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Utilisation options for biodegradable kitchen waste in Estonia. SWOT analysis

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Abstract

The most critical issue in municipal waste management in Estonia is the biodegradable fraction because the source sorting and central collection and treatment of that fraction is neither economically nor environmentally cost effective. Over the last three years, scientists from Tallinn University of Technology (TUT) collected data about the biodegradable waste produced in Estonia during 2002–2012. The waste volumes, qualities, and energy potential were estimated. Biodegradable waste, such as manure, sludge and biomass from unused lands, is the best resource for renewable energy production in the anaerobic digestion process in Estonia. The current paper focused on the waste from trade companies, garden waste and kitchen waste because the quantity of this type of waste has gradually increased in recent years. The SWOT analysis shows that the composting method for the utilisation of this type of waste is a better solution. Also, the benefits and disadvantages of home composting and central collection and treatment of bio-waste are analysed.

Keywords: anaerobic digestion; biodegradable waste; composting; kitchen waste; SWOT analysis.

Nomenclature

MSW	Municipal Solid Waste
SEIT	Stockholm Environment Institute Tallinn Research Center
TUT	Tallinn University of Technology
WWTP	Waste Water Treatment Plant

1. Introduction

The Estonian Waste Act in accordance with the Directive 2008/98/EC of the European Parliament [1] and of the Council of 19 November 2008 on waste requires that the percentage of biodegradable waste in the waste disposed to the landfills does not exceed 35% since July 2013 and 20% from July 2020. The Waste Act [2] also prohibits disposal of untreated waste in landfills. However, some recent researches show that the bio-waste content in the municipal waste amounts to 50% or even more [3]. Therefore, the most critical issue in municipal waste management in Estonia is the biodegradable fraction because the source sorting, and central collection and treatment of that fraction is neither economically nor environmentally cost effective. Biodegradable waste, such as manure, sludge and biomass from unused lands, is the best resource for renewable energy production in the anaerobic digestion process in Estonia [4]. Their economically usable energy potential was estimated to be around 112 mln. m^3 per year [5]. Other biodegradable waste, such as waste from trade companies, waste from gardens and parks, as well as kitchen waste may decompose under anaerobic and aerobic conditions. The future for biodegradable waste using as a resource for renewable energy depends not only on the availability of the equipment, but also on economic- and political factors. The focus of this paper is on organic waste from trade companies, garden waste and kitchen waste, because the quantity of this type of waste has gradually increased in recent years. Kitchen waste and waste from trade is mostly fibrous- and well structured. These properties are optimal for composting, but the waste can also be used for biogas production in a dry digestion process [6]. The main composting type for source separated organics in

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Finland, Germany, UK, Ireland and France is composting in open windrows [7]. The objective of the research was to estimate the utilisation options for kitchen waste, waste from trade companies, and terrace and gardening waste in Estonia.

2. Materials and Methods

Over the last three years, scientists from TUT collected data about the biodegradable waste produced in Estonia during 2002–2012 in all 15 counties. The data about the amount of waste generated were received from the Estonian Environment Information Centre, from official statistics and from TUT research projects. The data collected by the scientists of TUT involved all types of biodegradable waste, such as total municipal waste, terrace and gardening wastes (including cemetery waste); biodegradable waste from 98 food industry companies, sewage sludge from 145 wastewater treatment plants, waste from 264 trade companies, manure from 292 farms and energy crops from all 15 counties of Estonia. The current article focuses on the waste from trade companies, garden waste and kitchen waste in Tallinn and Harju County, because the quantities of this type of waste have gradually increased in recent years. The method of statistical analysis using Mathcad 2001 Professional software was applied for the received data evaluation, and SWOT analysis was carried out for the comparison of different methods of bio-waste utilisation.

3. Results and discussion

Municipal solid waste (MSW) is typically composed of a biodegradable organic fraction, such as kitchen scraps, food residue, food processing waste, and grass cuttings that are suitable feedstock for biogas production plants. Also, MSW consists of a combustible fraction, like wood, paper and paperboard, textile, which are suitable for incineration-based energy generation plants. MSW also consists of non-degradable fractions such as metal, glass, sand and stones which need to be removed. Table 1 shows the composition of mixed municipal waste in Estonia [8].

