence on climate change. Methane gas is 21 times more potent than carbon monoxide. Landfill gas also contains hundreds of toxic contaminants known as Non-Methane Organic Compounds (NMOCs) as well as inorganic toxic contaminants like mercury and sometimes even radioactive contaminants like tritium. NMOCs include such toxic compounds as benzene, toluene, chloroform, vinyl chloride, carbon tetrachloride, and 1,1,1 trichloroethane, which, although less than 1% by weight, are hazardous'.

The paragraph above shows that the landfilling of biodegradable waste creates a negative impact on the environment. Treating biodegradable waste before landfilling it helps to reduce the impacts of landfills on the environment, and to reduce the risk to human health (Rapport *et al*, 2008).

The European Union Landfill Directive (1999/31/EC) requires that all compost-like outputs that are landfilled have to be stabilised. The standard used to measure the biological stability of compost-like outputs is the Static Respiratory Index AT (aerobic test). The minimum stability standard for compost-like outputs set in the EPA waste licences in Ireland is AT4 of 10mg O_2/g d.m (dry matter). It assesses how much oxygen is consumed by organic material in a unit time of 4 days.

Treating biodegradable can bring savings in waste disposal costs. Some European Union countries charge landfill tax or levy on any waste that is landfilled. In some countries there are two rates charged, a higher rate for untreated waste, and a lower rate for treated waste. Thus in some countries diverting compost-like outputs from landfills results in financial savings. In

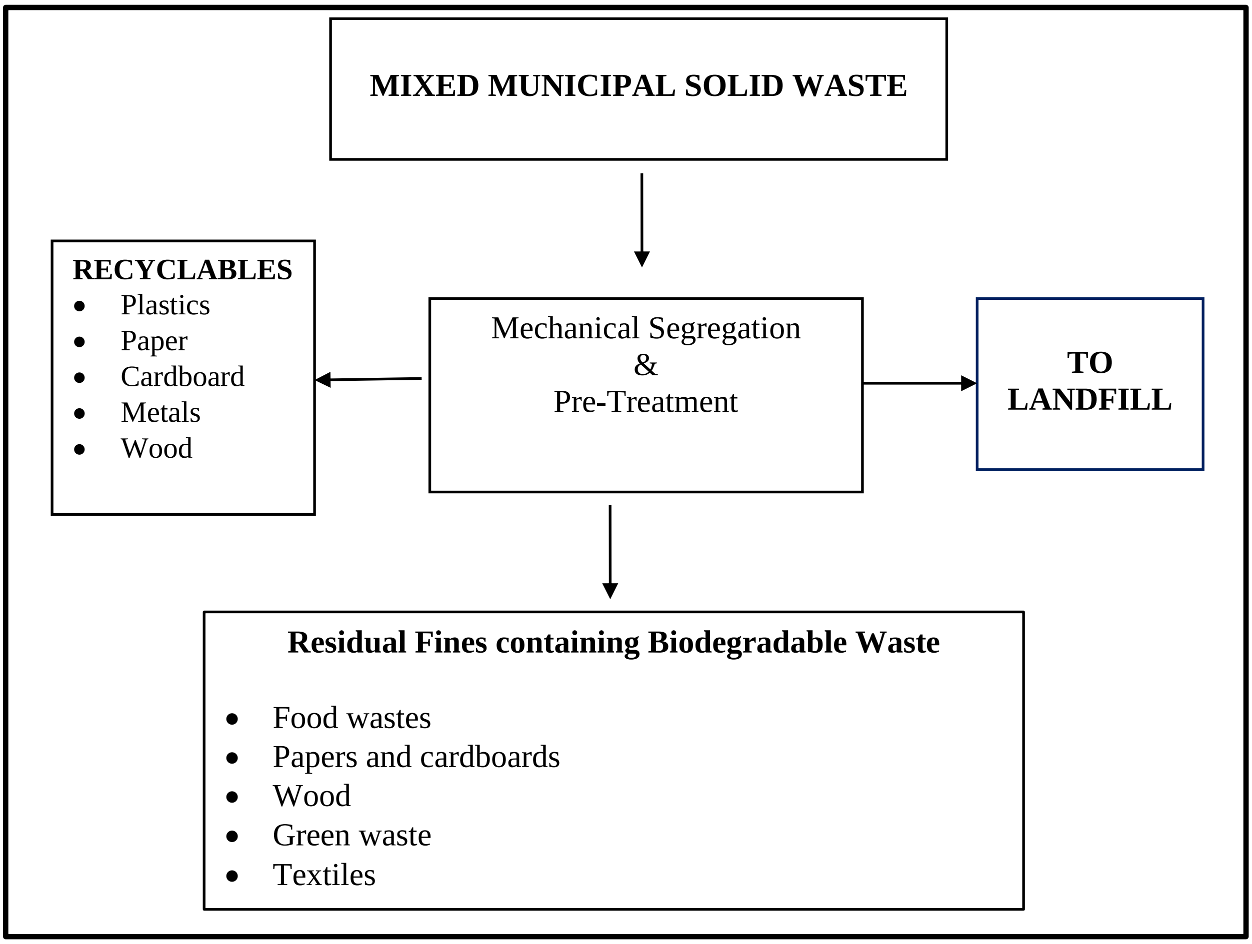
Ireland, the landfill levy is €75 per tonne of waste, but properly stabilised biowaste is exempt from the landfill levy.

2.4 Summary of Mechanical Biological Treatment of Municipal Solid Waste

2.4.1 Mechanical Segregation

The first stage in the treatment of mixed MSW after collection is its mechanical segregation into non-biodegradable and biodegradable components. The segregation can be carried out in Waste Transfer Stations, Mechanical Biological Treatment (MBT) plants or at Material Recovery Facilities. The segregation process may involve manual sorting and or the use of mechanical equipment. The segregation process of MSW can be summarised diagrammatically as presented in Figure1. The diagram shows the different types of waste material that can be found in mixed MSW.

Figure1: Summary of mechanical separation of mixed municipal solid waste



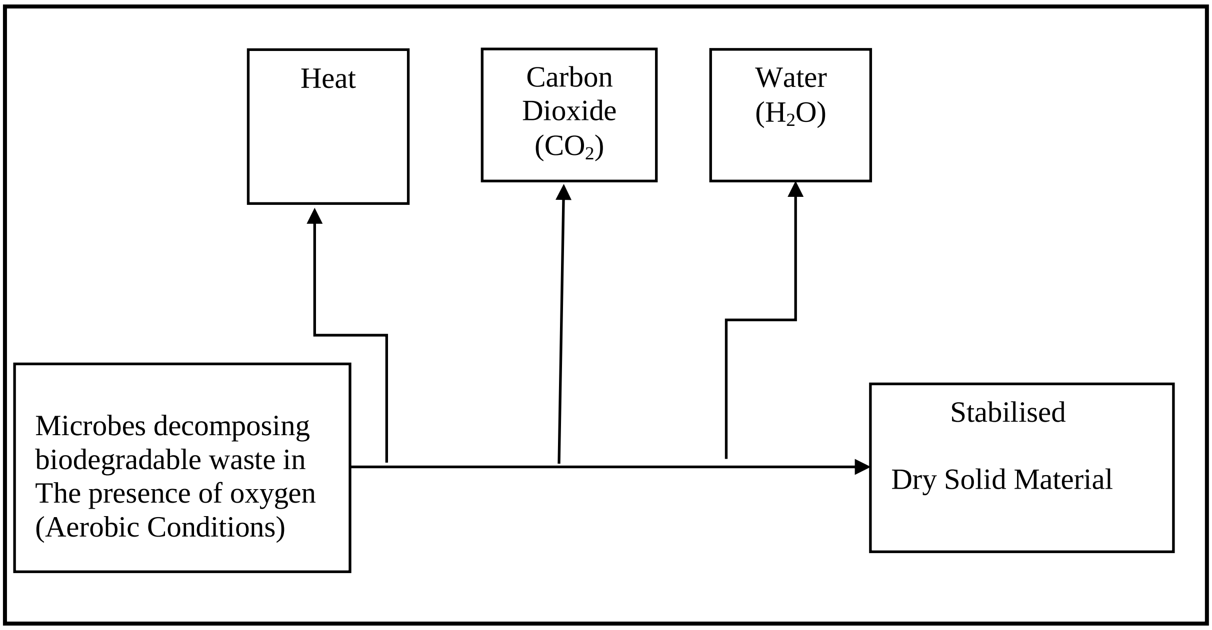
2.4.2 Biological Treatment of Biodegradable Waste Fractions

After the mechanical segregation of the different components of mixed MSW, residual fines containing biodegradable waste are sent for biological treatment. The biological treatment process of biodegradable fractions of MSW involves the decomposition of organic matter in the waste by living microbes (DEFRA, 2007; Velis et al., 2009). Different microbes (bacteria and fungi) can decompose organic matter under aerobic conditions and under anaerobic conditions. There are two types of engineering processes used to speed up the biological treatment of biodegradable waste. These are Aerobic and Anaerobic processes.

Aerobic Biological Treatment Process

In aerobic biological treatment, biodegradable waste is decomposed by microbes in the presence of oxygen. Figure 2 summaries the aerobic biological treatment process. The diagram shows the different products of the process.

Figure 2: Diagram illustrating Aerobic Biological Treatment Process



During treatment, harmful pathogens (bacteria, fungi and protozoa) and weed seeds are killed by high temperatures that are achieved during the decomposition of waste.

Aerobic Biological Treatment Technologies

The main aerobic biological treatment technologies used in the treatment of biodegradable waste are stated and briefly described in this section.

(i) Windrow Composting System,

Windrow composting system is a low technology system in which the waste in piled in long narrow rows called windrows. In can be carried indoors or outdoors. The rows are regularly turned and watered to improve aeration, porosity and moisture content.

