The Biological Treatment of Organic Food Waste

HALYNA KOSOVSKA

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Halyna Kosovska

THE BIOLOGICAL TREATMENT
OF ORGANIC FOOD WASTE

Supervisor & Examiner:
Monika Ohlsson

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Abstract

This Master Thesis “The Biological Treatment of Organic Food Waste” is done in the Master’s Programme in Sustainable Technology at the Royal Institute of Technology (KTH) in co-operation with the company SRV återvinning AB.

The report is dedicated to analyze different biological treatment methods (that is composting and fermentation), which are used for the handling of organic food waste. From this analysis I will suggest the best method or methods for the company SRV återvinning AB (the Södertörn Area in Sweden) and for the Yavoriv Region in Ukraine in order to increase the environmental performance and to improve the environmental situation in the regions.

To be able to do this, a lot of factors are taking into consideration and are described and discussed in this Thesis Work. General characteristic of the regions, different means of control for organic food waste handling, sorting methods of organic waste, as well as composting and fermentation methods for treatment of organic waste are described and the advantages and disadvantages of these methods, their treatment and investment costs are distinguished in the Thesis.

Different treatment methods are discussed from technical and economical points of view for applying them for the SRV and the Södertörn Area in Sweden and for the Yavoriv Region in Ukraine and some solutions for these two regions are suggested. Also some recommendations for further studies are done.
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Glossary of terms

**Aerobic process** – a process requiring the presence of oxygen.

**Anaerobic digestion** – organic matter broken down by bacteria in the absence of air, producing a gas (methane) and solid (digestate). *See also fermentation.*

**Anaerobic digestion plant** – plant where the fermentation of organic waste takes place. *See also biogas plant, fermentation plant.*

**Anaerobic process** – a process from which air or oxygen not in chemical combination is excluded.

**Animal By-products (ABP)** – are any parts of animals and products of animal origin that are not intended for human consumption. These wastes have been categorized from Category 1 for very high risk to Category 3 for lower risk materials. Risk in this case mainly refers to the potential for animal disease transmission.

**Biodegradable waste** – defined in the Waste Directive as waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, paper and paperboard. *See also biological waste, compostable waste, organic waste.*

**Biogas** – gas, rich in methane and carbon dioxide, which is produced by the fermentation of organic waste, animal or plant origin ferments, human sewage or crop residues in an airtight container. It is used as a fuel for stoves and lamps, to run small machines, to generate electricity and as vehicle fuel. Biogas fuels do not usually cause pollution to the atmosphere, and since they come from renewable energy resources they have great potential for future use.

**Biogas plant** – plant where the fermentation of organic waste takes place. *See also anaerobic digestion plant, fermentation plant.*

**Biological treatment (biotreatment)** – is a biological process (for example, anaerobic digestion and composting) that changes the properties of waste using microorganisms such as bacteria and fungi.

**Biological waste (bio-waste)** – is waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, paper and paperboard. *See also biodegradable waste, compostable waste, organic waste.*

**Biomanure** – is obtained from the anaerobic digestion and is rich in plant nutrients and its high content of organic matter makes it a valuable soil conditioner for soils of low humus content and poor structure, for example compacted clay soils. *See also digestate.*

**Bio-rest** – is the solid residue arising from anaerobic digestion, which can be cured and used as a fertilizer or as a soil conditioner. *See also fertilizer.*

**Burnable waste** – is waste which can be processed in the incineration plant. *See also combustible waste.*

**Catering waste** – is a specific class of Category 3 Animal By-Products including materials that may contain or have come in contact with meat, such as food waste from restaurants and other commercial and domestic kitchens.
**Combustible waste** – is waste, which can be processed in the incineration plant. See also burnable waste.

**Compost** – a product rich in minerals and ideal for gardening and farming as a soil conditioner, mulch, resurfacing material or landfill cover. See also soil improver.

**Compostable waste** – is waste, which can be processed in the composting or fermentation plant. See also biological waste, biodegradable waste, organic waste.

**Composting** – is process where organic waste, including food waste, paper and yard waste, is decomposed under aerobic conditions, resulting in compost.

**Digestate** – is obtained from the anaerobic digestion and is rich in plant nutrients and its high content of organic matter makes it a valuable soil conditioner for soils of low humus content and poor structure, for example compacted clay soils. See also biomanure.

**Fermentation** – is conversion of organic substances in anaerobic conditions by organisms, especially bacteria, fungi or yeasts to produce other substances, such as biogas and digestate. See also anaerobic digestion.

**Fermentation plant** – is a plant where the fermentation of organic waste takes place. See also anaerobic digestion plant, biogas plant.

**Fertilizer** – is organic or inorganic plant food rich in nutrients, which may be either liquid or granular, used to amend the soil in order to improve the quality or quantity of plant growth. Fertilizer could be obtained during the composting of fermentation processes.

**Food waste** – is uneaten waste that comes from the preparation of food and consists of fruit/vegetable scraps, dairy, meats and breads and other starchy foods. Food waste is generated from residences and commercial establishments such as households and restaurants, grocery stores, hotels, institutional cafeterias and kitchens and other commercial and industrial sources like employee lunchrooms, etc.

**Garden waste** – includes the yard trimmings, leaves, shrubs, plants, grass, street trees, tree trunks, park trees etc. that arise from households, council parks and garden maintenance, and commercial premises. See also green waste, park waste, yard waste.

**Green waste** – includes the yard trimmings, leaves, shrubs, plants, grass, street trees, tree trunks, park trees etc. that arise from households, council parks and garden maintenance, and commercial premises. See also garden waste, park waste, yard waste.

**Household waste** – means any solid waste (including garbage, trash, and sanitary waste in septic tanks) derived from households. In this report also means organic household waste.

**Incineration** – the destruction of solid, liquid, or gaseous wastes by controlled burning at high temperatures. Hazardous organic compounds are converted to ash, carbon dioxide, and water. Burning destroys organics, reduces the volume of waste, and vaporizes water and other liquids the wastes may contain. The residue ash produced may contain some hazardous material, such as non-combustible heavy metals, concentrated from the original waste.

**Incombustible waste** – is the waste, which can not be processed in the incineration plant.
Landfilling – is disposal of solid waste at engineered facilities in a series of compacted layers on land. Landfills are lined with impermeable materials to prevent leachates from polluting groundwater. Landfilling also means the frequent daily covering of the waste with soil.

Municipal solid waste (MSW) – is garbage or refuse that is generated by households, commercial establishments, industrial offices or lunchrooms and sludges not regulated as a residual or hazardous waste.

Open composting – is the biological decomposition of the organic waste in the piles under aerobic conditions. See also windrow composting.

Organic food waste – is food waste, mainly food scrap, which is readily biodegradable in biological treatment such as composting or anaerobic digestion. See also organic household waste.

Organic household waste – is food waste (food scrap) originates in the households. See also organic food waste.

Organic waste – is waste such as paper, plastic, yard waste, wood, food, textiles, and other organics. In this thesis work organic waste also means organic food waste.

Park waste – includes the yard trimmings, leaves, shrubs, plants, grass, street trees, or tree trunks, park trees or tree trunks etc. that arise from households, council parks and garden maintenance, and commercial premises. See also garden waste, green waste, yard waste.

Polychlorinated Biphenyls (PCBs) – are chemicals used primarily, as flame-retardants, as coolants in industrial processes and in electrical transformers. They resemble the dioxins and furans in their structure and environmental properties. They accumulate in fat and are probable human carcinogens. PCBs mimic estrogen and interfere with thyroid hormone.