Table 1. Mixed municipal waste (landfilled) composition (%) in Estonia

Waste components	2008
paper and cartoon	18
kitchen waste	30
plastics	19
glass	8,1
waste from gardens	5
combustible material	6,3
non combustible	4,3
textile	4,4
metal	2,5
electronic waste	0,6
wood	0,4
other bio waste	1,4
Total	100

The biggest parts of waste components consisted of kitchen waste, followed by paper and cartoon. The quantity of other components was smaller. According to research on the composition of mixed municipal waste in Estonia, which was carried out in 2012/2013 by SEI Tallinn Research Center, the average mixed municipal waste contains 31.8% of bio waste (kitchen waste, garden waste, other bio waste) and 13.5% of paper waste, which can be included in the biodegradable fraction of municipal waste [9]. The World Bank study summarised biogenic waste as a mean of 64% for low-income countries, 59% for middle-income countries, and 28% for high-income countries [10].

During the period from 2002 to 2010, the average quantity of municipal solid waste in Estonia was around 507,000 tons/year. The maximum quantity of municipal solid waste was produced in 2007. Since 2008, the quantity of generated waste has been constantly decreasing, which is connected to the slowdown of economic growth in the country. Approximately 381,000tons of municipal solid waste was produced in 2012, which was smaller by up to 41% compared to 2007. The quantity of municipal solid wastes varies from county to county and from town to town, but and the largest quantity of MSW during 2002–2010 was generated in Tallinn.

Biodegradable waste generation of trade companies is increasing from year on year with an increasing number of stores. In 2010, the quantity of this type of waste was approximately 3 times more (14,300 tons) than in 2004 (5,340 tons). The average quantity of biodegradable waste generation in Estonia from grocery stores during 2004–2010 was 9,103 thousand tons/year. The largest amount of biodegradable waste from trade companies was generated in Harju County (2,862 tons/year) because there is a large population, more shops and the largest town in Estonia–Tallinn, is located there.

In Estonia, only 2,189 tons of terrace and gardening waste were generated in 2002, but in 2009 the growth of waste was significant (22,094 tons). This increase in waste was explained by the increased waste disposal in Tallinn cemetery in 2009 and 2010. The largest amounts of terrace–and gardening waste generation during 2002–2010 were in Harju County. The largest waste producer was Tallinn cemetery.

The collection and analysis of kitchen waste (Table 2) was only conducted in Tallinn and Harju County, as they are the biggest source for this waste pollution in Estonia. Up to 2004 all kitchen waste (100%) was sent to landfill, but since 2006 waste reusing has been implemented.

Table 2. Kitchen waste income and reuse during the years 2004-2012 [11]

Years	Income, incl. generated (tons/year)	Reuse	% of reusing	% of landfilled
2004	0,087	0		100
2005	0,864	0		
2006	0,129	0,134	100	2
2007	1,592	1,599	100	
2008	8,146	8,144	100	0
2009	9,805	9,491	97	0
2010	10,653	10,057	94	
2011	10,957	8,556	78	2

Tallinn is the first town in Estonia were municipal bio-waste (kitchen waste) has been collected separately. Kitchen waste includes organics matter, such as fresh fruit and vegetables, prepared foods, cooked and uncooked meats and fish, and other foods: cheese and eggs, bread, coffee grinds, tea bags, etc. wilted flowers, tissue paper. The properties of kitchen waste are optimal for composting.

Many local authorities, which comprise settlements and areas of high population density, have imposed the separate collection of bio-waste on houses with more than 10 apartments. In houses with fewer than 10 apartments, the source sorting of bio-waste and composting on site is still recommended but a separate container for bio-waste is not compulsory. The majority of separately collected bio-waste in Estonia is produced in Tallinn. In 2012, the total amount of separately collected organic kitchen waste (code 20 01 08 in the List of Waste 2000/532/EC [12]) in Estonia was 12,838 tons, of which 10,375 originated in Tallinn and 1,027 in Harju County [13].