(ii) Aerated Static Pile Composting System,

In Aerated Static Pile composting system, waste is piled or placed on a perforated piping system. The perforated pipes serve to supply air during the treatment process. Aerated Static Pile composting can be carried out indoors or outdoors

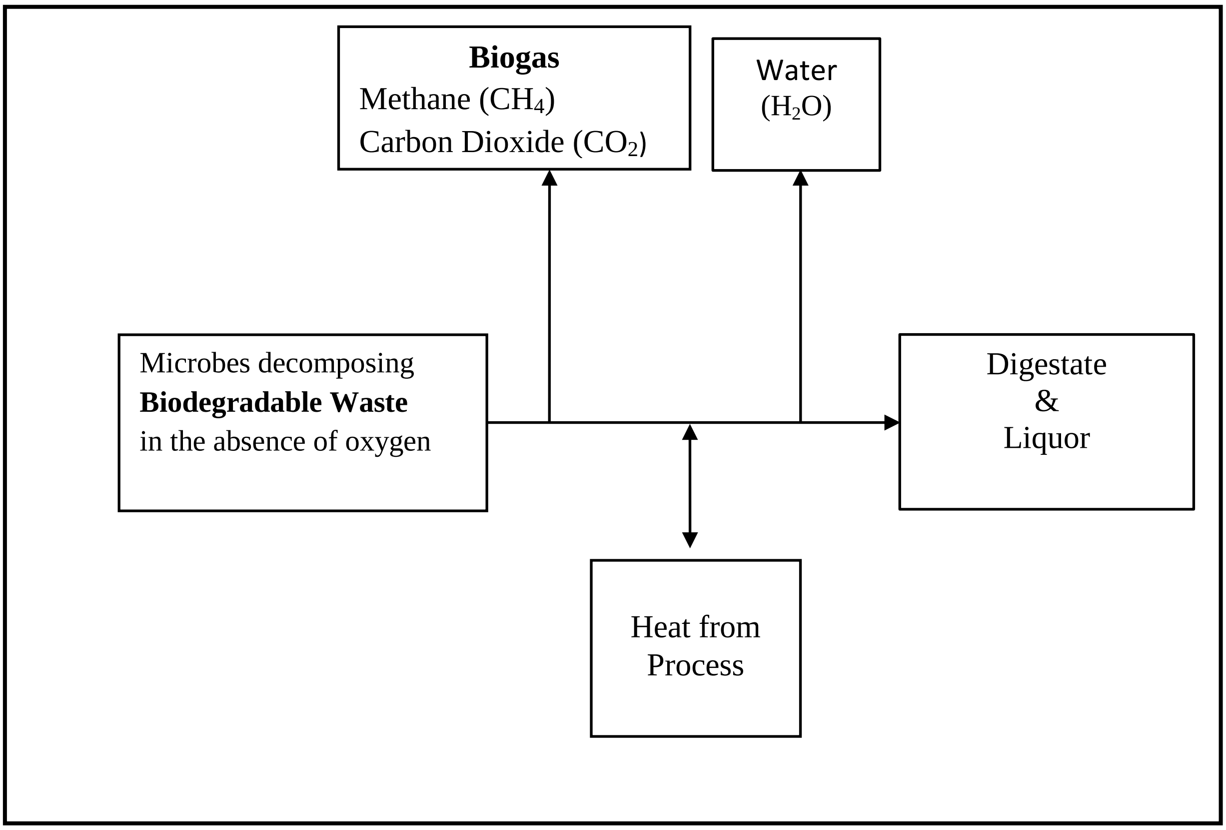
(iii) In-Vessel Composting (IVC) system

In-vessel composting systems are referred to as Advanced Biological Treatment (ABT) technologies (FAS, 2005). These composting systems require highly skilled labour for designing, construction, operating and maintenance as compared to windrow composting. In this composting system, the biological treatment of waste takes place inside a closed reactor. The enclosed reactor can be a tunnel, channel, container, vertical tower, rotating drum, agitated bay or a silo (DEFRA, 2007and FAS, 2005).

Anaerobic Biological Treatment Process

Anaerobic biological treatment of waste is also referred to as Anaerobic Digestion (AD). In this process, microbes decompose the waste in the absence of oxygen. Figure 3 summarises the process and shows products of the process.

Figure 3: Diagram illustrating Anaerobic Biological Treatment Process



There are two types of anaerobic digestion systems, dry anaerobic digestion systems and wet anaerobic digestion systems (Environmental Agency, 2013; European Bio Plastics, 2010). In dry anaerobic systems the process is run at moisture content levels of less than 85% while in wet anaerobic systems the process is run at moisture content level greater than 85%. Two main useful products are obtained from the anaerobic composting of waste, these are biogas and the digestate.

2.5 Uses of Compost-Like Outputs

This section discusses the different possible uses of compost-like outputs.

2.5.1 Agricultural

Compost-like outputs can be applied to agricultural land as an organic fertiliser. According to Taylor *et al*, *2010* ‘BioCompost was shown to be a valuable source of stable organic matter and major plant nutrients, and in field-based research increased winter wheat yields by *c.*1 t/ha and crop available N supply by *c.*50 kg N/ha .In addition, risk assessment work (based on EU Technical Guidance) indicated that there were little or no risks to human health or the environment from BioCompost use on tillage land.'

These findings were made in a research study that was carried out in the United Kingdom at the Allerton Project, Loddington, Leicestershire. The research was started in October 2008 and the findings were made at harvest in 2009. Compost-like outputs can also be applied as organic fertiliser or manure on agricultural land used to grow non-food crops.

2.5.2 Landfill Cover and Final Capping of Landfills

Compost-like outputs can be used as material for landfill daily cover and material for the final capping of landfills. Although this saves natural soil from being used, it is loss of resources as the buried organic nutrients cannot be recovered.

2.5.3 Soil Improvement

Compost-like outputs are also used to improve soils that are low in organic content. They can improve the physical properties and structure of soil and they also help to complete the natural carbon cycle (Velis *et al*., 2009). Organic matter found in compost-like outputs can help to improve soil permeability, drainage, aeration and water holding capacity. Nutrients from the organic matter can help the soil to support plant growth or vegetation. Vegetation growing on improved soils can prevent or reduce soil erosion by wind and water. Some of the improved soils are turned into agricultural land for growing food crops. In dry climate areas, compost-like outputs can also be used as mulch to reduce soil water losses.

2.5.4 Land restoration

Land can be polluted or damaged by human activities like mining, farming, forestry and manufacturing industries. Sometimes polluted or damaged land needs to be restored or repaired so that it can be used for productive purposes. Compost-like outputs can be used as material for land restoration. They can be mixed with or applied to the final topsoil layer to improve the soil and support plant growth on the rehabilitated area. Compost-like outputs can be used in the restoration of brownfield sites, mine tailings and closed landfills. These are briefly discussed below. The compost-like outputs will provide organic matter and nutrients needed to support plant and vegetation growth on these sites.

Brownfield Sites

A brownfield is described as land that;

- has been affected by its former use or use of lands surrounding it;
- is derelict or underused;
- may have real or perceived contamination, and requires intervention to bring it back to beneficial use.

Examples of brownfield sites include, abandoned gas works, service stations, metal works, tanneries, refineries, smelters, dry cleaning facilities, and closed landfills. Restored brownfield sites can be put to others uses such as grasslands, woodlands or sports fields.

Mine Tailings and Mine Reclamation

Mine tailings are waste rock materials that are left after the mining and extraction of mineral ore from the rocks. This waste rock material usually cannot support plant growth. Restored mine tailings can be used to grow energy crops or as sports fields.

2.5.5 Topsoil Manufacturing

Compost-like outputs can be blended with mineral aggregate materials like sand, clay, recycled aggregates, rock aggregates, iron and steel furnace slags to form a product similar to natural topsoil. The aggregate materials provide structure for the soil, and the compost-like outputs provide organic matter and plant nutrients soil that the soil that can support vegetation growth. Soils manufactured using compost-like output can be used in landscaping and land restoration projects.

2.5.6 Bioremediation

Compost-like outputs can be used as components of bioremediation mixes. According to Compost for Soils ,2011, ‘ Bioremediation using compost can be used to degrade or stabilise the following contaminants, Poly Aromatic Hydrocarbons, Total Phenols, Pentachlorophenol, Heavy Metals (Stabilisation), Total Petroleum Hydrocarbons, benzene, toluene, ethyl-benzene, xylene, and Trinitrotoluene.’

When these bioremediation mixes are tilled into and mixed with polluted soil, microorganism (bacteria) that are supported by organic matter and nutrients from the compost-like outputs break up organic pollutants and, the bacteria can also stabilise and reduce the mobility of inorganic pollutants.

2.5.7 Refuse Derived Fuel

Digestate from the anaerobic biological treatment of biodegradable waste can be processed into fuel pellets after non-combustible materials are removed. This type of fuel is called refuse derived fuel (RDF). It is used as a source of fuel in incinerators, cement kilns and in power plants. RDF can save natural energy resources and can also result in financial savings.

2.6 Hazards Associated With Compost-Like Outputs

Compost-like outputs can contain hazardous materials and substances. These hazardous substances originate from the mixed municipal solid waste that is used to produce the compost-like outputs. These hazardous materials and substances have the potential to damage or pollute the environment. They can also pose a risk to animal and human health. Hazardous material and substances of most concern found in compost-like outputs and their potential risks are presented below.

2.6.1 Physical Impurities

The main physical impurities found in compost-like outputs are plastics, glass, metals and stones. The physical impurities come from glass bottles, aluminium and steel cans, and plastics that are discarded in mixed municipal waste bins in homes. Their main impact on the environmental is visual impact. On lands that are used for grazing animals, there might be a risk of their ingestion by animals. Sharp materials can cause injuries to animals and humans.

2.6.2 Heavy Metals

Heavy metals are metallic chemical elements that have relatively high densities and are toxic at low concentrations. Heavy metals that are regarded to be most toxic to the environment and of concern are Lead (Pb), Mercury (Hg), Chromium (Cr), Cadmium (Cd), Copper (Cu), Nickel (Ni) and Zinc (Zn). Heavy metals find their way into compost- like outputs from chemicals, batteries and small electrical gadgets that are discarded in mixed waste bins in homes.

If compost-like outputs containing heavy metals are used on land (agricultural or non-agricultural), these heavy metals can cause soil, groundwater and surface water pollution. If absorbed by plants, heavy metals can interfere with and reduce plant growth. Some plant species can take up and store heavy metals in their tissues and fruits. Through plants and food crops, heavy metals can their find their way into the food chain.

In humans and in animals heavy metals can cause reduced growth and development. They can damage body organs and the nervous system, and they can also cause cancer. Humans and animals can become exposed to heavy metals through drinking contaminated water, eating contaminated food and being exposed to contaminated soils.

2.6.3 Toxic Organic Compounds

Toxic organic compounds can find their way into compost-like outputs through discarding the following substances in mixed municipal waste bins herbicides, pesticides, detergents containers, cleaning chemicals, grease, solvents and engine oils. Some of these toxic organic compounds are resistant to chemical, biological and natural environmental degradation. Examples of toxic and persistent organic compounds that can be found in compost-like outputs are poly-aromatic hydrocarbons (PAHs), polychlorinated byphenyls (PCBs), and pesticides (DDT, HCB, Aldrine and diedrin). Plants and vegetation grown on soils containing compost-like outputs can absorb these compounds in the tissues. If these plants find their way into the food chain these stored up toxic organic compounds can cause dieses or illness in animals and human health. Ways that these toxic organic compounds can find their way into the food chain is through the grazing of livestock on contaminated grass, growing vegetable and fruits on contaminated soils.

2.6.4 Pathogens

Pathogens are microorganisms (bacteria, protozoa, fungi, or viruses) that can cause an illness in another organism (plant or animal). Examples of harmful bacteria that can be found in compost-like outputs are Escherichia coli (*E.*coli), salmonella. Recently legionella longbeache was found in compost sample by scientists at the University of Strathclyde in the United Kingdom.

Pathogens can find their way into the food chain is through the grazing of livestock on contaminated grass, growing vegetable and fruits on contaminated soils.

2.7 Use of Compost-Like Outputs in Selected European Union Countries

This section discusses (i) regulatory regimes used to control the use of compost-like outputs (ii) quality standards for compost-like outputs, and (iii) legally permissible uses of compost-like outputs in France, Ireland, Italy, Spain and the United Kingdom.

Regulatory regimes here mean systems of regulations used to regulate the use of compost-like outputs. Quality standards provide specifications and guidelines for the use of compost-like outputs. The standards set maximum allowable concentration values, sometimes called limit values of harmful substances permissible in the compost-like outputs. Most standards place maximum allowable concentration values on physical impurities, heavy metal traces, organic compounds and on pathogens. Regulatory regimes and quality standards are used to ensure that compost-like outputs are used in a way that does not impact negatively impact on the environment.