Producer responsibility – requires industry and commerce involved in the manufacture, distribution and sale of particular goods to take greater responsibility for the disposal and/or recovery of those goods at the end of their useful life.

Soil improver – a product rich in minerals and ideal for gardening and farming as a soil conditioner, mulch, resurfacing material or landfill cover. See also compost.

Solid waste – refers to municipal mixed type of solid waste generated by household, business, traditional market, industry (excluded non-hazardous materials), and street.

Source separation – means the preparation of materials for recycling and biological treatment by separation from wastes at the point of generation. See also source sorting.

Source sorting – is the preparation of materials for recycling by separation from wastes at the point of generation. See also source separation.

Swedish Association of Waste Management (RVF) – is a stakeholder and trade association in the field of waste management and recycling. The members are municipal bodies and corporate members. RVF’s policy for waste management aims at sustainable development and the handling of waste in such a way that people’s health and the environment are protected. It is also committed to responsibility for the different parts of waste management, the various recycling and treatment methods, quality in waste management, the competence and status of personnel, cost efficiency, technical development, and information.
Swedish Board of Agriculture (SJV) – is the Government's expert authority in the field of agricultural and food policy, and the authority responsible for the sectors agriculture, horticulture and reindeer husbandry. Its responsibility includes monitoring, analysing and reporting to the Government on developments in these areas, and implementing policy decisions within its designated field of activities.

SP Swedish National Testing and Research Institute (SP) – performs research for innovation and sustainable growth. They develop technology in close conjunction with universities, other research institutes and international partners. SP’s mission is to contribute to growth and competitiveness of industry as well as to safety, conservation of resources and a good environment in society. Their objective is to assist in the development and manufacture of products and systems with a high technological content, high inherent safety and minimum environmental impact, and so to contribute to growth in the form of skilled work opportunities in Sweden.

Transmissible Spongiform Encephalopathies (TSE) – are infectious deceases of animals and humans that are caused by a deterioration of brain tissue; are progressive and always fatal.

Waste – defined in the EC Waste Framework Directive as any substance or object, which is included in a category of waste, and which the owner disposes of or intends to or is obliged to dispose of.

Waste handling – is a complex system that can be divided into five basic areas of operation: generation, collection, transportation, treatment and utilization or final disposal. See also waste management.

Waste management – is the collection, transport, processing or disposal of waste materials, usually ones produced by human activity, in an effort to reduce their effect on human health or local amenity. A sub-focus in recent decades has been to reduce waste materials’ effect on the environment and to recover resources from them. See also waste handling.

Windrow composting – is the production of compost by piling organic matter, like food waste and garden waste, in long rows (windrows). See also open composting.

Yard waste – includes the yard trimmings, leaves, shrubs, plants, grass, street trees, or tree trunks, park trees or tree trunks etc. that arise from households, council parks and garden maintenance, and commercial premises. See also garden waste, park waste, green waste.
Abbreviations

ABP: Animal by-products
BOD: Biological Oxygen Demand
EMAS: Eco-Management and Audit Scheme
EU: European Union
HH: Household
HHW: Household waste
ISO: International Organization for Standardization
KRAV: Kontrollföreningen för Ekologisk Odling
LNG: Liquid natural gas
MSW: Municipal solid waste
OHHW: Organic household waste
PCB: Polychlorinated Biphenyls
RVF: The Swedish Association of Waste Management
SEK: Swedish Krona
SJV: The Swedish Board of Agriculture
SP: SP Swedish National Testing and Research Institute
SPCR: SP Certifiering
SRV: Södertörns Renhållningsverk
TS: Dry Content
TSE: Transmissible Spongiform Encephalopathies
VOC: Volatile Organic Compound

h: hour
kg: kilogram
kg/day: kilogram per day
kr: Swedish krona
kW: kilowatt
l: liter
m: meter
m²: square meters
m³: cubic meters
mil: million
t: ton
t/a: ton per annual
t/y: ton per year
y: year

CH₄: Methane
CO₂: Carbon Dioxide
NH₃: Ammonium
1. Introduction

The management of specific waste streams, such as organic biodegradable waste, represents an important element of the general European Union Waste Management Strategy by helping to reduce the impact of waste on the environment, by ensuring that waste is treated in an environmentally sound manner. Action on a specific waste stream is occasioned by its volume, its hazardousness, its treatment properties and its effects on the ecosystem.

So far, biodegradable waste has been regulated by the EU instruments, relevant to this waste stream, in order to reduce its negative consequences on the environment.

If properly regulated and managed, biodegradable waste may contribute towards effective resource management and sustainable development. In particular, biological treatment has the following advantages:

- biological treatment contributes towards efforts to reduce the greenhouse effect, as it diverts biodegradable waste from landfilling, where it would produce methane, a powerful greenhouse gas;
- the use of compost in agriculture is a way of maintaining or restoring the quality of soils because of the unique properties of the humified organic matter contained in the compost itself;
- the use of compost in horticulture and in home gardening is a valid substitute for peat, thus reducing the rate of exploitation of wet lands;
- anaerobic digestion is a means of producing “green energy”, with the possibility of obtaining a residue that can be used as a soil improver or as a fertilizer for arable land.

Sweden is a one of the leading countries in waste management, especially in handling of organic waste. There are approximately 100 small composting plants, about 25 large composting plants, 12 anaerobic digestion plants are working and several new large scale anaerobic digestion plants are planned in Sweden [1]. The latter development is very much encouraged by government and society, especially when the generated biogas is used as a fuel for vehicles. The municipalities have comprehensive plans, which suggest that biological treatment can be doubled within a few years. Many new sites are planned, and several of Sweden’s municipalities are planning to introduce separate collection of source-sorted bio-waste.

Anyway the source separation of waste is very spread in Sweden already now. About 35 percent of the Swedish municipalities have separate collection of compostable household waste with central treatment [2, 3]. In municipalities, which have implemented far-reaching source separation of biowaste, it has been found that 20–40 per cent of households’ waste in bins and bags is separated [4]. Source separation is a key component in the successful diversion of waste from landfill and incineration and reduces the demand for expensive landfill space. Also source separation reduces the cost for local authorities who then do not have to finance the sorting of waste for recycling. It also facilitates the recycling process. It has also proved in other jurisdiction to have a beneficial impact in creating a public understanding regarding recyclable products and the value of resources.

Biowaste in Sweden consists of waste from households, restaurants, supermarkets, food industries; and also organic material from gardens and parks, and waste from slaughterhouses. Contrary to most of the other European countries, Sweden allows using of animal manure and animal by-products for composting and anaerobic digestion, if they manage to achieve the Animal By-Product Regulation.

Opposite to Sweden, Ukraine is a developing country, where waste management and especially biological treatment of waste is on the first stage of developing. A lot of efforts should be made to reach the level of European countries in waste handling. Using the experience of Sweden, Ukraine can start to establish its own waste management strategy for organic waste.
1.1. Aims and Objectives

Aim:
The aim of this Thesis Work “The Biological Treatment of Organic Food Waste” is to study the methods for biological treatment and sorting of organic food waste, which is carried out in Sweden. And from this to suggest the best suitable treatment method for organic waste, which could be used in the Södertörn area in Sweden and in the Yavoriv Region in Ukraine in order to improve the environmental situation there.

Objectives:
- To overview the main environmental problems in the Södertörn area in Sweden and in the Yavoriv Region in Ukraine concerning food waste. And also to investigate the characteristic of the organic waste situation there: the information about the organic food waste in Ukraine; the amount of food waste in SRV’s municipalities; places where these wastes come from; etc.
- To study different rules and regulations for organic waste handling in Sweden and Ukraine.
- Overview different sorting methods of organic waste, their advantages and disadvantages.
- To study what kinds of biological treatment methods are used in Sweden and Ukraine for handling the out sorted organic food waste and investigate their advantages, disadvantages, as well as investment and treatment costs for them.
- To suggest the best suitable method for treatment of the organic food waste in the Södertörn area in Sweden and in the Yavoriv Region in Ukraine, using the experiences of the different treatment plants in Sweden and taking into account different aspects of these two regions.