The separate collection of bio-waste was implemented in Tallinn with an organised waste collection system in 2007, and it was remarkably successful. The number of bio-waste containers in Tallinn has now reached 3,000 with a total volume of 530 cubic metres. Those containers came into use in Tallinn within two years (2007–2008). Unfortunately, it is not known how many dwellings with fewer than 10 apartments practice the home composting of bio-waste in their backyards [14]. The Estonian Ministry of the Environment has carried out a questionnaire [15] about the waste management situation amongst Estonian local authorities. According to the survey, most of the local composting facilities are either at the wastewater treatment facilities where sludge is processed with a marginal amount of gardening waste, or facile open windrow composting sites for gardening waste. Technologically equipped composting facilities where biodegradable kitchen waste can also be processed are only at the regional landfills or waste stations [15]. Therefore, in most of the municipalities the collection routes for separately collected bio-waste are long, which makes the transportation costs high and the economical feasibility of central collection of bio-waste questionable.

The quantity of generated biodegradable municipal waste in Estonia (ton per year) and Tallinn was presented in Table3. The Table 3 shows, that 37% of MSW of Estonia was generated in Tallinn, therefore, in this table the waste from trade companies, kitchen waste, terrace/ garden waste and food waste was only presented for Tallinn and Harju County.

Table 3. Quantity of municipal waste generated in Estonia, in Tallinn waste from Harju County

NN	Type of waste	Waste quantity (thousand tons per year)						
		2004	2005	2006	2007	2008	2009	2010
	Total MSW in Estonia	558	478	518	579	513	441	413
1	MSW of Tallinn City	210	186	180	197	178	172	154
2	Trade	1.403	1.379	1.180	1.040	3.231	6.073	5.727
3	Kitchen waste	0.087	0.864	0.129	1.592	8.146	9.805	10.653
4	Terrace and gardening	0.065	0.754	0.501	0.410	0.558	17.922	9.198
5	Food Industry	9.578	8.291	7.253	6.688	3.997	4.545	4.660

The value of industrial pollution constantly decreases and the share of industrial waste was an average of only 3.46% of MSW from Tallinn. The quantity of other waste, such as waste from trade, kitchen waste and waste from terrace and gardening has increased year on year.

3.1. Choice of a suitable method for waste from trade companies and kitchen waste

The anaerobic digestion process and composting are two ways to decrease of these waste types. The first option for possibilities of biodegradable waste utilisation is biogas production during the anaerobic digestion process. Today, only manure and sludge from WWTP with waste from the food industry is ready for use in biogas production in Estonia. The economically usable biogas quantity in Estonia such as waste from trade (0.1mln. m3/year) and terrace and gardening waste (0.3mln. m3/year) is very small [5]. The average quantity of kitchen waste is 5,279 tons per year and the theoretical potential of biogas production is only 0.5mln. m3/year. The economically usable biogas potential of this substrate in Estonia is only 10% [16] and the theoretical amount of biogas (0.05mln. m3/year) producing even less than for other waste types. The energy potential of this type of waste is very small and, therefore, the composting process may be better.

Composting is a process of controlled biological decomposition of biodegradable materials under managed conditions that are predominantly aerobic and that allow the development of thermophilic temperatures as a result of biologically produced heat, in order to achieve compost that is sanitary and stable [17]. Composting is an aerobic process where organic material is transformed through decomposition into a soil-like material called compost. It is a process that occurs naturally in the environment but, as a controlled process, composting can be an invaluable waste management tool, causing a volume and weight reduction in the raw materials and producing a potentially valuable end product. The product is rendered more stable and made suitable for application to gardens and productive land as a soil improver. When carried out under ideal conditions, the only outputs to the atmosphere from composting are carbon dioxide and water [18].

In basic equation form, the overall material balance for composting approximates to:

$$C_pH_qO_rN_s \cdot aH_2O + bO_2 \rightarrow C_tH_uO_vN_w \cdot dH_2O + dH_2O + eH_2O + CO_2 \quad (1)$$

The organic matter + oxygen → compost + water + carbon dioxide

The transformations that take place occur through a range of processes initially involving bacteria, fungi, moulds, protozoa, actinomycetes, and other saprophytic organisms feeding upon decaying organic matter, while in the later stages of decomposition, macroscopic organisms such as mites, millipedes, centipedes, beetles and earthworms further break down and enrich the composting materials [18].