2.7.1 France

Regulations and Quality Standards for Compost-Like Outputs

Compost-like outputs are regulated by the NF U44-051 Standard for urban compost. This is a statutory quality standard used for both compost-like outputs and compost derived from source separated material. If compost-like outputs meet this standard, they can be used in the same way as compost derived from source separated organics. Summary of the NF U44-051 Standard is presented in Table1.

Table1: NF U44-051 Standard Limit Values

Parameter	Units	Limit Value (dry matter)
Arsenic (As)	mg/kg	18
Cadmium(Cd)	mg/kg	3
Chromium (Cr_{tot})	mg/kg	120
Copper (Cu)	mg/kg	300
Mercury (Hg)	mg/kg	2
Nickel (Ni)	mg/kg	60
Lead (Pb)	mg/kg	180
Selenium (Se)	mg/kg	12
Zinc (Zn)	mg/kg	600
Fluoranthene	mg/kg	4
Benzo(b) fluoranthene	mg/kg	2.5
Benzo(b) pyrene	mg/kg	1.5
Helminth Ova	/1.5g	Absent in 1.5g
Salmonella	/25g	Absent in 25g
Plastics - Films >5mm	%w/w	< 0.3
Other Plastics >5mm	%w/w	< 0.8
Glasses & Metals >2mm	%w/w	< 2

(*Source: The Institute for Prospective Technological Studies (IPTS), Seville, Spain- August 2012 Technical Report)*

Use of Compost- Like Output in France

Compost-like outputs that meet the NFU44-051 Standard can be used as compost with no restrictions (Environmental Agency, 2009). According to this same source, most of the compost-like outputs that meet this standard are used on agriculture land as manure. Information on the amount of compost-like outputs used in agriculture and the locations where it is used in France could not be obtained.

2.7.2 Ireland

Regulations and Quality Standards for Compost-Like Outputs

Waste and compost-like outputs (*Stabilised Biowaste*) are regulated by the Environmental Protection Agency under the Waste Management Acts (1996-2003) and Environmental Protection Act (1992). Facilities composting biodegradable waste must have a Waste Licence issued by the Environmental Protection Agency under the Waste Management Acts, or a Waste Permit which is issued by a Local Authority. Composting standards for composts and stabilised biowaste are set in the EPA Waste Licences. Summary of the standard is presented in Table 2.Class A and Class B composts are derived from source segregated biodegradable waste.

Table 2: EPA Waste Licence Maximum Concentration Limits

Parameter	Units (dry mass)	Limit		
		Compost		Stabilised Biowaste
		Class A	Class B	
Cadmium(Cd)	mg/kg	0.7	1.5	5
Chromium (Cr)	mg/kg	100	150	600
Copper (Cu)	mg/kg	100	150	600
Mercury (Hg)	mg/kg	0.5	1	5
Nickel (Ni)	mg/kg	50	75	150
Lead (Pb)	mg/kg	100	150	500
Zinc (Zn)	mg/kg	200	400	1500
Polychlorinated Biphenyls (PCBs)	mg/kg	-	-	0.4
Polycyclic Aromatic Hydrocarbons (PAHs)	mg/kg	-	-	3
Salmonella sp.	/50g	Absent in 50 g sample		-
Faecal Coliforms	MPN/1g	<1000		-
Stability	mg/O_2/g	$AT_4 \leq 10$		$AT_4 \leq 10$
Impurities >2mm	%w/w	<0.5%	<0.5%	<3%
Gravel and Stones >5mm	%w/w	<0.5%	<0.5%	-

MPN = most probable number

The Department of Agriculture, Food and the Marine also regulates the biological treatment of biodegradable waste and the production of composts through Animal By-Products Regulations 2003 (S.I.No.248 of 2003).

Use of Compost-Like Outputs in Ireland

The Environmental Protection Agency only allows compost-like outputs to be disposed by landfills or by incineration. Compost-like outputs cannot be used for any other purposes under the existing waste regulations and legislation in Ireland. This was confirmed by the office of Environmental Protection Agency. Compost-like outputs produced at present are sent to landfill, either for disposal or used as landfill cover. [Nolan, C (c.nolan@epa.ie), 25 October 2013. *CLO Query*. (chikononh@hotmail.com)].

2.7.3 Italy

Regulations and Quality Standards for Compost-Like Outputs

In Italy compost-like outputs are regulated under the following regulations,

- Law on fertilisers (L 748/84) as modified by Decree 27 March 1998 → BWC/GC/SSC.
- Technical Regulation DCI 27/07/84 MSWC/MBTC.
- Draft Decree on the use of MBT (Compost) based on Article 18 of Decree 22/97

A summary of the maximum concentration limits for composts derived from the above mentioned regulations is presented in Table 3.

Table3: Law on Fertilisers Limits for Composts

Parameter	Units	Limit (dry matter)
Cadmium(Cd)	mg/kg	1.5
Chromium (Cr^{VI})	mg/kg	0.5
Copper (Cu)	mg/kg	230
Mercury (Hg)	mg/kg	1.5
Nickel (Ni)	mg/kg	100
Lead (Pb)	mg/kg	140
Zinc (Zn)	mg/kg	500
Plastics < 3.33 mm	%w/w	< 0.45 %.
Plastics > 3.33 < 10 mm	%w/w	0.05 %.
Other inert material > 3.33 mm	%w/w	< 0.9 %
Salmonella sp.	/25g	Absent in 25 g sample
Enterobacteriaceae	cfu/g	≤ 1.0 x 103
Fecal Streptococcus	MPN/g	≤ 1.0 x 103
Nematodes	/50g	Absent in 50 g sample
Trematodes	/50g	Absent in 50 g sample
Cestodes	/50g	Absent in 50 g sample

cfu = colony forming units

Use of Compost-Like Outputs in Italy

Compost-like outputs that meet the requirements of the Law on Fertilisers are permitted to be used on agricultural land (Environmental Agency, 2009). In some areas of Italy farmers are encouraged to use compost-like outputs. At the regional level financial incentives are given to farmers to use mixed-waste derived compost on land (SLR, 2005). Compost-like outputs are also used for brownfield sites reclamation and for daily landfill cover.

2.7.4 Spain

Regulations and Quality Standards for Compost-Like Outputs

In Spain composts and compost-like outputs are regulated by the Real decree 824/2005 on fertilisers. A summary of the Real Decree 824/2005 limit values is presented in Table 4

Table 4: Real decree 824/2500 on Fertilisers

Parameter	Units	Limit (dry matter)		
		Compost		
		Class A	Class B	Class C
Cadmium(Cd)	mg/kg	0.7	2	3
Chromium (Cr)total	mg/kg	70	250	300
Chromium (Cr^{VI})	mg/kg	0	0	0
Copper (Cu)	mg/kg	70	300	400
Mercury (Hg)	mg/kg	0.4	1.5	2.5
Nickel (Ni)	mg/kg	25	90	100
Lead (Pb)	mg/kg	45	150	200
Zinc (Zn)	mg/kg	200	500	1000
Total impurities > 2mm (glass ,metals, plastics)	%w/w	< 3		
E.coli	MPN	<1000		
Salmonella spp.	cfu/g	Absent in 25 g sample		

Use of Compost-Like Outputs in Spain

Compost-like outputs are permitted to be used on agricultural land. They are used in sparsely populated regions, such as Estamadura, where the benefits of applying organic matter to agricultural land, to prevent desertification, have had widespread political support. Soils in this region have low organic content. Desertification is a key driver for the use of compost-like outputs in these areas, and the government has adopted a national Action Plan under the UN Convention to Combat Desertification (Environmental Agency, 2009). The use of compost-like outputs to improve soils and combat desertification is also helping to solve the problem of municipal solid waste (MSW) management that some areas in region mentioned above are facing.

2.7.5 United Kingdom

Regulations and Quality Standards for Compost-Like Outputs

The use of compost-like outputs is regulated and controlled by the Environmental Agency under the Environmental Permitting Regulations. It is also regulated under the Animal By-Product Regulations. These regulations apply to the whole of the United Kingdom (England, Northern Ireland, Scotland and Wales).

The quality standard used for controlling the use of compost-like outputs is the *End –Use Standard for Separated Organic Materials (SOM) in Land Restoration/Reclamation*. The standard is presented in Table 5.

Table 5: End-Use Standard for the use of SOMs in Land Restoration/Reclamation

Parameter	Units	Limit
Total Zinc	mg/kg dm	<2500
Total Copper	mg/kg dm	<1000
Total Cadmium	mg/kg dm	<20
Total Nickel	mg/kg dm	<300
Total Lead	mg/kg dm	<750
Total Chromium	mg/kg dm	<1000
Total Mercury	mg/kg dm	<16
Organic Matter	% dm	>15
E.coli	cfu/g	<1000
Salmonella spp	/25g	Absent
Stability	$mgCO_2/g$	<16
Total plastic >2mm	%w/w	<2.5
Total other physical contaminants	%w/w	<2.5

Use of Compost-Like Outputs in the United Kingdom

Compost-like outputs that meet the *End-Use Standard for the use of SOMs in Land Restoration/Reclamation are* permitted to be used for land reclamation/restoration subject to the following conditions:

- The compost-like outputs must satisfy the requirements of Animal By-Products
- The restored land must not be used for grazing livestock or for growing crops that could enter the food chain.
- Final soil heavy metal concentration must not exceed the maximum soil concentration stipulated in the 'Sludge (Use in Agriculture) Regulations '1989.

2.8 Conclusions of Literature Review

Compost-outputs are a resource. The use of compost-like outputs on land can cause a risk to the environment through the pollution of soil, groundwaters and surface waters. The use of compost-like outputs on agricultural land used for the growing of food-crops can pose a risk to animal and human health.

The literature review revealed that there is very little published research information on the use of compost- like outputs in Ireland. This presented a chance for the author to carry out this research study on the biological treatment of municipal waste and the resultant compost- like in Ireland.

3. OBJECTIVES OF THE STUDY

3.1 Objectives of the Study

The general objective of the study is to gain an understanding of how waste from mixed municipal solid waste is treated and sanitised to produce compost-like outputs, and to understand how compost-like outputs can be used as a resource on land without impacting negatively on the environment and on human health.

The specific objectives of the research study are:

(i) To investigate why compost-like outputs are permitted to be used on agricultural land and in land restoration in some European Union Member States while it is prohibited in Ireland.

(ii) To investigate the technologies and processes used to treat biodegradable waste from mixed municipal solid waste in Ireland.

(iii) To examine potential uses of compost-like outputs that can help to divert them from landfills in Ireland as part of eliminating the landfilling of municipal wastes.

(iv) To gather the views of producers on the current situation on compost-like outputs in Ireland

3.2 Relevant Stakeholders

Some of the relevant stakeholders in Ireland who would be interested in the study topic on use of compost-like outputs on land are:

- The Department of the Environment, Community and Local Government
- The Environmental Protection Agency
- The Department of Agriculture, Food and the Marine
- Mechanical Biological Treatment facility owners
- Waste Collection Businesses
- Farmers

- Landscaping businesses
- Food Retailers
- The Composting Association of Ireland.
- Insurance Companies involved with food retailers and farmers.
- The general public who are food consumers.

4. METHODOLOGY

4.1 Introduction

The purpose of this chapter is to describe the methods used to collect new information and data for this research study.