1.2. Methodology of work

The information, which is used in this Thesis Work, was collected through:
- personal interviews or interviews by phone with contact persons from composting and fermentation plants; from companies, which produce equipment for these plants; from companies, which produce equipment for sorting the waste; from the associations, which establish requirements for the composting and fermentation plants for getting the quality certification and approval;
- e-mails from the representatives of different companies;
- visits to some composting and fermentation plants;
- brochures, which I got from some companies and plants;
- Internet from the home pages of some companies and plants; from different articles about biological treatment methods of organic waste;
- from the literature about biological treatment methods of organic waste.

1.3. Scope and limitation of study

The main attention in this report is focused on different composting methods and fermentation techniques which are used in Sweden (exception is Rotocom rotary composting system, which is not used in Sweden). There are a lot of other biotreatment methods used all over the world, but because of the limitation of time, given for this work, it was impossible to distinguish all composting and fermentation systems.

The same situation goes for the sorting methods, which are used for sorting of organic waste. The sorting methods, described in the report, are common for Sweden, but also some of them are spread in other countries.

Under organic waste mainly food waste (from households, restaurants, supermarkets, institutional kitchens and food industry) is described. Sometimes green waste from gardens and parks (for
composting) and slaughterhouse waste and manure (for fermentation) is included, since food waste is co-treated with these kinds of organic waste. Other types of organic waste, such as plastic, textiles, paper and other organics, are not distinguished and the methods for handling or recycling them are not overviewed.

In the analysis and discussion mainly technical aspects are taking into the account to compare the different composting and fermentation systems. Economical side also plays some role in it, but relative role, since it was difficult to make own correct calculations for the SRV and for Ukraine. The figure I got from other companies can not be translated to the SRV, or even more to Ukraine, because the different companies are not the similar, are not with the same conditions, are not on the same stage of process developing and they need different kinds of work, consequently the prices will differ from each other.

1.4. Outline of the report

To describe all information for fulfilling the aim and objectives of this Diploma, the report is divided on 9 chapters. These chapters with the brief descriptions of the content are listed below:

1. Introduction
The chapter describes the aim and objectives of the Thesis Work, methodology of work, background and description of the problems in the two regions.

2. The study area
This chapter gives general information about the Södertörn Area in Sweden and the Yavoriv Region in Ukraine, and also the characteristic of organic waste situation in these two areas.

3. Means of control for organic food waste handling
The main regulations, national and regional goals, requirements for the certification and approval of composting and fermentation plants for handling the waste in Sweden, and legislation in Ukraine in waste handling sphere are written.

4. Biological treatment of organic food waste
This chapter highlights the theoretical information about composting and fermentation of organic waste.

5. Sorting the organic food waste
Several sorting methods of organic waste which are used in Sweden are overviewed in this chapter.

6. Biological treatment of organic food waste done in Sweden and Ukraine
This chapter describes all biological treatment methods used in Sweden and Ukraine, their advantages and disadvantages, investment and treatment costs of these methods, experiences of plants from using them, etc.

7. Biological treatment of organic food waste done in Sweden and Ukraine
Situation concerning the biological treatment of organic waste in Ukraine is described in this chapter.

8. Discussion
All information about different biotreatment and sorting methods of organic waste is analyzed and some solutions for treatment the waste in the best way for the SRV and the Södertörn Area in Sweden and the Yavoriv Region in Ukraine are discussed and suggested.

9. Conclusions
The main conclusions from this Thesis Work are stated in this chapter.
1.5. Background

This Master Thesis “The Biological Treatment of Organic Food Waste” in Master’s Programme in Sustainable Technology done at the Royal Institute of Technology (KTH) in co-operation with the company SRV återvinning AB.

This work is written to find solutions for the company SRV återvinning AB and the Södertörn area in Sweden at the same time, and for the Yavoriv Region in Ukraine in some their problems, and also in how to provide the handling of organic waste in a biological way to fulfill their intentions in following the corresponding regulations, to create more clear environmental profile of activity and to improve the environmental situation in the regions.

At first, this work was planning to be like comparison between Sweden and Ukraine, their environmental situations and problems, biological treatment methods used for handling the organic waste, experiences of using them in these two countries. During the work, it became understandable that, in practice, there is no sorting and biotreatment of organic waste in Ukraine. So, now the project describes the Swedish experiences of using different sorting and biotreatment methods, and basing on that, some solutions for the SRV are proposed. Also, according to that information, some suggestions are given for Ukraine to develop biological treatment of organic waste there.

Due to this, I think this Thesis Work will be interesting both for the SRV and the Södertörn Area in Sweden and for the Yavoriv Region in Ukraine.

1.6. Description of the problems

1.6.1. In the Södertörn area in Sweden

The company SRV återvinning AB is responsible for the treatment of organic waste of the Södertörn area in a biological way. The company has a site for treatment the waste called Sofielund, where the fermentation, composting and landfill of waste take place.

There is an open (windrow) composting of food waste from households (waste comes from Sollentuna waste collecting facility), organic food waste from supermarkets and green waste from gardens and parks (these wastes come mainly from the Södertörn area and Stockholm area). Crushed green waste is mixed with food waste and is put into the long piles for about 7 months. During the process the material is returned (once a week) to relieve the access of air to all parts of composting material. After the compost is ready, uncomposted material (like plastic, metal things, etc.) is separated and uncontaminated compost is mixed with the soil or is sold to other companies. Mixing the material with soil is done to be able to use this compost for the plantation of plants or as a soil improver. Also the compost can be mixed with the sand and used in the construction industry. Separated residue material after the composting was brought to the landfill before 2005, but now, since it is not allowed more, it goes to the incineration. So, one of the option to solve is to reduce the amount of residue, which is got after the sieving of the compost.

Organic household waste for treatment SRV gets from Sollentuna kommun, which collects the waste from different regions. The waste is put in a special kind of plastic bags for organic waste; these bags are broken down during the composting process. These bags are spread among households for free. Sometimes to avoid bad smell, people make too big knot on these bags, and plastic of high density in one place is difficult to be composted – this is another problem, since ready compost consists of small particles of this not yet degraded plastic material.

There is no sorting of household organic waste in the Södertörn area. Households put their waste in two bins: one bin is for burnable waste; and the second one is for incombustible waste. Food waste
is put to the first bin together with other combustible waste and then all these wastes go to the incineration. In order to follow the National goal, it is desirable if as much as possible organic waste will be treated by biological means. The SRV wants to reach this aim.

In the Södertörn area restaurants have to sort out their organic waste, according to local law (renhållningsordning).

The amount of waste, which was composted at Sofielund during 2004, was 7 242 t/y of food waste and 6 945 t/y of green waste, but the plant has a permission to compost of 15 000 t/y of food waste and the same amount of green waste [5]. So, it would be good to increase the treatment capacity of the composting plant.

The fermentation plant is not working at the moment because of problems in the equipment. The capacity of this plant is 4 000 t/y of organic waste, when the permission is for treatment of 50 000 t/y of waste [5].

So, the main problems, which SRV would like to solve, are the following:
- to reduce the smell during the composting process;
- to reduce the time of the composting process;
- to increase the capacity of the composting process;
- to increase the quality of composted material;
- to decide whether to build a new fermentation plant of bigger capacity;
- to get the approval from SJV and quality certification form SP and RVF;
- to follow the EU Directives, Swedish laws, National and Regional goals.