Compost technology has three important functions, the first of which is “pre-processing”. Pre-processing consists of the preparation or processing of a raw waste such that it constitutes a suitable substrate for the compost process. The second function is the conduct of the compost process. The third function is the preparation of the compost product for safe and nuisance-free storage and/or the upgrading of the product so as to enhance its utility and marketability [19]. The technologies can roughly be divided into small-scale, domestic or local composting and large-scale, central or industrial composting. The large-scale composting usually involves technological measures for the better control of the whole process and quality of the compost, as well as to reduce the environmental impact like air emissions, leachate and pathogens. The distinctive features of different composting technologies are open or closed composting; with or without forced aeration; and different process techniques like windrow, container, box channel or tunnel composting.

Open-air windrow composting is the simplest technique. Generally, these plants work without forced aeration and waste gas collecting [20]. Windrow composting has been the common practice for large scale composting globally. This process is less costly than the other technologies but it is more difficult to control and it can generate undesirable emissions and odour’s [21].

In-vessel composting refers to a group of composting systems, which range from enclosed halls to tunnels and containers or bins. In-vessel systems attempt to create optimum conditions for the microorganisms, thereby giving improved control of the composting process and accelerating decomposition. As in all composting systems, the supply of air to all the material being composted is an in-vessel compost technology is promoted for managing food scraps in areas with limited space. This is a great solution as long as the compost unit's characteristics meet the needs of the institution managing the organic residual's key factor in determining the effectiveness of the process [17].

In-vessel compost technology is promoted for managing food scraps in areas with limited space. This is a great solution as long as the compost unit's characteristics meet the needs of the institution managing the organic residuals. There are a number of parameters to consider: amount of waste/week; amount of space available for primary and secondary processing; carbon material required and where it can be sourced and stored; batch or continuous feed; retention time; and space needed for curing. Odor control is one of the reasons in-vessel technology is employed. However, if the recipe or balance is not correct or if the compost system is not really designed to manage the intended feedstock, there will be odors and they will escape from any unit. Limitations of the chosen in-vessel unit must be identified [22].

Home composting is small-scale composting for domestic gardening and kitchen waste (without meat, bones or fatty foods). The main technologies applied for home composting are composting in an aerated (turned) pile or a covered/closed composting bin, mulching, soil incorporation and vermicomposting. Mulching is suitable for chopped yard waste (leaves, grass, branches), which is simply spread around the trees or on flower or vegetable beds. Soil incorporation is more suitable for kitchen scraps. Digging the kitchen waste into the ground also helps to avoid the odour problem.

Vermicomposting uses earthworms to turn organic waste into compost. The main negative environmental impacts accompanying composting process are air emissions (odour and greenhouse gases), pathogens and insects, and leachate. There are also some positive impacts such as the usage of compost as a fertiliser or soil amendment, avoiding disposal of biodegradable waste, reducing the amounts and environmental impact and costs of transportation and treatment of municipal solid waste, and contributing to the sustainable waste management model.

Two methods of organic matter decomposition were analysed and the results were presented in Table 4 and Table 5.