4.2 Research Questions

The main research questions that emerged of the literature review were:

i. What biological treatment technologies and systems are used to treat organic residuals from mixed municipal solid waste in Ireland?

ii. What is the quality of compost-like outputs produced in Ireland like?

iii. What is the quantity and trend of compost-like outputs being produced in Ireland?

iv. What can compost-like outputs be used for in Ireland?

v. What are the views and opinions of biological treatment facility owners on the current situation with regards to compost-like outputs in Ireland?

vi. What needs to done in order to allow compost-like outputs to be used on land in Ireland?

A list showing more questions that emerged from the literature review are in Appendix A.1 of this report.

4.3 Principal Research Strategy

The principal research methodology that was used for this dissertation was the Case Study Methodology. A case study is defined as 'a comprehensive description and analysis of a single situation or case (Cavana et al, 2000).'The author selected the Case Study Methodology because by closely studying and analysing one individual biological treatment plant and one country, it is easier to understand the principles of how the treatment processes work.

4.4 Identifying and Selecting the Cases for the Research Study

The author decided to study individual facilities in Ireland treating biodegradable waste from mixed

municipal solid waste (MSW) as case studies to investigate how waste is biologically treated.

The author also decided to study Ireland as a country as a case study. The study also examines the quantity and quality of compost-like outputs produced in the whole of Ireland.

4.5 Identifying and Selecting Case Studies

The author contacted the Composting Association of Ireland (Cre), requesting for the names and addresses of all composting facilities treating biodegradable waste from mixed municipal solid waste in Ireland [Chikono, N. (nathan.chikono@mail.itsligo.ie), 5 February 2014. *Information on mixed municipal solid waste (MSW) compost in Ireland.* (percy@cre.ie).]The author was directed to the Composting Association of Ireland by the Environmental Protection Agency for names of facilities treating residual MBT biodegradable waste. [Nolan, C (c.nolan@epa.ie), 05 March 2014. *CLO Query - Biological Treatment Plants treating MSW in Ireland*. (nathan.chikono@mail. Itsligo.ie)].The names of the facilities treating residual biodegradable waste from mixed municipal solid waste in Ireland are presented in Table 6.

Table 6: Facilities Treating Biodegradable Waste from mixed MSW in Ireland.

Name of Facility	Facility Address	County
Enrich Environmental Ltd	Larkhill , Kilcock	Meath
McGill Environmental Systems Ltd	Coom, Glenville	Cork
Miltown Composting Systems Ltd	Miltown, Fethard	Tipperary
O'Toole Composting Ltd.	Ballintrane, Fenagh	Carlow

The author requested for assistance from the Composting Association of Ireland to contact these fours facilities introducing the author and requesting for permission to carry the research studies at the facilities. The author also contacted the facilities requesting for permission to carry out the research studies. There was only one response, from Milltown Composting Systems. There was no response from the other three facilities. Miltown Composting Systems Limited was then used as Case Study. The author's aim was to study more than one case study.

4.6 Data Collection Methods

The methods that were used to collect new information and data were:

(i) Semi-Structure Interview

(ii) Field Observation

(iii) Database Search

These methods are briefly described below.

Semi-structured Interview and observation

Information at Miltown Composting Systems Limited facility was collected using the semi-structured interview method Interviewing is a data collecting method in which the researcher asks for information verbally

from the respondents. A direct, face to face interview with the respondent was used for this research. The type of interview used was the semi-structured interview. In semi- structured interviews the researcher makes a list of predetermined questions, he can then ask extra questions during the interview. The author prepared list of questions prior to the interview to act as a guide to the interview. The interview guide that was prepared by the author is presented in Appendix A. 2 of this report. The direct, face to face semi- structured interview method was selected as the main data collection method because:

- The method allows an easy conservation to be carried out between the interviewer (researcher) and the interviewee (respondent).
- The researcher can adjust the pre-planned questions during the interview depending on the situation and what new information he is getting. The researcher can add extra questions as necessary.
- The researcher will be present and can clarify questions and issues to ensure that they are clearly understood where there are doubts or confusion. The interviewee (respondents) can also ask the researcher questions for clarification.
- Interviewees can give more information that the researcher might have left out on his/her questions.
- In face to face interviews, confidential or sensitive information can be discussed.

Field Observation

The observation involved a tour of the composting facility by the author. During the tour the author observed materials and work activities. Some photographs were taken during the tour of the facility. Taking photographs is quick method of accurately collecting and recording research information. Photographs also help to increase the credibility of the research.

Database Search

National information and data on Ireland on compost-like outputs was obtained through searching databases. Information was obtained from the Environmental Protection Agency databases. The EPA database was used because the EPA is responsible for compiling national waste records in Ireland. The Environmental Protection Agency is a government agency, so their database was deemed to be accurate and credible by the author.

Addressing the Issues of Reliability and Validity in the Research

To address the issue of reliability and validity of the information from Miltown Composting Systems Limited, the author used two data collection methods, the semi-structured interview method and the field observation method. The field observation method allowed the author to verify and cross-check information and data supplied during interview. Employing two or more data collection methods to verify information is called triangulation. Triangulation helps to increase the credibility and validity of the results.

5. RESULTS

5.1 Introduction

The purpose of this chapter is to present the findings of the research. On the 16th of April 2014, the author visited Miltown Composting Systems Limited facility to collect research information. A semi-structured interview was held with the facility manager, Mr Derry Murphy. A script of the questions that were asked during the semi-structured interview with Mr Derry Murphy is presented in Appendix A.3 of this report. The research findings presented in this section are based on the semi-structure interview that the author held with Mr Derry Murphy and observations made by the author during the tour visit of the composting facility on 16 April 2014

Miltown Composting Systems Limited facility is located at Miltownmore, Fethard, County Tipperary. It is located approximately 10.6 km south east of Cashel Town. The facility is situated approximately 4.7 km to the south east of Rosegreen and about 5.5km to the south west of Fethard. Maps showing the location of the facility are presented in Appendix B of this report. The facility accepts organic residual fines separated mechanically from mixed municipal solid waste for composting.

5.2 Biological Treatment of Biodegradable waste from mixed MSW

5.2.1 Biological Treatment Technology

The plant uses the *Aerobic Biological Treatment* process. The treatment technology used at the facility is the *In-Vessel Composting System*. All materials being treated and all composting activities are confined within a building. The composting building at the facility is divided into four areas. Each area is dedicated for a different phase of the biological treatment process.

By carrying out the biological treatment in a building, the treatment process and composting conditions can be easily controlled and managed. Optimum conditions are required for the aerobic microorganisms for them to decompose the waste within the required time period. Conducting the composting within a building is also a way of protecting the environment from the polluting effects of the composting process. The treatment process produces leachates, dust, odours and gases that have to be controlled.

The composting system used at the facility is the *Aerated Static Pile* system. During the biological treatment, the biodegradable waste is placed in bays that are constructed inside the composting building. The bays have perforated aeration pipes embedded in their floors. The biodegradable waste is placed on top of these perforated pipes. The advantage of the *Aerated Static Pile* composting system over other *In-Vessel Composting Systems* is that it is a low cost technology system. It is easy to operate and maintain, and can treat large volumes of material at one given time.

5.2.2 Material Handling

During the biological treatment process, the material is handled and moved by front-end loading shovels and a dumper truck. The facility uses the *Batch Composting System*. Waste delivered to the facility is stockpiled in the composting building until there is enough waste for a *Batch*. A *Batch* is made up of 120 tonnes of waste. Once the treatment of a *Batch* starts, there is no addition of new material at any stage of the treatment process.

In the *Batch* system there is no continuous flow of material. The material is moved using the mechanical loading shovels and dumper trucks from one stage of treatment to the next, in a one-way one direction system. The one-way one- direction system is to ensure that there is no cross-contamination.

5.2.3 Regulation of the Biological Treatment Activities

The activities at the facility are regulated by the Environmental Protection Agency through an EPA waste licence, Waste Licence number W0270-01. This Waste Licence gives directions and conditions for (i) waste acceptance, (ii) infrastructure for the composting of waste, (iii) material handling, (iv) standards for compost quality, (v) storage and movement of finished products (vi) disposal of waste from the facility and (vii) record keeping.

The material is composted following standards given in Schedule E of Waste Licence W0270-01: *Standards for Compost Quality*, and Irish Animal By-Products national standards.

5.3 The Biological Treatment Process

The facility accepts residual organic fines from mixed municipal solid waste for biological treatment. The waste comes from different Waste Transfer Stations from different counties in Ireland. Waste is delivered to the facility by licenced waste transporters. This material falls under Chapter 19 12 of the European Waste Catalogue; *Wastes from the mechanical treatment of waste. (For example sorting, crushing, compacting, peletising) not otherwise specified.*

Upon arrival, waste trucks are weighed on an electronic weighbridge. The material is received under the European Waste Catalogue EWC 19 12 12, *Other Wastes (including mixtures of materials) from mechanical treatment of wastes other those mentioned in 19 12 11.* After the weigh in the trucks are directed into the composting building to offload the waste. The trucks are then weighed again when empty. The following information is recorded for each load of waste delivered to the facility, (i) vehicle registration (ii) facility of origin (ii) net weight in tonnes (iv) date of delivery. An electronic record is entered into the computer system and paper record is also generated.

5.3.1 Pre-Processing

Material arriving at the facility is already shredded and screened to a size of 40mm to 50mm.

Incoming waste is offloaded in the Waste Reception Area inside the composting building. The material is stockpiled until there is enough feedstock material (120 tonnes) to make a composting batch. Shredded woodchip and material screened from mature compost- like outputs may be added to the feedstock material to enhance the composting process. Material screened from mature compost-like outputs helps to introduce composting microorganisms (bacteria and fungi) into the new feedstock material

5.3.2 Biological Treatment Stage 1

When there is enough material to make a batch (120 tonnes), the material is thoroughly mixed together. All the material for the batch is then loaded into a single composting bay in Area 1 of the composting building. The batch is given a unique identification batch number. The batch number and the date on which the batch was placed in the composting bay are recorded. A composting record is opened and maintained for the batch.

The biological treatment process works by micro-organisms feeding on the sugars, starches and proteins in the biodegradable waste. This leads to the breakdown and decomposition of the material. This decomposition results in the generation of heat and the release of water and gases. Temperature in the waste must rise to about 60°C to show that the micro-organisms are active and that the decomposition is taking place. The temperature in composting material has to be maintained at around 60°C. This first stage of the biological treatment process takes between 2 to 4 weeks.

Important parameter and conditions that are closely monitored and controlled during the biological treatment of the waste are *Temperature, Oxygen* levels and *Moisture* levels.

If the compost is allowed to become too hot, high temperatures will kill the composting micro-organisms (bacteria and fungi). This will slow down the biological treatment process. Temperature is measured and monitored by temperature probes that are inserted into the waste pile.

Oxygen is important to keep the aerobic microorganisms alive and active. Oxygen levels are measured daily using portable meters. Oxygen is supplied through the aeration processs via the perforated pipes.

Moisture content levels of 40 % to 60% are required. If the waste becomes too dry, the microorganisms will not be able to break it down, and some composting bacteria may die due to dryness. Too much moisture will result in the excess water filling up air pockets in the waste. This will create anaerobic conditions in the waste which will kill the aerobic bacteria. Moisture levels are measured daily.

5.3.3 Biological Treatment Stage 2 – Pasteurisation

After the first stage of treatment, all the batch material is removed from the bay in Area 1 and is transferred to another composting bay in Area 2 of the composting building. The second phase of composting is called pasteurisation at the facility. Pasteurisation is carried out to comply with Animal By-Products Regulations. This is required to sanitise the material. The material is subject to Animal By-Products Regulations because organic waste from households may contain animal by-products. Animal By-Products Regulations require the material to be treated in a closed composting reactor for a specified period at a specified temperature level. Other composting systems that can achieve the same results as a closed composting reactor are permitted to be used by the Department of Agriculture, Food and the Marine.