1.6.2. In the Yavoriv Region in Ukraine

One of the main problems for the Yavoriv Region is that 50% of its land is destroyed due to the production and extraction of sulphur and mining works of the chemical plant “Sirka” (“Suphur”). This company is closed now, but there are a lot of quarries left after that activity. A zone of influence of mining is about 90 km² [6]. At the moment some of these quarries are being flooded with water from the rivers Shklo and Gnoyenec. There are a lot of other quarries still left and an environmentally sound solution of this problem should be found.

Another problem is that there are a lot of spontaneous dumping sites in the region where different kinds of waste are put without any sufficient care. These places are the sources of spreading different deceases, contamination of soil, ground water and air pollution, odour problems from the organic fraction; and also take a lot of land space which could be used more reasonable. That is why it is important to separate the organic waste from the residual waste and treat it properly, but there is still no waste treatment in Ukraine.

To solve these problems, to improve the environmental situation in the region, the biological treatment methods of organic waste can be used.
2. The Study Area

In this Thesis Work the main attention is focused on organic waste handling, especially food waste, in Sweden (the Södertörn area) and Ukraine (the Yavoriv region), using biological treatment methods. To be possible to compare the usage of these biotreatment methods in these two countries and suggest the best methods of food waste handling there, at first general characteristic of Sweden and Ukraine should be overviewed, that is geographic and climate characteristic, economic, social and environmental characteristics, etc.

These both countries are situated in Europe but there are a lot of differences between them, especially in economic development and in environmental awareness and protection (Figure 2.1).

![Figure 2.1. The map of Europe](image)

2.1. General information about the Södertörn Area in Sweden

2.1.1. Geographic and climate characteristics

Sweden is situated in the Northern part of Europe. The capital of Sweden is Stockholm. Stockholm is situated in a coastal area in the southern part of Sweden. The city lies between an archipelago and lake Mälaren. The climate is typical for Nordic countries: the average temperature is 6.6 degrees Celsius. Normally there are 116 frost days. In Stockholm area it rained at least 1 mm on 91 days [8].
There are 21 counties in Sweden. The Södertörn area is a part of Stockholm County (Stockholms län) and lies on the south of it (Figure 2.2). The county of Stockholm has the highest density of inhabitants of the Swedish counties and about 20% of the population of Sweden is living in the County. In the Södertörn area there are about 276,000 inhabitants. The territory of the region is about 1,200 km². This area consists of 5 municipalities: Huddinge, Haninge, Salem, Nynäshamn and Botkyrka. Most of the population of the Södertörn area lives the urban areas. Huddinge is the most density-populated area, it covers an area about 130 km² with the total population of about 83,000 inhabitants [9, 10, 11, 12, 13].

![Figure 2.2. The map of the Södertörn Area in Sweden](image)

### 2.1.2. Regional economic and industrial situation

Sweden is well-developed country with strong economy. Its activity is based on different commercial and industrials sectors. There are a lot of companies active within most industries; a lot of them are represented in the Södertörn area. At the same time, there are also some farms in the region, which cultivate crops and breed livestock.

Obvious profiles in the Södertörn area include Kungens Kurva, which is the Huddinge region's largest commercial centre, Flemingsberg with its research into primarily biotechnology and biomedicine, and the Länna Corporate Estate with factories, logistics and manufacturing activities. Large companies like Ericson Radio Systems AB, Statoil Lubricants and Teligent are situated in the Nynäshamn municipality. There are also a lot of small and medium sized enterprises in the five municipalities of the Södertörn area. The commercial activity is supported through local business networks [15, 16].

### 2.1.3. Environmental and Waste management status

Sweden has for a long time been a country with “green” ideology and always tries to take care of the environment. That is why there are no very many severe and dangerous problems in the country and in the Södertörn area, which would influence the environment and people health.

Instead main attention is focused on improving already existing legislation and treatment methods for handling the waste, source separation the waste, etc.

The largest amount of waste in Sweden is generated by industry. Specific and hazardous waste is managed in a respective way according to the legislation about the industrial and producer responsibility (See chapter 3.1).

Also a lot of waste is generated by households. All municipalities in Sweden are responsible for taking care of household waste.
One of the areas, in which Sweden has been in the forefront, is recycling, particularly for household waste. Most Swedes have to carefully recycle and separate their own waste for the refuse collectors on a daily basis. Even in the midst of winter, in raging snowstorms, you can see people in front of the recycling stations with their household waste. It shows that public awareness of the benefits of recycling is very high. In Sweden, environmental awareness starts early, since from the kinder gardens young children are already taught the basic skills and benefits of sorting waste for recycling [17, 18].

The Swedish Association of Waste Management, RVF, has noted that as much as 80% of household waste is now recovered for use as material, energy, or soil nutrients. Approximately 30% of household waste, or 145 kg per inhabitant, is recycled for material [18]. While there are many possible factors for Swedes’ interest in recycling, RVF believes that increased information drives have contributed to changing people’s behaviour, motivating them to separate waste for material recycling, and encouraging them to help reduce the amount of household waste, which is sent to landfills.

There are a lot of composting and biogas plants in Sweden. Most composting plants (approximately 100) are rather small (<5 000 tons/annual), and about 25 composting plants are considered to be large. 12 anaerobic digestion plants are working and several new large-scale biogas plants are planned [1]. The latter development is very much encouraged by government and society, especially when the generated biogas is used as a fuel for vehicles.

The Södertörn area is involved in biological treatment of organic waste, since it has a fermentation and composting plant. Anyway to increase the environmental performance of the region and in order to follow the corresponding regulations (see chapter 3), some improvements have to be done in the area, such as implementation of source sorting system of household waste, more advanced biotreatment methods, etc.

In the meantime, interest in recycling and responsible waste management is helping Sweden to protect its environment for generations to come.

2.2. General information about the Yavoriv Region in Ukraine

2.2.1. Geographic and climate characteristics

Ukraine is situated on the east of Europe. The capital of Ukraine is Kyiv. Ukraine is divided into 24 administrative regions called oblast. Lviv Oblast is situated in the western part of Ukraine. The Yavoriv Region is located in the northern-western part of Lviv Oblast (Figure 2.3). The regional center of this region is the town Yavoriv. The territory of the region is 1 548 km² and is divided between 2 town (Yavoriv and Novoyavorivsk), 4 settlement (Ivano-Frankove, Nemyriv, Krakovec, Shklo) and 31 village councils (there are 132 villages). The region consists of 123 500 inhabitants, among them there are 56 000 inhabitants – urban population and 67 500 inhabitants – rural population [6].

The Yavoriv region belongs to temperately warm, enough humid climatic zone. The average annual temperature of air is +7.5°C. The duration of frostless period is 160 days. The average annual amount of atmospheric precipitation is 580-840 mm. The relative humidity of air is high – 70-80% [6].
2.2.2. Regional economic and industrial situation

Ukraine is middle developed (transitional) country with not strong economical situation in there. There are a lot of industries in Ukraine, and at the same time it still has a lot of agricultural activity.

The main industrial potential in the Yavoriv Region was the production of sulfur. The level of sulfur extraction was approximately 600 000 tones per year. The production and sales of those products were managed by state owned chemical company “Sirka” (“Suphur”). Small and middle enterprises and trades are broadly developed in the region as well. One more direction of the industry development in region is the oil and gas extraction. The reserves of investigated gas sources are about 1 900 million m$^3$ and investigated oil sources are about 10 million tones [6].