Table 4. SWOT analysis

SWOT	Aerobic degradation: industrial composting, home composting	Anaerobic degradation: biogas production, anaerobic digestion
STRENGTHS	Reduction of biodegradable fraction in disposed MMW, reduction of the environmental impact of landfills (landfill gas and leachate production), increases life-span of landfills	Reduction of biodegradable fraction in disposed MMW, reduction of the environmental impact of landfills (landfill gas and leachate production), increases life-span of landfills
	Low investments and operational costs compared to anaerobic digestion, facile technical requirements, home composting has a widespread applicability, no permits required	Can combine different sources of organic waste, such as: agricultural activities, slaughter houses, olive processing plants, waste water treatment plants etc
	Compost can be used to enhance soil nutrients for plant growth	Production of biogas which can be converted to energy
	Home composting reduces the waste transportation and treatment costs and environmental impacts of those	Fast process cycle
	National and EU legislation and necessary know-how exists	Controlled process, controlled gas, odor and wastewater emissions
WEAKNESSES	Limited range of input material, not suitable for sludge and other high moist containing materials	Limited range of input material, not effective/ optimal for gardening and other lower moist containing organic waste
	Slow process, but can be accelerated with agents and technological facilities (aeration, in-vessel, tunnel)	High investments and operational costs compared to aerobic composting, strict and technical requirements
	Problems related to the establishment of the facility (area selection, permits, social reactions)	Problems related to the establishment of the facility (area selection, permits, social reactions)
	Source sorting of bio waste requires separate collection infrastructure (bins)	Requires stabile and high-quality in-put material, thus not suitable for source sorted bio waste from households
	Uncontrolled greenhouse gases, VOCs and dust emissions unless additional technological facilities are used for gas collection	Need for post-treatment of digestate
	Attraction of rodents and insects, possible smell problems	
OPPORTUNITIES	Reduction of waste and greenhouse gas emissions, sustainable management of organic waste	Reduction of waste and greenhouse gas emissions, sustainable management of organic waste
	Suitable for bio waste generated in private households and detached houses areas, a closed loop model if compost as end product is used *in situ*	Harvest residues from agriculture, solid and liquid manure, biogenic urban waste, residues from the food industry, pulp and paper sludge, and sewage sludge are appropriate ingredients for anaerobic digestion
	Independent on the stabile input material flow, process can be adjusted according to the amounts of incoming bio waste	Biogas resulting by anaerobic digestion is a source of renewable energy because it replaces fossil energy
	Suitable for post-treatment of the digestate of anaerobic digestion	Under controlled conditions the digestate can be used as soil fertiliser
THREATS	Lack of awareness of citizens may result in poor quality of source sorted bio-waste and can lead to bad quality compost	Digestates differ greatly depending on input materials, process operation and retention time in reactor, thus may need a post treatment in aerobic composting
	Lack of demand for compost and accompanying products	Dependant on the stable and high-quality input material flow
	Lack of oxygen may turn the process anaerobic which contributes to the methane emissions and smell production	No legislation for the utilisation or compositional requirements of digestate
	Negative impact on the value and prices of surrounding real estate and properties	Negative impact on the value and prices of surrounding real estate and properties

Table 5. Comparison of two different methods for waste utilization

Comparison	Aerobic degradation: home composting, industrial composting	Anaerobic degradation: biogas production, anaerobic digestion
Essence	Aerobic degradation of organic waste to produce compost	Controlled decomposition of organic waste in the absence of oxygen
Technology	Aerated or static windrow, tunnel, in-vessel, vermicomposting	Reactor, methane tank
Investments	None or low or moderate	High
Operational costs	Low or moderate	High
Emissions	Uncontrolled, CO2, CH4, smell, leachate	Controlled, CH4, biogas
Preferred input material	Garden waste, kitchen waste, food residuals	Sewage sludge, manure, silage, wastes from the food and beverage industry
Outcome product	Compost, warmth	Biogas, energy, digestate

As tables 4 and 5 show, the aerobic degradation of kitchen waste and for waste from trade companies is the better variant for its utilisation.

4. Conclusion

The biodegradable fraction in mixed municipal waste in Estonia is considerable and it must be utilised, because its degradation is a major contributor to greenhouse gas emissions. This fraction of waste should not be mixed with another municipal waste.

The largest quantity of MSW during 2002–2010 was generated in Tallinn (37%). The separate collection of bio-waste was implemented in Tallinn with an organised waste collection system in 2007, and it was remarkably successful.

Today, only manure and sludge from WWTP with waste from the food industry is really to use for biogas production in Estonia. The quantity of waste from trade, kitchen waste and waste from terraces and gardening has increased year on year, but its energy potential is very small, therefore, the composting process is better.

The SWOT analysis has shown that the composting process is better solution for kitchen waste and waste from trade companies

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