During pasteurisation, the material is thoroughly mixed. The whole batch material is then completely covered (wrapped) using a sheeting material. Temperature measuring probes are placed into the material. This covering simulates a closed composting reactor. Temperature is allowed to rise to 60°C inside the reactor. It is maintained at 60°C for a period of 48 hours. After 48 hours the covering material is removed, and the material is thoroughly mixed again. The material is covered again and the temperature is again allowed to rise to 60°C. It is maintained at 60°C for another 48 hours again. High temperatures of 60 degrees kill pathogens, parasites and weed seeds.

After the pasteurisation, the material is left in the bay until temperatures start to drop below 50°C. The material is then transferred to Area 3 of the composting building for the third phase of the treatment process. The second phase of treatment takes about 10 to 14 days. At this stage the material is starting to look like humus material.

5.3.4 Biological Treatment Stage 3 – Curing

Curing is carried out to ensure that all the biodegradable material in the waste is completely used. This is to ensure that the material will not become biologically active again after the treatment is completed.

During curing, material coming from the second phase of the treatment is placed in windrows in Area 3.The biological treatment process continues until the material is stable. Temperature, oxygen levels and moisture content continue to be monitored. The windrows are periodically turned to aerate the compost. When temperature levels start to drop to below 20°C, it is an indication that there is little decomposition activity taking place. It indicates that there is now little biodegradable material left for the bacteria to feed on. When the material is cured and stabilised, temperature must not rise after the windrows are turned. The stabilisation phase takes 3 to 4 weeks.

To confirm that the material is stabilised, samples of the material are taken and are sent to a laboratory for maturity tests. Maturity at the facility is assessed using the AT4 (Respiration Activity) Test. To be considered to be stable the AT4 value must be less than or equal to 10mg O_2/g dry matter. The stabilised mature material is what is called *Compost-Like Outputs (CLO*). It is given this name to distinguish it from compost derived from source separated biodegradable waste. In Ireland, stabilised compost-like outputs are called *Stabilised Biowaste.*

5.3.5 Stage 4 Treatment - Post- Processing

The fourth and final phase of the treatment is involves screening the material to remove over-sized particles. The material is screened using a trommel screen consisting of two mesh sizes. The first half of the screen is of mesh size 12 mm and last half is 15 mm. Oversize materials ejected at the far side of the screen. The screened product looks like humus- soil like material. The screened material is stored in two different areas inside the building before it is removed from the facility for disposal to landfills.

5.4 Quantity and Quality of Compost-Like Outputs

5.4.1 Quantity of Compost-Like Outputs Produced

In 2013, the facility accepted 8 260, 9 tonnes of biodegradable organic fines from mixed municipal waste for composting. The quantity of compost-like outputs produced from this quantity of incoming biodegradable waste could not be obtained. The author could only obtain the estimated volume reduction achieved at the facility. The estimated volume reduction of the treated waste at the facility is 40%. It was not possible to use this to estimate the quantity of compost-like outputs produced in 2013.

All compost-like outputs produced at the facility are disposed of by landfill. The 12 mm sized compost-like outputs are used as daily landfill cover at landfills. The 15 mm compost- like outputs is tipped in landfills as void fill material. Information on the cost of treating a tonne of organic fines and the cost of disposing a tonne of waste could not be obtained. It was said to be confidential commercial information.

5.4.2 Quality of Compost-Like Outputs

Prior to the interview, the author made arrangements with the Facility Manager to have an analysis of stabilised compost-like outputs from the facility .A sample of stabilised compost-like outputs was taken and was sent to NRM Laboratories, Berkshire, United Kingdom. The sample was received by the laboratory on 9 April 2014. The laboratory has UKAS accreditation. It is accredited to ISO/IEC 17025.

A sample of compost-like outputs from the facility was also sent to IAS Laboratories, Bagenalstown, Carlow, Ireland for a stability test. The sample was received on 26 March 2014.

Levels of plant nutrients, heavy metal trace elements, organic compounds and physical impurities from the sample that was analysed and stability results are summarised and presented in Table 7. A full report of the analytical results of the sample is presented in Appendix C.1 of this report.

Table7: Levels of Elements in the Miltown Composting System Sample

Parameter	**Units**	**Value** **(dry matter)**
Plant Nutrients		
Total Nitrogen	mg/kg	22696
Total Phosphorus	mg/kg	4649
Total Potassium	mg/kg	8439
Total Copper	mg/kg	414
Total Carbon	mg/kg	232400
Organic Matter	(% w/w)	43.2%
Heavy Metal Traces		
Total Arsenic (As)	mg/kg	5.16
Total Cadmium (Cd)	mg/kg	3.16
Total Chromium (Cr)	mg/kg	30.5
Total Copper (Cu)	mg/kg	414
Total Lead (Pb)	mg/kg	340
Total Mercury (Hg)	mg/kg	0.50
Total Nickel (Ni)	mg/kg	42.9
Total Zinc (Zn)	mg/kg	938
Organic Compounds		
Polychlorinated Biphenyls (PCB's)	mg/kg	Not detected
Polycyclic Aromatic Hydrocarbons (PAH's)	mg/kg	Not detected
Physical Impurities		
Total Plastics > 2mm	w/w %	0.02
Total Glass > 2mm	w/w %	0.08
Total Metals > 2mm	w/w %	< 0.01
Stones > 2mm	w/w %	< 0.01
Stability		
AT4 over 4 days	mg O_2/g	6.3

5.5 National Quantity and Quality of Compost-Like Outputs

5.5.1 Quantity of Compost-Like Outputs Produced in Ireland

The quantity of compost-like outputs landfilled in Ireland was reported for the first time by EPA in 2010. The quantities of compost –like outputs landfilled in Ireland and reported by the EPA to date are presented in Table 8.

Table 8: Quantities of Compost-Like Outputs Produced in Ireland

Year	Stabilised Biowaste Confined to Landfill (Tonnes)
Second Half of 2010	486
2011	19080

5.5.2 Quality of Compost-Like Outputs Produced in Ireland

Information on the quality of compost-like outputs produced in Ireland was obtained from the EPA report, *STRIVE Report Series No.22, Development of an Industry- Led Quality Standard for Source- Separated Biodegradable Material Derived Compost, 2007-2013*. These results were obtained from the Irish EPA database. A table extracted from the above mentioned report showing the number samples, maximum values, median values, standard deviation, 75th percentile and 90th percentile of the National results is presented in Appendix C.2 of this report.

The National mean values for heavy metal traces, and levels of pathogens and physical impurities are summarised and presented in Table 9

Table 9: Compost-Like Analytical Results - Irish National Results

Parameter	**Units**	**Value** **(dry matter)**
Heavy Metal Traces – Mean Values		
Cadmium (Cd)	mg/kg	1.81
Chromium (Cr)	mg/kg	43.38
Copper (Cu)	mg/kg	246.80
Lead (Pb)	mg/kg	315.35
Mercury (Hg)	mg/kg	0.67
Nickel (Ni)	mg/kg	43.94
Zinc (Zn)	mg/kg	549.31
Arsenic (As)	mg/kg	6.80
Selenium (Se)	mg/kg	0.70
Pathogens		
Escherichia Coli	cfu/g	870
Salmonella	/25g	0
Physical Impurities		
Glass	w/w %	2.72
Metal	w/w %	0
Plastic	w/w %	0.8
Total	w/w %	**3.52**

5.5.3 Brownfield Sites

There is no national database on brownfield sites in Ireland. Brownfield sites are privately owned properties. Information on brownfields can be obtained from local authorities. It was not possible to contact local authorities to get information because of time constraints. The hand in deadline time for this dissertation did not allow enough time for the author to complete the research on brownfield sites in Ireland. This can be done as a separate research study a later stage

6. DISCUSSION

6.1 Introduction

This chapter discusses the findings of the research. It gives a brief analysis of the analytical results. Limitations of the data collection methods used for this research are also briefly discussed.

6.2. Miltown Composting Systems Limited Results

6.2.1 Biological Treatment of Biodegradable Waste

The biological treatment process followed at Miltown Composting Systems Limited is in compliance with the EPA Waste Licence conditions, and also in compliance with Irish and EU Animal By-Products Regulations. The stability test results of 6.3 mg O_2/g d.m indicates that the biological treatment at the facility meets the requirements of the EPA licence of stabilising the waste. By stabilising biodegradable waste, the facility is achieving the main objective of protecting the environment from greenhouses from biodegradable waste.

6.2.2 Analysis of Analytical Results – Miltown Composting Systems Ltd.

Plant Nutrient Analysis

The analysis of a compost-like outputs sample from shows that compost-like outputs are a source of organic matter and major plant nutrients (Nitrogen, Phosphorus, Potassium and Carbon). They can be used as a substitute for chemical fertilisers.

It was suggested by the Miltown Facility Manager, Mr Derry Murphy that compost-like outputs could be diverted from landfills and be used as organic fertilisers on plantations growing non-food crops for the bioenergy market in Ireland. This will help to reduce total disposal costs by reducing transport costs. Non-food biomass crops mentioned were willow and Elephant Grass (miscanthus). Nitrates and Phosphorus Regulations can be used to protect the environment and control the effects of nutrients from compost-like outputs.

Heavy Metals Trace Analysis

The levels of heavy metal traces the from sample from Miltown Composting Ltd were compared to the EPA Standard for Compost and for Stabilised Biowaste, and to the UK standard for the end use of separated organic material outputs from mixed resources (SOMs) for land restoration. The comparison in presented in Table 10. The UK standard was chosen for comparison because, of all the EU countries studied during the literature review of this research study, the United Kingdom is the closest to Ireland. Their annual rainfall totals and patterns, and soil types are closely related when compared to those of continental southern European countries.

Table 10: Comparison of Heavy Metal levels with EPA and UK Standards

Parameter (mg/kg) In dry matter	**Miltown Composting System Ltd Results**	**EPA Compost Quality Standard**		**EPA Stabilised Biowaste Standard**	**UK Standard for End Use of CLO**
		Class 1	**Class 2**		
Cadmium	5.16	**0.7**	**1.5**	**5**	**20**
Chromium	3.16	**100**	**150**	**600**	**1000**
Copper	414	**100**	**150**	**600**	**1000**
Mercury	0.50	**0.5**	**1**	**5**	**16**
Nickel	42.9	**50**	**75**	**150**	**300**
Lead	340	**100**	**150**	**500**	**750**
Zinc	938	**200**	**200**	**1500**	**2500**

This batch of compost-like outputs would not meet standards for Class1 and Class 2 composts in Ireland. This is because Cadmium, Copper, Lead and Zinc levels exceeded the limits for Class1 and Class 2 Composts.

This batch of compost-like outputs met and satisfied the requirements of EPA standard for *Stabilised Biowaste*. Although the value of Cadmium for the sample is 5.16, the EPA licence for the facility states that 'No sample should exceed 1.2 times the limit value set'. The limit for Cadmium is 5 mg/kg. The sample value for Cadmium did not exceed (1.2 x5) i.e. 6.0 mg/kg. Heavy metal trace values for the sample all below the limit values for the UK Standard for the

End use of separated organic material outputs from mixed resources (SOMs) for land restoration/reclamation.