The Yavoriv region mainly consists of settlements and villages, so the main type of population employment there is agriculture and forestry. About 35% of the Yavoriv land is covered with forests [6]. And that is why manufacturing industry is in process of wide development. The sector of agriculture consists of collective village, farmers and individual agricultural farms, which produce the wheat, potatoes, vegetables, meal and milk and cultivate breed livestock.

2.2.3. Environmental problems

In contrast to Sweden, Ukraine doesn’t have enough money and respective legislation to pay significant attention on environmental protection.

The main method of handling the waste in Ukraine is landfilling. There are 770 landfills in Ukraine. Most of landfills (80-90%) work in the overloaded regime without any preventive measures to avoid contamination of ground waters and air basin. All these landfills are situated closed to the cities and big towns and take waste just from urban areas. In the rural areas all wastes are taken to the boundary of villages and are put in the natural hollows (gullies, ditches, etc.). Also often waste are removed to the forest glades, fields, other places, which are not provided to be used as landfills. There are about 1 000 huge spontaneous dumping sites of waste in Ukraine, which corresponds to about 66% of all landfills in the country [19].

Councils (municipalities) in Ukraine provide sanitary cleaning and collecting the waste with special trucks just for 52% of country population and only in urban areas [19]. There is no system of collecting and handling the waste in small towns and rural areas.
There are four incineration plants in Ukraine: in Kyiv, Sevastopol, Harkiv and Dnipropetrovsk. Their capacity is 1.2 million tons of waste per year or 12% of the total volume of them [19]. All these incineration plants are physically and morally obsolete. And the activity of Ukrainian incineration plants is recognized as dangerous. There are no incineration plants in the Yavoriv Region.

According to the Yavoriv region, the main environmental problems there, concerning the waste, are the following:

- Contamination of water objects;
- Absence of purifying structures in towns and settlements of the region;
- Inobservance of requirements of environmental protection legislation;
- A lot of territory of the region is contaminated with economical household waste and waste from mining industry;
- Insufficient recultivation of disturbed soils;
- Pollution of atmospheric air with exhausted gases from motor transport.
- Contamination of environment by pesticides and chemical pesticides.

And also:

- Elemental landfills take a considerable squares of arable lands and populated areas;
- Elemental (spontaneous) landfills are the source of contamination of arable lands, which are closed to these landfills;
- The landfills are the places of reproduction of agricultural vermins (pests) [6].

There are almost no certificated landfills in the region. Regional councils (municipalities) control the work of village landfills insufficiently. Absence of costs for sufficient maintenance of landfills and insufficient attention from municipalities lead to inobservance of environmental and sanitary legislation on these objects.

2.3. Characteristic of the organic waste situation

_Waste_ is any substance or object, which is included in a category of waste, and which the owner disposes of or intends to or is obliged to dispose of (the definition is stated in EC Waste Framework Directive 75/442/EEC 1975).

The following wastes belong to **organic waste**:

- paper;
- plastic;
- yard waste;
- wood;
- food;
- textiles; and
- other organics.

This Thesis Work is devoted to food waste and different biological treatment methods to handle this type of waste. But also other kinds of biodegradable waste will be mentioned in this work since food waste is co-treated with them.

The **biodegradable waste** includes food and garden waste, paper and board, wood and some textiles and therefore has a potential to be composted or digested [20].

If try to compare amount of different kinds of waste in developed, transitional and undeveloped countries (*Table 2.1*), one can see that developed countries are the producers of mainly paper and organic waste, when transitional and undeveloped countries produce mostly organic waste and other wastes take much smaller parts of total amount of countries’ waste.
Table 2.1. Distribution of waste by categories in different countries [19]

<table>
<thead>
<tr>
<th>Category of waste (% of total mass (weight))</th>
<th>Developed</th>
<th>Transitional</th>
<th>Undeveloped</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>34</td>
<td>16</td>
<td>1.5</td>
</tr>
<tr>
<td>Organics</td>
<td>26</td>
<td>45</td>
<td>64</td>
</tr>
<tr>
<td>Others</td>
<td>12</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>Glass</td>
<td>11</td>
<td>1.5</td>
<td>4</td>
</tr>
<tr>
<td>Plastic</td>
<td>7</td>
<td>12</td>
<td>0.5</td>
</tr>
<tr>
<td>Metals</td>
<td>7</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Textile, rubber, leather</td>
<td>3</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

So, since organic waste occupies a significant part of waste produced in different countries and because of the environmental problems they cause, this waste should be taken into special account and be handled in environmentally friendly way.

2.3.1. In Sweden and the Södertörn area

The concept of household waste and comparable waste comprises waste in bins and bags, bulky waste, including green waste, hazardous waste, and shop and office waste. In addition to this there is the share of household waste covered by producer responsibility, which goes to recycling or is recovered in some other way (for example, energy recovering), such as newspaper, packaging waste, and waste from electric and electronic equipment. In 2003 waste from households was to a large extent recycled through incineration (38%) or through recycling of material (29%). A minor part of the household waste was treated in biological treatment plants and the remaining part was landfilled. Waste from production industry was to a great extent recycled through recycling of material or recycling of energy through incineration of waste. In 2003 more than 75% of the waste from production industry was recycled and 14% was landfilled [21].

In 2004 the total quantity of household waste in Sweden amounted to 4 168 580 tons (463 kg per inhabitant), in comparison to 2003 it is more or less the same [22]. Spot checks of waste in bins and bags conducted in several municipalities in recent years have shown that a single-family house produces 11.3 kg and a flat 7.2 kg of waste per week in bins and bags [4]. The spot checks also show that households have succeeded well in separating their hazardous waste.

About 35 percent of the Swedish municipalities have separate collection of compostable household waste with central treatment. 344 500 t of organic waste (105 000 t household and restaurant waste + 239 500 t green waste) was recovered in 2004 [1].

2.3.2. In Ukraine and the Yavoriv region

The annual amount of household waste in Ukraine is 38-40 million m³ or approximately 10 million tons per year. The total amount of solid household waste is about 1 billion tons annually (Table 2.2) [19].
Table 2.2. Morphological composition of household waste in Ukrainian cities [19]

<table>
<thead>
<tr>
<th>Type of the waste</th>
<th>In average, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food waste</td>
<td>25</td>
</tr>
<tr>
<td>Paper</td>
<td>20</td>
</tr>
<tr>
<td>Wood</td>
<td>3</td>
</tr>
<tr>
<td>Textile</td>
<td>4</td>
</tr>
<tr>
<td>Metals</td>
<td>10</td>
</tr>
<tr>
<td>Glass</td>
<td>12</td>
</tr>
<tr>
<td>Leather, rubber</td>
<td>3</td>
</tr>
<tr>
<td>Plastic</td>
<td>5</td>
</tr>
<tr>
<td>Siftings</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
</tr>
</tbody>
</table>

Ukraine belongs to transitional countries and the composition of waste is similar to such type of countries.
3. Means of control for organic food waste handling

The main driving force, incentive to changes for development in an environmentally friendly way for different kinds of activities in any countries are different laws, regulation, ordinances, which state requirements for companies, plants, enterprises and which have to be fulfilled and implemented in the industrial sector. There are a lot of means of control, which affect the organic waste handling in Sweden, and there is some legislation in Ukraine. The main means of control will be overviewed in this chapter.

3.1. EU/Swedish laws, regulation and ordinances

More than 30 years ago, Sweden hosted the United Nations Conference on the Human Environment. This international event placed the environment on the global political agenda, and for a number of the participating member nations it was the foundation for greater insight into environmental threats. Since then the Swedish government implemented environmental policies that led to significant results in a number of areas, for instance in reducing hazardous substances in products and waste and in promoting material recycling and energy recovery from waste [23].