Heavy metals levels in compost-like outputs are determined by the source of the material. There are no technologies in Ireland that can reduce the level of heavy metals during the biological treatment process. One way of reducing heavy metals in compost-like outputs that was suggested was by educating waste producers and homeowners. They can be educated on what chemical materials not to dispose of in the mixed waste bin.

Existing regulations can be used to protect the environment (soils, groundwater and surface waters) and animal and human health from the harmful effects of heavy metals. Regulations that can be used in Ireland are (i) S.I No.148/1998 – Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998, and (ii) S.I No.267/2001 – Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 2001. These regulations require the maximum concentrations of heavy metals in soils to be measured first before application of the compost-like outputs can be used.

Physical Impurities

The values of physical impurities from the sample from Miltown Composting Ltd were compared to the EPA Standard for Stabilised Biowaste and to the UK standard for End-Use of SOMs for land restoration/reclamation. The comparison is presented in Table 11.

Table 11: Comparison of Physical Impurity levels with EPA and UK Standards

<table>
<tr><th>Determinand</th><th>Miltown Composting System Results % w/w</th><th>EPA Stabilised Biowaste Standard</th><th>UK Standard for End Use of SOMs</th></tr>
<tr><td>Plastics > 2mm</td><td>0.02</td><td rowspan="4">< 3%</td><td>< 2.5%</td></tr>
<tr><td>Glass > 2mm</td><td>0.08</td><td rowspan="3">< 2.5%</td></tr>
<tr><td>Metals > 2mm</td><td>< 0.01</td></tr>
<tr><td>Total</td><td>0.10</td></tr>
</table>

The values for physical impurities for the sample are below the limit values of EPA and UK standards. In terms of physical impurities, the facility is capable of producing compost-like outputs that will meet the UK standard for CLO for land restoration. Technology can be used to improve the quality of compost-like outputs, in terms of physical impurities. Screen sizes can be made smaller in order to reduce the amount of large size impurities.

6.3 National Results

6.3.1 Quantities of Compost-Like Outputs

Compost-like outputs do not cease to be waste in Ireland, as there is no End of Waste Criteria for compost-like outputs in Ireland. Under existing regulations they will be always regarded as waste and they cannot be used as a resource.

The amount of compost-like outputs landfilled in 2011 was 19 080 tonnes. This indicates that the level of treatment of biodegradable waste from mixed municipal waste is still very low. There was an increase in the amount compost-like outputs landfilled in from an estimated 972 tonnes in 2010 (482 x 2) to 19 080 in 2011.It is difficult to predict if the amount of compost-like outputs being produced in Ireland will continue to increase over the coming years. This is because there is a national drive to encourage the separation of biodegradable municipal waste at source. Source separation of biodegradable might lead to a decrease in the amount biodegradable waste in mixed municipal solid waste.

The amount of biodegradable fines residues separated from mixed municipal waste and disposed to landfills untreated is also reported by the EPA for 2010 and 2011. The amount of untreated organic fines residues disposed to the landfill in the second half 2010 was 41 631 tonnes. The amount reported for the whole of 2011 was 20 824 tonnes. This decrease may be attributable to an increase in the separation of biodegradable municipal waste at source.

6.3.2 Analysis of National Analytical Results

Heavy Metals Trace

The mean values of levels of heavy metal traces from samples from the Irish Database were compared to the EPA and the UK standards. The comparisons are presented in Table 12.

Table 12: Comparison of National Heavy Metal levels with EPA and UK Standards

Parameter (mg/kg) dry matter	Irish National Results	EPA Stabilised Biowaste Standard	UK Standard for End Use of CLO
Cadmium	1.81	**5**	**20**
Chromium	43.38	**600**	**1000**
Copper	246.80	**600**	**1000**
Mercury	0.67	**5**	**16**
Nickel	43.94	**150**	**300**
Lead	315.35	**500**	**750**
Zinc	549.31	**1500**	**2500**

National mean values for heavy metal trace levels are below both the limit values for EPA and the UK standards. This implies that on average, compost-like outputs produced in Ireland meet the EPA requirements for heavy metal traces for Stabilised Biowaste, and on average compost-like outputs produced in Ireland meet the requirements of the UK Standard for End-Use of compost-like outputs for land restoration/reclamation.

Physical Impurities

The levels of physical impurities from the Irish National Database were compared to the EPA and the UK standard. The comparisons are presented in Table 13. The results show that at national level, glass is the main constituent making up physical impurities in compost-like outputs in Ireland. Educating waste producers and home owners on the importance of recycling glass bottles can contribute towards reducing glass contamination in compost-like outputs.

Table 13: Comparison of National Physical Impurity levels with EPA and UK Standards

<table>
<tr><th>Determinand</th><th>Irish National Results % w/w</th><th>EPA Stabilised Biowaste Standard</th><th>UK Standard for End Use of CLO</th></tr>
<tr><td>Total Plastics > 2mm</td><td>0.8</td><td rowspan="3">< 3%</td><td>< 2.5%</td></tr>
<tr><td>Total Glass > 2mm</td><td>2.72</td><td rowspan="2">< 2.5%</td></tr>
<tr><td>Total Metals > 2mm</td><td>0</td></tr>
</table>

6.4 Limitations and Problems with Data Collection Methods used

6.4.1 Case Study Methodology

The main problem encountered with the case study methodology was getting the cases to study. Only one out of four facilities was able to offer the author permission to carry out the study. The author was not able to study the different technologies and systems used to treat MSW biodegradable waste in Ireland.

6.4.2 Semi-structured Interviews

The main problems that the author encountered with this kind of data collection method were,

(i) Interviewees may not have answers to some of the questions due to lack of records.

(ii) Researcher can prepare questions which the interviewee might not be able to answer.

(iii) It can be difficult to get appointments for interviews because facilities might be busy.

(iv) This method can involve travelling long distances for the interviews. This can be time consuming if there are a lot of cases to be studied.

7. CONCLUSIONS

7.1 Introduction

This section presents conclusions of the study. The conclusions are discussed under the objectives of the study. The specific objectives of the research study were:

(i) To investigate why compost-like outputs are permitted to be used on agricultural land and in land restoration in some European Union Member States while it is prohibited in Ireland.

(ii) To investigate the technologies and processes used to treat biodegradable waste from mixed municipal solid waste in Ireland.

(iii) To examine potential uses of compost-like outputs that can help to divert them from landfills in Ireland as part of eliminating the landfilling of municipal wastes.

(iv) To gather the views of producers on the current situation on compost-like outputs in Ireland

7.2 Conclusions

Why use of compost-like outputs on agricultural and non-agricultural is prohibited in Ireland.

Waste management regulations forbid the use of compost-like outputs on agricultural on non-agricultural land in Ireland. The regulatory regimes are the main reason for the non-use of compost-like outputs for other purposes. The second reason is that there are no end- of-waste criteria for biodegradable waste from mixed municipal solid waste in Ireland. An end –of- waste Determines or specifies when certain waste ceases to be waste and gains the status of a product or a raw material.

If the landfilling of municipal wastes is to be eliminated, as stated in the government policy document 'A Resource Opportunity', there is need by the waste regulatory authorities in Ireland to develop end-of-waste criteria and quality standards for compost-like outputs.
Regulations that regard compost-like outputs as waste also need to be changed so they can be fully exploited as a resource as mentioned in the government policy document 'A Resource Opportunity'

Biological Treatment of Biodegradable waste from mixed municipal solid waste in Ireland.

Biodegradable waste from mixed municipal solid waste is treated using modern MBT engineering technology in Ireland. The technology mainly used is the *In-Vessel Aerobic Process Composting System*.

The facility that was studied as a case study meets the requirement of Environmental Protection Agency Waste Licence Standard for the biological treatment of stabilised biowaste. The facility meets the requirements of Irish and EU Animal By-Products Regulations. Biodegradable waste from mixed municipal solid waste is treated using modern Biological Treatment technologies in Ireland.

Potential uses that can help to divert compost-like outputs from landfills in Ireland.

At present all compost-like outputs produced in Ireland are being disposed by landfill**.** Potential uses of compost-like outputs in Ireland are

- restoration of brownfield sites
- land spreading as organic fertilisers on plantations growing bioenergy biomass crops.

Analytical results of compost-like outputs from Ireland indicate that the quality of compost-like outputs produced in Ireland would meet the United Kingdom Standard for End –Use of compost-like outputs for land restoration/reclamation. Compost-like outputs from Milltown Composting System Limited could be used for small scale trials on plantations growing willow in County Tipperary or for trials for the restoration of brownfield sites in the local area.

The UK standard could be adopted for trials. Also where compost-like outputs are to be used for land restorations, site risk assessments may be requested by the regulatory authority in order to protect the environment. In Ireland, there is already Groundwater Protection Schemes for on-site wastewater treatment systems, landfills and for land spreading. These schemes can also be adopted in the risk assessment process.

Views of producers on the current situation on compost-like outputs in Ireland

The view is that if the regulations permitted compost-like outputs to be used on land in Ireland, producers have ideas on products they can make that can bring financial benefits. If regulations permitted the use of compost-like outputs on land this will help to reduce disposal costs, mostly by reducing transport costs. It was recommended that the regulatory authorities should develop standards for the end use of compost like outputs in Ireland.

The author hopes that this study will generate interest among stakeholders which will bring interest in further research of this topic in Ireland.

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APPENDICES

APPENDIX A RESEARCH FORMS

These forms were written by the author to help in information collection.

A.1 Research Questions

QUESTIONS FOR COMPOSTING PLANTS

Section 1 – Biological Treatment Process and Technology

- What is the biological treatment process used?
- What is the composting technology used?
- What is the composting system used?
- How is the operation regulated by regulatory authorities?

Section 2 – Treatment Process from Start to Finish

Treatment Stages:

- From which areas in Ireland does the waste come from?
- What composting standards are followed at the composting facilities?
- What are the main stages or phases of the biological treatment process?
- How long does the treatment process take to produce stabilised compost-like outputs?
- How much volume or weight reduction is achieved by the treatment process?

***Quality Assurance*:**

- How is the issue of Animal By-Products addressed during the treatment process?
- Are there ways or technologies of reducing hazardous substances (biological, chemical and physical) in the final product?
- Are there quality standards for the final product?
- Is the biological treatment at the composting facilities adequate to protect the environment?
- Is there a periodical analytical testing (biological, chemical and physical analysis) of compost-like outputs carried out at the composting facilities?

Section 3 – Quantities of Compost-Like Outputs Produced

- What is the quantity of compost-like outputs produced at the facilities annually?
- Are there records of annual quantities since the facilities started producing compost-like outputs?

Section 4 – Production and Disposal Costs

- How are compost-like outputs from the composting facilities disposed of?
- Are there any tests carried on compost-like outputs at their site of disposal?
- Are there any other uses of compost-like outputs from the facilities?
- What is the total cost of treating biodegradable waste to produce one tonne of compost-like outputs?
- What is the total cost of disposing one tonne of compost-like outputs?
- Are there any allowances or subsidies from the government for treating biodegradable waste from mixed municipal solid waste?

Section 5 - Views and Opinions on the Current Situation

- Do composting facilities owners have or see any potential uses of compost-like outputs on land?
- Do composting facilities owners see any opportunities for financial benefits if they were allowed to produce compost-like outputs for selling?
- What are the views and opinions of composting facilities owners on the current situation with regards to the non-use compost-like outputs in Ireland?