A growing proportion of legislation affecting Sweden is enacted by the European Union. Some of these laws apply directly, without prior sanction by the Riksdag, while others must be implemented in existing Swedish legislation before they can take effect.

Also different laws very strictly regulate waste management in Sweden. All Swedish environmental legislation is gathered in an environmental act having several laws connected to regulating different fields of environmental problems. Waste management is controlled by the law of waste management, laws regulating landfill, producer responsibility, waste transport and law of environmentally hazardous activity. Swedish legislation on waste management also agrees with European legislation on waste management since Sweden is a member of the European community.

The European community has suggested a “waste hierarchy” which describes the environmental priority between different treatment options for waste:

- **waste minimisation** – avoiding production of waste by optimising production and consumption;
- **reuse** – using the same product longer and possibly in several ways decreases the total environmental impact of the product;
- **recycling** – making some kind of use of the waste, it also could be composting and digesting;
- and **landfill** – waste is put to a landfill and is not used in any way [21].

Waste management in Sweden has three major groups of organisations that in different ways have the ultimate responsibility for taking care of different types of waste. Responsibility in a juridical sense, in practice the everyday handling of waste is generally handed over to a waste management contractor or a company owned by the local council.

**Local councils.** The local councils are responsible for all kinds of waste produced by households. Organic waste, which is put in bins, is collected by truck and transported to some kind of treatment plant. Other wastes, such as furniture, electronic products, hazardous waste, etc., are supposed to be delivered to recycling centres where the waste is manually sorted in different containers for different treatment of different kinds of waste.

**Producer responsibility.** Producers of some specific products have a responsibility for taking care of their product once it is turned into waste. Producer responsibility is supposed to have an environmental positive effect by influencing producers to produce products that are easier to recycle and have a smaller environmental impact. In 1993, the principle of extended producer responsibility was made mandatory by law in Sweden for the purpose of dealing with waste...
problems at an early stage in the production process, i.e. when designing a product, selecting materials and manufacturing the goods. If you are a producer of packaging, tyres, waste paper, motor vehicles, electrical and electronic products, newspaper, you have the producer’s responsibility to see whether it is collected and treated in an environmentally safe way. In practice producers of each type of waste have formed a trade association to be able to organize collection and recycling systems.

**Industry and other producers of waste.** Industry and other producers of waste such as shops, shopping centers, hotels, farms and any other plant separate from a household are responsible for their own waste. In practice minor companies and plants have the opportunity to use the waste management systems organized by the local councils. Larger industries do however usually engage a waste contractor and sometimes have their own recycling and waste treatment systems. They are responsible for all kinds of waste, which are produced in industry and enterprise activity, including agriculture and forestry [21, 24].

In 1999 the Environmental Code came into force, replacing several separate laws. It is the main legislation, like “umbrella”, for different acts concerning the physical environment [25]. Also the Agenda 21 document was established and it states that many of the best methods to achieve sustainable development in the future will have to be developed at the local level. All 290 Swedish municipalities implemented Agenda 21 and have widened their scope from sustainable development to include environmental affairs as well [18].

In 2001 a new law was taken, banning landfilling of organic waste from 2005 and combustible waste from 2003. This law is currently one of the most discussed and important laws in Swedish waste management as it in practice very much restricts the possibility to landfill in advantage of incineration, biological treatment and recycling. Another new feature in Swedish legislation is tax on landfilling. This tax has almost the same effect as prohibiting landfilling of combustible and organic waste, and increasing of incineration. To encourage biological treatment and recycling a tax on incineration is being discussed [21].

From the 1 of January 2002 in Sweden combustible waste has to be collected separately and may not be landfilled. On 1 January 2003 the tax on landfilling waste was raised to SEK 370 per ton. The tax has thus risen by almost 50 per cent since it was introduced in 2000 [18].

In December 2002 the government issued an ordinance and regulations on the incineration of waste. This means that the EU directive was then introduced in Swedish legislation.

In May 2003 the government presented its bill “A Society with a Non-toxic and Resource-saving Ecocycle” (2002/03:117), which is based on an agreement between the Government, the Left Party and the Green Party. The most important things of this bill are:

- The government wants to increase biological recycling and proposed new interim goals for biological treatment of food waste from households, restaurants, large-scale catering centres and shops, and food and similar waste from the food industry, etc.
- The collection of hazardous waste from households should be improved, and the government clarifies the responsibility of municipalities in this field. Hazardous waste should not be transported to incineration plants and mixed with other waste
- The owner of waste will have statutory responsibility for waste, which is not the responsibility of local authorities or producers. This will make it clear that the waste-owner should consider recycling and making use of the possibilities it presents.
- The government clarifies that producers will continue to have full responsibility for collecting packages and newspaper from household waste.
- The local authorities will have greater influence on planning, coordination, and information within producer responsibility. This is also clarified in changes to the ordinances.
- The requirements for waste incineration must be made stricter. The Government considers that waste for incineration should be well sorted, classified and controlled.
- Wastes that are suitable for recycling have to be separated from other waste at source.
- Waste management planning has to be strengthened at municipal, regional and national levels [4, 26].

In June 2003 the Swedish Environmental Protection Agency presented new general recommendations for composting and digestion NFS 2003:15 [27]. These also meant tougher environmental requirements concerning materials for biotreatment and treatment conditions.

Since 2005 it is not allowed to landfill organic waste in Sweden. There is a landfill tax as well [18].

Altogether, this means that recycling of organic waste is promoted and the capacity of biological treatment is increasing.

3.1.1. Regulation on animal by-products (EC No 1774/2002)

The main regulation for composting and biogas plants is the Regulation on animal byproducts (EC) No 1774/2002. To be allowed to handle animal by-products (meat, manure, digestive tract content, milk, bones and skins, fish and shells, etc.), composting and fermentation plants have to follow this Regulation. Biotreatment plants, which handle only food waste from kitchens, are exempted from the ordinance, and simplified rules will be drawn up for them. Until these are ready, national legislation should be applied [4].

Animal by-products are the parts of a slaughtered animal that are not directly consumed by humans, including dead on farm animals and catering waste (i.e. food waste originating from restaurants, catering facilities and kitchens) that contains or has been in contact with meat products, whether cooked or uncooked. Some of these products are used in animal proteins like meat-and-bone-meal, fats, gelatin, collagen, pet food and other technical products, such as glue, leathers, soaps, fertilizers, etc. [28].

The EC ordinance on animal by-products came into force on 1 May 2002. It replaces the National Board of Agriculture’s ordinance SJVFS 1998:34. This revised EU Regulation (EC) No 1774/2002 classifies animal waste in order to certify the correct handling before other treatment or processing occurs. The ordinance divides animal waste into three categories, each associated with a different treatment method. The regulation includes rules about how animal waste shall be handled to minimize possible contamination from pathogens. And also all out sorted household waste, catering or restaurant waste are included but not private home composts.

The new Regulation on animal by-products was adopted by the European Parliament and the Council applies it on 1 May 2003. It introduces stringent conditions throughout the food and feed chains requiring safe collection, transport, storage, handling, processing, uses and disposal of animal by-products. It sets up a completely new approach. In the past, raw material of a lower health standard than the one used for human food were permitted for use in animal feeds. For example, animals that died on farm and were unfit for human consumption could enter the animal feed chain. This practice of recycling cadavers and material unfit for human consumption into the feed chain was the main factor in the spreading of the TSE epidemic, but also of other food scandals, such as the dioxin crises and foot and mouth disease. This practice is now prohibited [28].