IRELAND

- What is the quantity of compost-like outputs produced in Ireland annually?
- What is the trend of the quantity of compost-like outputs in Ireland?
- What is the quality of compost like outputs produced in Ireland like?
- Is there a big difference in the quality of compost-like outputs derived from mixed municipal solid waste and that of composts derived from source segregate biodegradable municipal solid waste?
- How does the quality of compost-like outputs produced in Ireland compare to the standards of compost-like outputs used for land restoration in the United Kingdom?

A.2 Semi-Structured Interview Guide

---

1. General Information

Facility Name:	Facility Address:
Information Supplied By (Interviewee) : Position:	
Name of Interviewer (Researcher):	
Date of Interview :	Time:

2. Section 1 – Biological Treatment Technology

Main Questions Pre-Planned	**Extra Questions By Researcher**	**Questions by interviewee**
1. What is the biological treatment process use? 2. What is the composting technology used? 3. What is the composting system used? 4. How is the operation regulated by the regulatory authority?		

3. Section 2 – Treatment Process from Start to Finish

Main Questions Pre-Planned	**Extra Questions By Researcher**	**Questions by interviewee**
1. Where does the waste come from? 2. What are the main stages or phases of the biological treatment process? **3.** How much volume or weight reduction is achieved by the treatment process?		

1. How is the issue of Animal By-Products addressed during the treatment process? 2. Are there quality standards for the final product? 3. Is the biological treatment at the composting facilities adequate to protect the environment? **4.** Is there a periodical analytical testing of compost-like outputs carried out at the composting facility?		

4. Section 3 – Quantities of Compost-Like Outputs Produced

Main Questions Pre-Planned	**Extra Questions By Researcher**	**Questions by interviewee**
1. What is the quantity of compost-like outputs produced at the facility annually? 2. Are there records of annual quantities since the facility started producing compost-like outputs?		

5. Section 4 – Production and Disposal Costs

Main Questions Pre-Planned	**Extra Questions By Researcher**	**Questions by interviewee**
1. How are compost-like outputs from the composting facility disposed of? 2. What is the total cost of treating biodegradable waste to produce one tonne of compost-like outputs? **3.** What is the total cost of disposing one tonne of compost-like outputs?		

6. Section 5 – Views and Opinions on the Current Situation

1. Does your facility have any potential uses of compost-like outputs on land?

2. Do you see any opportunities for financial benefits if your facility was to be allowed to produce compost-like outputs for selling?

3. View and opinion on the current situation with regards to the non-use of compost-like outputs in Ireland?

<u>Other Comments:</u>

A.3 Semi-Structured Interview Questions asked –Miltown Composting Systems Ltd.

1 General Information

Facility Name: *Miltown Composting Systems Ltd.* **Facility Address:** *Miltownmore ,Fethard ,County Tipperary*
Information Supplied By (Interviewee) : *Mr Derry Murphy* **Position:** *Facility Manager* **Contact E-mail**: *derry@miltowncomposting.ie*
Name of Interviewer (Researcher): *Nathan .H Chikono*
Date of Interview : *16 April 2014* Time: *9:55*

2. Section 1 – Biological Treatment Technology

Main Questions Pre-Planned	**Extra Questions By Researcher**
1. What is the biological treatment process used? 2. What is the composting technology used? 3. What is the composting system used? 4. How is the operation regulated	• What is the importance of composting material indoor? • What is the advantage of APS system over other systems? • How is material handled and moved?

3. Section 2 – Treatment Process from Start to Finish

Main Questions Pre-Planned	**Extra Questions By Researcher**
1. From which areas does the waste come from? 2. What are the main stages or phases of the biological treatment process? **3.** How much volume or weight reduction is achieved by the treatment process? 4. How is the issue of Animal By-Products addressed during the treatment process? 5. Are there quality standards for the final product? **6.** Is there a periodical analytical testing of compost-like outputs carried out?	• Where is pre-processing done? • What EWC codes are given to material received for treatment? • Does pre-processing affect quality of compost-like outputs produced? • What composting standards are followed at the composting facilities? • How long does the treatment process take to produce stabilised compost-like outputs? • Are there ways or technologies of reducing hazardous substances in the final product? • What are the indications that the material is mature? • How is the stability of the material determined?

4. Section 3 – Quantities of Compost-Like Outputs Produced

Main Questions Pre-Planned	Extra Questions By Researcher
1. What is the quantity of compost-like outputs produced at the facility annually? **2.** Are there records of annual quantities since the facility started producing compost-like outputs?	• Where are the compost-like outputs disposed of? • Where is the nearest landfill?

5. Section 4 – Production and Disposal Costs

Main Questions Pre-Planned	Extra Questions By Researcher
1. How are compost-like outputs from the composting facility disposed of? 2. What is the total cost of treating biodegradable waste to produce one tonne of compost-like outputs? 3. What is the total cost of disposing one tonne of compost-like outputs?	• Are there any tests carried on compost-like outputs at their site of disposal? • Are there any other uses of compost-like outputs from the facilities? • Are there any allowances or subsidies from the government for treating biodegradable waste from mixed municipal solid waste?

6. Section 5 – Views and Opinions on the Current Situation

4. Does your facility have any potential uses of compost-like outputs on land?

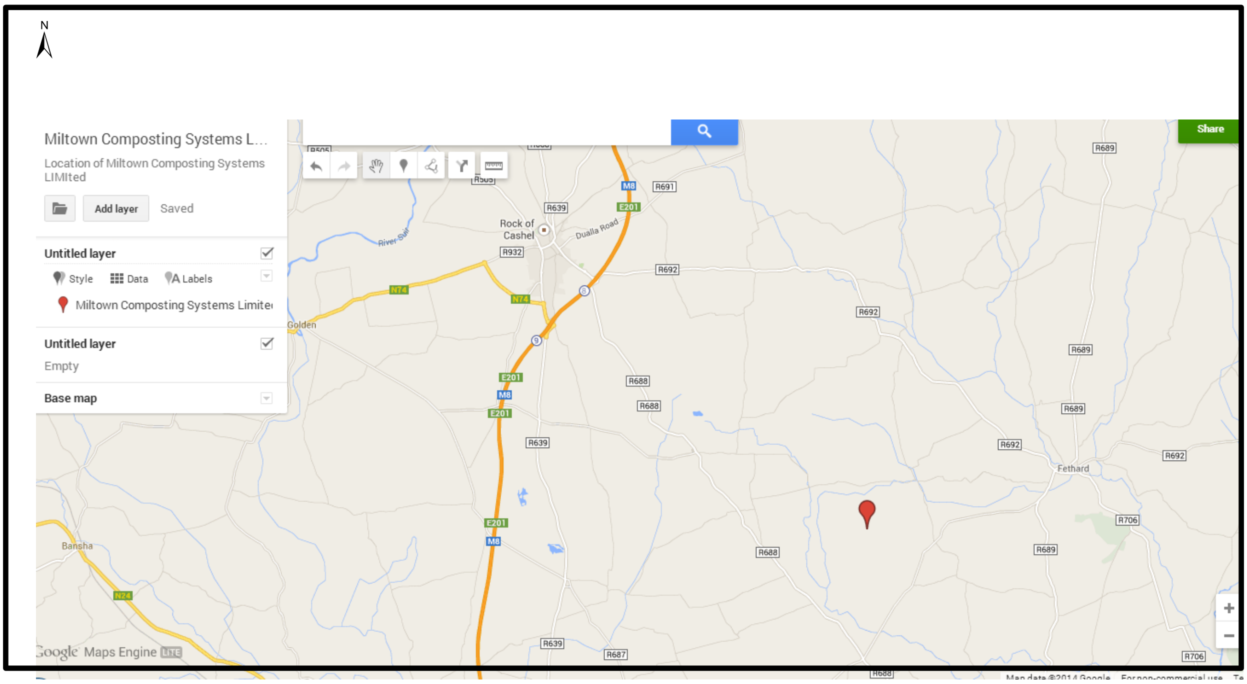
5. Do you see any opportunities for financial benefits if your facility was to be allowed to produce compost-like outputs for selling?

6. What are the views and opinions of composting facilities owners on the current situation with regards to the non-use compost-like outputs in Ireland?