Animal waste used to be classified in to two categories; low-risk and high-risk waste. In the revised Regulation, as was mentioned above, the classification is made in to three categories based on their potential risk to animals, the public or to the environment, and sets out how each category must or may be disposed of.

Category 1 material comprises, for example, Special Risk Materials (residues of prohibited substance e.g. hormone used for growth promotion, or environmental contaminants e.g. dioxins, PCBs) and waste from animals suspected of being infected by TSEs (Transmissible Spongiform
Encephalopathies\textsuperscript{1}. Also catering waste from trains, boats and airplanes operating internationally is included in this category. These materials must be completely disposed of as waste by incineration or landfill after appropriate heat treatment. Recycling of Category 1 material through biological treatment is not allowed.

**Category 2 material** includes animal waste or by-products other than Category 1 material or Category 3 material, for example, animal by-products presenting a risk of contamination with other animal diseases (e.g. animals which die on farm or are killed in the context of disease control measures on farm, at risk of residues of veterinary drugs, to eradicate epizootic disease or for some other reason considered unfit for human consumption). Waste of this category can be processed through biological treatment (digestion, composting) or landfill preceded by sterilization at 133°C, or incineration.

Only **Category 3 material**\textsuperscript{2} comprises, for example, waste from parts of animals that has been inspected and declared healthy (i.e. by-products derived from healthy animals slaughtered for human consumption) and may be used in the production of feeds following appropriate treatment in approved processing plants. This category also includes catering waste and household waste and can be processed through biological treatment after hygienisation at 70°C for 1 hour [29].

Category 2 and 3 waste can, after being processed according to the regulation above, be used for agricultural purposes except for one restriction: bio-fertilizers are not allowed to be used on pasture grounds (RVF- Sweden) [30].

Compost and digestate consisting of separated biological household waste is approved for use as fertilizer in ecological cultivation.

### 3.2. National and Regional Goals

In April 1999 the Swedish Parliament adopted fifteen National Environmental Quality Objectives, describing what quality and state of the environment and the natural and cultural resources of Sweden are environmentally sustainable in the long term. In a series of decisions from 2001 to 2003, Parliament subsequently adopted a total of seventy-one interim targets, indicating the direction and timescale of the action to be taken to move towards these fifteen objectives (Figure 3.1).

Ultimately, Parliament’s efforts to attain the environmental quality objectives are concerned with ensuring that the next generation – our children and grandchildren – and generations to come are able to live their lives in a rich and healthy environment [31].

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\textsuperscript{1}TSE – infectious deceases of animals and humans that are caused by a deterioration of brain tissue; are progressive and always fatal.

\textsuperscript{2}More detailed description of Category materials is in the Appendix 1.
The 15 environmental quality objectives are the following:

1. Reduced Climate Impact
2. Clean Air
3. Natural Acidification Only
4. A Non-Toxic Environment
5. A Protective Ozone Layer
6. A Safe Radiation Environment
7. Zero Eutrophication
8. Flourishing Lakes and Streams
9. Good-Quality Groundwater
10. A Balanced Marine Environment
11. Thriving Wetlands
12. Sustainable Forests
13. A Varied Agricultural Landscape
14. A Magnificent Mountain Landscape
15. A Good Built Environment

From these fifteen objectives only the 15th National Quality Objective “A Good Built Environment” is interesting in case of biological treatment of organic food waste. This objective says: “Cities, towns and other built-up areas must provide a good, healthy living environment and contribute to a good regional and global environment. Natural and cultural assets must be protected and developed. Buildings and amenities must be located and designed in accordance with sound environmental principles and in such a way as to promote sustainable management of land, water and other resources”. This objective is intended to be achieved within one generation.

The outcome within a generation for this Environmental Quality Objective should include the following:
- Land and water areas are free of toxic and dangerous substances and other pollutants.
- The use of energy, water and other natural resources is efficient, resource saving and environmentally sound; the preferred energy sources are renewable.
- The quantity and dangerousness of waste are decreasing.
- Waste and residues are separated by categories and recycled on a cooperative basis by urban areas and the surrounding rural areas.

Some of the Interim targets of the “A Good Built Environment” Quality Objective are listed below:
- **Interim target 5, 2005.** The quantity of waste disposed of to landfill, excluding mining waste, will be reduced by at least 50% by 2005 compared with 1994, at the same time as the total quantity of waste generated does not increase.
- **Interim target 6, 2008.** All landfill sites will conform to uniform standards by 2008 and will meet stringent environmental requirements in accordance with Council Directive 1999/31/EC on the landfill of waste.
- **Interim target 9, 2010.** By 2010 at least 35% of food waste from households, restaurants, caterers and retail premises will be recovered by means of biological treatment. This target relates to food waste separated at source for both home composting and centralized treatment.
- **Interim target 10, 2010.** By 2010 food waste and comparable wastes from food processing plants etc. will be recovered by means of biological treatment. This target relates to waste that is not mixed with other wastes and that is of such a quality as to be suitable, following treatment, for recycling into crop production [31, 32].

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3 There are just some outcomes within generation; the rest is listed in Appendix 3.
4 The rest Interim targets are in the Appendix 3.
According to National goals, the government is responsible for following them. On the regional level the regional state authority, County Administrative Board (Länsstyrelse) is responsible for following the regional goals. It is seeing to that national interests are taken into account in planning, that laws are implemented and that governmental directives are followed. Issues like implementing the national regional development policy, transport policy and environmental policy are the responsibility of the county administration.

In connection to the national goals, the counties have formulated the regional situation in the regional environmental goals. In the Environmental Code from 1999 there are regulations on environmental quality standards. The standards are tools for reaching the national environmental goals and in addition, they are necessary in order to fulfil EU membership obligations [33].

There are some proposals for regional environmental goals for Stockholms län (Stockholm County), which are not implemented yet:
- At least 35% of food wastes from households, restaurants, big kitchens and stores in county will be recycled by the biological treatment till 2010 at latest.
- Food waste and comparable waste from food industries in a county will be recycled by biological treatment till 2010 at latest [34].

According to Swedish legislation all municipalities have drawn up waste management plans comprising all kinds of waste generated within the municipality. The aim of the waste management plans is to establish goals, strategies and action plans in order to improve the handling of waste from an environment point of view.

The municipal waste management plans deal with matters as waste avoidance and waste minimisation, information and education activities, economical incentives like differentiated waste handling fees, etc., source separation, collection and transportation of waste and waste fractions. The regional waste handling plan focuses on the treatment, recycling and final disposal of waste.

3.3. Approval and certification of composting and fermentation plants

To follow the rules, to be more attractive in eyes of customers, to have an opportunity to sell products easier and get more profit from it, it is very important for companies, including biogas and composting plants as well, to be approved by the competent authorities and have a quality certificate for compost and digestate, which they produce.

3.3.1. Approval by SJV

Biogas and composting plants shall be a subject to approval by the competent authority. Such competent authority in Sweden, which gives approval for biogas and composting plants, is Swedish Board of Agriculture (SJV) ⁵. These plants are approved by SJV according to Regulation (EC) No 1774/2002. This approval allows the plants to treat the animal by-products and it means that plants are able to produce compost or biomanure, which can be used as a fertilizer for the arable land.

To be approved by SJV, biogas and composting plants must do the following:
- meet the requirements of Annex VI, Chapter II, Part A of Regulation (EC) No 1774/2002;
- handle and transform animal by-products in accordance with Annex VI, Chapter II, Parts B and C of the Regulation;
- be checked by the competent authority in accordance with Article 26;
- establish and implement methods of monitoring and checking the critical control points;

⁵ SJV, the Swedish Board of Agriculture, is the Government's expert authority in the field of agricultural and food policy, and the authority responsible for the sectors agriculture, horticulture and reindeer husbandry. Its responsibility therefore includes monitoring, analysing and reporting to the Government on developments in these areas, and implementing policy decisions within its designated field of activities [35].
ensure that digestion residues and compost, as appropriate, comply with the microbiological standards laid down in Annex VI, Chapter II, and Part D.