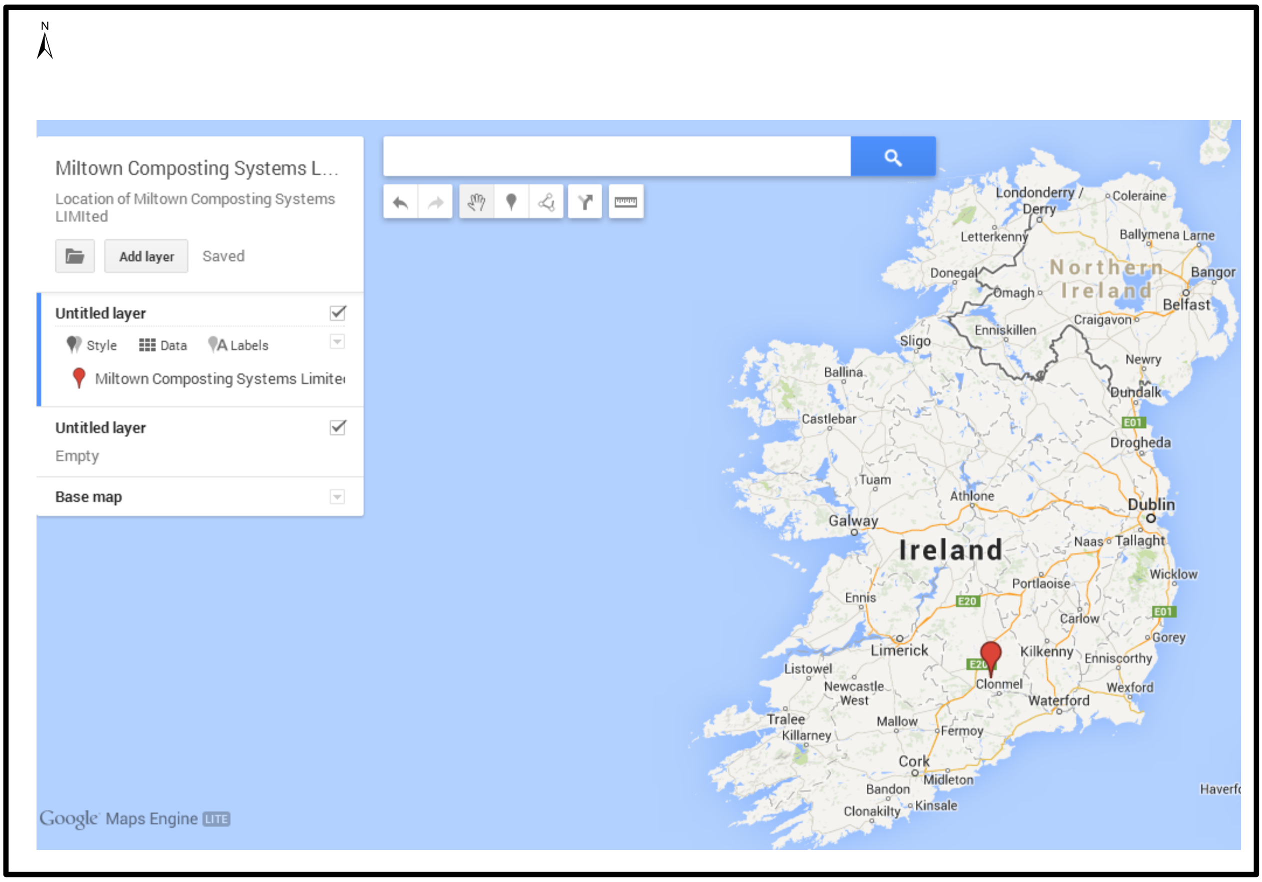
<u>Other Comments:</u>

APPENDIX B MILTOWN COMPOSTING SYSTEMS LTD. LOCATION MAPS

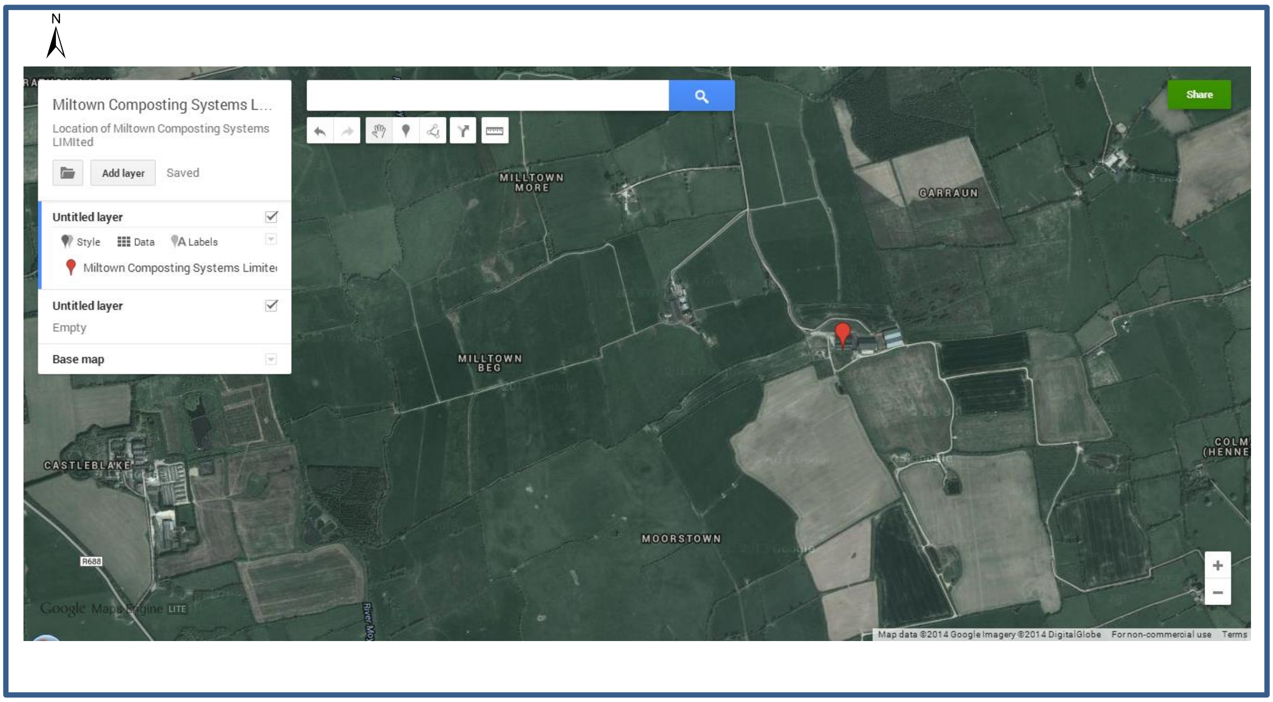
B.1 Map Showing the Location of Miltown Composting Systems Ltd. facility



B.2 Map of Ireland Showing the Location of Miltown Composting Systems Ltd. facility



B.3 Aerial Photograph showing the Location of Miltown Composting Systems Ltd facility



APPENDIX C COMPOST-LIKE OUTPUTS ANALYTICAL RESULTS

C.1 Laboratory Report Miltown Composting System Ltd Analytical Results

nrm laboratories

Purchase Order : 1998

MILTOWN COMPOSTING
SYSTEMS LTD
MILLTOWNMORE
FETHARD
CO TIPPERARY

N966

Please quote above code for all enquiries

DERRY MURPHY

COMPOST

ANALYSIS REPORT

Sample Reference :
191213FS

Sample Matrix : COMPOST

Laboratory References	
Report Number	30705
Sample Number	54757

Date Received	09-APR-2014
Date Reported	17-APR-2014

The sample submitted was of adequate size to complete all analysis requested.
The sample will be kept as the dry ground sample for at least 1 month.
If we are unable to accurately measure the density of the sample due to its non-homogeneous state, the density will be assumed to be 700 g/l.

ANALYTICAL RESULTS

Determinand	In the dry matter Value	Units	As received (Fresh) Value	Units
Bulk Density			586	g/l
Dry Matter			64.1	%
Moisture			35.9	%
Organic Matter LOI	43.2	%w/w		
Organic Carbon	25.1	%w/w		
pH			7.9	
Electrical Conductivity			5540	uS/cm
Electrical Conductivity			554	mS/m
Water Soluble Nitrate-N 1:5	790.2	mg/kg	297.0	mg/l
Water Soluble Ammon-N 1:5	95.8	mg/kg	36.0	mg/l

Released by Joe Cherrie Date 17/04/14

NRM Coopers Bridge, Braziers Lane, Bracknell, Berkshire RG42 6NS
Tel: +44 (0) 1344 886338 Fax: +44 (0) 1344 890972 Email: enquiries@nrm.uk.com www.nrm.uk.com

Purchase Order : 1998

MILTOWN COMPOSTING
SYSTEMS LTD
MILLTOWNMORE
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If we are unable to accurately measure the density of the sample due to its non-homogeneous state, the density will be assumed to be 700 g/l.

ANALYTICAL RESULTS

Determinand	In the dry matter Value	In the dry matter Units	As received (Fresh) Value	As received (Fresh) Units
Total Soluble Nitrogen	886.0	mg/kg	333.0	mg/l
Ammonium-N : Nitrate-N Ratio	0.1:1		0.1:1	
Water Soluble Phosphorus (P)1:5	7.3	mg/kg	2.7	mg/l
Water Soluble Potassium (K)1:5	5547	mg/kg	2085	mg/l
Total Nitrogen	22696	mg/kg	8530	mg/l
Total Carbon	232400	mg/kg	87350	mg/l
Carbon : Nitrogen Ratio	10:1		10:1	
Total Phosphorus (P)	4649	mg/kg	1748	mg/l
Total Potassium (K)	8439	mg/kg	3172	mg/l
Total Copper (Cu)	414	mg/kg	156	mg/l

Released by *Joe Cherrie* Date *17/04/14*

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ANALYTICAL RESULTS

Determinand	In the dry matter Value	Units	As received (Fresh) Value	Units
Total Zinc (Zn)	938	mg/kg	352	mg/l
Total Lead (Pb)	340	mg/kg	128	mg/l
Total Cadmium (Cd)	3.16	mg/kg	1.19	mg/l
Total Mercury (Hg)	0.50	mg/kg	0.19	mg/l
Total Nickel (Ni)	42.9	mg/kg	16.1	mg/l
Total Chromium (Cr)	30.5	mg/kg	11.5	mg/l
PCB EC7			<2	ug/kg
PAH EPA16			2.5	mg/kg
Total Arsenic (As)	5.16	mg/kg		
Naphthalene			<0.05	mg/kg

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Sample Matrix : COMPOST

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ANALYTICAL RESULTS

Determinand	In the dry matter Value	Units	As received (Fresh) Value	Units
Acenaphthylene			<0.05	mg/kg
Acenaphthene			0.3	mg/kg
Fluorene			<0.05	mg/kg
Phenanthrene			0.2	mg/kg
Anthracene			<0.05	mg/kg
Fluoranthene			0.9	mg/kg
Pyrene			0.5	mg/kg
Benzo[a]anthracene			0.2	mg/kg
Chrysene			0.3	mg/kg
Benzo[b]fluoranthene			0.1	mg/kg

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The sample will be kept as the dry ground sample for at least 1 month.
If we are unable to accurately measure the density of the sample due to its non-homogeneous state, the density will be assumed to be 700 g/l.

ANALYTICAL RESULTS

Determinand	In the dry matter Value	Units	As received (Fresh) Value	Units
Benzo[k]fluoranthene			<0.1	mg/kg
Benzo[a]pyrene			<0.1	mg/kg
Indeno[1,2,3-cd]pyrene			<0.1	mg/kg
Dibenzo[a,h]anthracene			<0.1	mg/kg
Benzo[g,h,i]perylene			<0.1	mg/kg
PCB-28			<0.5	ug/kg
PCB-52			<0.5	ug/kg
PCB-101			<0.5	ug/kg
PCB-118			<0.5	ug/kg
PCB-153			<0.5	ug/kg

Released by Joe Cherrie Date 17/04/14

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MILTOWN COMPOSTING
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The sample will be kept as the dry ground sample for at least 1 month.
If we are unable to accurately measure the density of the sample due to its non-homogeneous state, the density will be assumed to be 700 g/l.

ANALYTICAL RESULTS

Determinand	In the dry matter Value	Units	As received (Fresh) Value	Units
PCB-138			<0.5	ug/kg
PCB-180			<0.5	ug/kg
Total Plastics > 2mm	0.02	%		
Total Glass > 2mm	0.08	%		
Total Metals > 2mm	<0.01	%		
Stones > 2mm	<0.1	%		

Released by *Joe Cherrie* Date *17/04/14*

C.2 Irish National Database Results –Ireland Compost-Like Outputs Analytical Results

Table A.1. Non-source-separated metals (mg/kg).

Parameter	Cadmium	Mercury	Lead	Nickel	Zinc	Copper	Chromium	Arsenic	Selenium
Maximum	36.50	18.80	1098.00	140.00	2688.00	1743.00	129.00	12.50	2.10
Minimum	0.01	0.05	0.23	4.86	9.66	21.70	0.33	0.48	0.12
Median	0.74	0.14	199.00	36.95	396.50	170.00	41.80	7.33	0.66
Mean	1.81	0.67	315.35	43.94	549.31	246.80	43.38	6.80	0.70
Standard deviation	4.68	2.41	299.42	29.42	534.30	292.51	27.25	2.90	0.48
Percentile (75th)	1.27	0.36	471.5	49.85	636	286.00	58.7	8.58	0.80
Percentile (90th)	2.27	0.55	769	79.55	1010.8	537.80	76.48	10.26	1.47
Number of samples	72	71	75	76	72	77	73	34	36

Table A.2. Non-source-separated pathogens.

Parameter	Total coliforms (cfu)	*Escherichia coli* (cfu/g fresh mass)	*Salmonella* (in 25 g)
Maximum	No data	24,600	0
Minimum	No data	3	0
Median	No data	3	0
Mean	No data	870	0
Standard deviation	No data	4,230	0
Percentile (75th)	No data	3	0
Percentile (90th)	No data	1,169	0
Number of samples	No data	34	32

Table A.3. Non-source-separated impurities (% dry weight)

Parameter	Plastic	Glass	Metals
Maximum	14.81	26.1	0
Minimum	0.00	0	0
Median	0.00	0	0
Mean	0.80	2.72	0
Standard deviation	2.35	5.40	0
Percentile (75th)	0.00	0.93	0
Percentile (90th)	2.29	7.78	0
Number of samples	57	61	56