The main specific requirements for the approval of biogas and composting plants\textsuperscript{6}, which are listed in the Regulation, are listed below [29]\textsuperscript{7}.

**Premises**

To be able to get the approval from SJV, biogas plants must be equipped with a pasteurization/hygienisation unit, which should have installations for monitoring temperature against time, recording devices to record the results of these measurements continuously and an adequate safety system to prevent insufficient heating; and with adequate facilities for cleaning and disinfecting vehicles and containers on leaving the biogas plant.

Now there is a report from RVF "Effektivitet av fordonsdesinfektion för transport av biogödsel. RVF. Utveckling 2005:04" where is written how to fulfill these requirements [36].

Composting plants, to get the approval, must be equipped with a closed composting reactor, which should have installations for monitoring temperature against time, recording devices to record the results of these measurements continuously and an adequate safety system to prevent insufficient heating; and with adequate facilities for cleaning and disinfecting vehicles and containers transporting untreated animal by-products.

Each biogas plant and composting plant must have its own laboratory or make use of an external laboratory. The laboratory must be equipped to carry out the necessary analyses and approved by the competent authority.

Also to be approved, composting and fermentation plants should follow the Specific requirements for the processing of Category 1 and Category 2 material (see chapter 3.1.1).

**Hygiene requirements**

Only manure and digestive tract content from Category 2 material and Category 3 material may be transformed in a biogas or composting plant, according to the requirements of SJV. If a plant wishes to process other Category 2 material, it has to be processed in an approved plant according to article 5 in the Regulation before going to the biogas or composting plant. And it is not allowed to bring Category 1 material to a biogas or composting plant.

Also the following hygiene requirements should be held:
- animal by-products must be stored properly until treated;
- containers, receptacles and vehicles used for transporting untreated material must be cleaned in a designated area;
- preventive measures against birds, rodents, insects or other vermin must be taken systematically;
- cleaning procedures must be documented and established;
- hygiene control must include regular inspections of the environment and equipment; etc.

**Processing standards**

Category 3 material used as raw material in a biogas plant equipped with a pasteurisation/hygienisation unit must be submitted to the following minimum requirements: maximum particle size before entering the unit – 12 mm; minimum temperature in all material in the unit – 70 °C; and minimum time in the unit without interruption – 60 minutes.

\textsuperscript{6} More detailed information about these specific requirements is in Appendix 2.
\textsuperscript{7} All these requirements are taken from the literature 29, except of some information where references are pointed out.
In a composting plant Category 3 material, used as raw material, must fulfill the following requirements: maximum particle size before entering the composting reactor – 12 mm; minimum temperature in all material in the reactor – 70 °C; and minimum time in the reactor at 70 °C (all material) – 60 minutes.

Digestion residues and compost
To can guarantee a good quality of the product, samples of the digestion residues or compost should be taken continuously at the biogas or composting plant and must comply with the standards which are listed in the Regulation.

Approval will be suspended immediately if the conditions, under which it was granted, are no longer fulfilled.

There are ten biogas plants in Sweden which are already approved by SJV:
- Alviksgårdens Lantbruk AB
- Uppsala kommun
- Svensk Biogas i Linköping AB
- Kristianstads Renhållning AB
- Kalmar Vatten och Renhållning AB
- Laholms Biogas AB
- Nordvästra Skånes Renhållnings AB
- TRAAB
- Gatukontoret i Borås
- Skövde slakteri AB

There are no composting plants in Sweden yet, which would have the approval from the Swedish Board of Agriculture.

All biogas and composting plants in Sweden have to have this approval from SJV to follow the Swedish regulations to be able to process Category 2 and 3 materials and to sell the compost and digestate for agricultural purposes.

3.3.2. Certification by RVF, SP

For the past few years it has been possible for plants producing compost or digestate from separated biowaste, such as source-separated biological household waste or garden waste, to put quality labels on their products. They do so by certifying their product through the certification system developed by the Swedish Association of Waste Management (RVF)\(^8\) and other stakeholders in the business. Certification involves strict requirements of the entire handling chain, from source separation to use. The inspecting body for this certification system is SP Swedish National Testing and Research Institute (SP)\(^9\) [4].

\(^8\) RVF, the Swedish Association of Waste Management, was founded in 1947. It is a stakeholder and trade association in the field of waste management and recycling. The members are municipal bodies (local authorities, associations of local authorities, municipal companies, and municipal regional companies) and corporate members. RVF’s policy for waste management aims at sustainable development and the handling of waste in such a way that people’s health and the environment are protected. It is also committed to responsibility for the different parts of waste management, the various recycling and treatment methods, quality in waste management, the competence and status of personnel, cost efficiency, technical development, and information [4].

\(^9\) SP. SP Swedish National Testing and Research Institute, performs research for innovation and sustainable growth. They develop technology in close conjunction with universities, other research institutes and international partners. The results benefit not only industry, but also the larger field of society as a whole. SP’s mission is to contribute to growth and competitiveness of industry as well as to safety, conservation of resources and a good environment in society. Their objective is to assist in the development and manufacture of products and systems with a high technological content, high inherent safety and minimum environmental impact, and so to contribute to growth in the form of skilled work opportunities in Sweden [37].
Biogas and composting plants at first have to get a permission from the SP and after that they may get and use the quality label of RVF “Certifierad Återvinning” to mark their products (Figure 3.2). To get a marking permit the plants should produce the product, which fulfils the requirements contained in a standard “SPCR 120.Certifieringsregler för Biogödsel” for biogas plants or in the new standard “SPCR 152.Certifieringsregler för Kompost” (which is based on the standard for biogas plants) for composting plants; or equivalent one recognized by SP [38, 39]. Also continuous quality control must be presented and it is performed by the biogas and composting plants and then their control is checked through inspections made by SP.

The certification system “SPCR 120.Certifieringsregler för Biogödsel” is a rule for biogas plants in getting the quality certificate and it consists of two parts:
- Demands on the product
- Demands on the plant

Demands on the product are divided into two parts:
- Pollution limits
- Nutrients content

Pollution limits characterize which metals and in what amount can be present in the product, which is going to be certificated. These limits are listed in the Table 3.1. But any materials such as plastic, ceramics, glass, stones, etc. are not allowed to be in the product.

Table 3.1. Metal limits in the compost or digestate [38]

<table>
<thead>
<tr>
<th>Metal</th>
<th>Maximum content, mg/kg TS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>100</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1</td>
</tr>
<tr>
<td>Copper</td>
<td>600</td>
</tr>
<tr>
<td>Chromium</td>
<td>100</td>
</tr>
<tr>
<td>Mercury</td>
<td>1</td>
</tr>
<tr>
<td>Nickel</td>
<td>50</td>
</tr>
<tr>
<td>Zinc</td>
<td>800</td>
</tr>
</tbody>
</table>

* TS – dry content

Nutrients content characterizes the list of nutrients, water content and organic substances, which should be in the product. It is listed in the Table 3.2.

Table 3.2. Parameters which should be indicated in a declaration about biomanure [38]

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Name</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total nitrogen</td>
<td>Tot-N</td>
<td>kg/ton and kg/m³</td>
</tr>
<tr>
<td>Ammonium-nitrogen</td>
<td>NH₄-N</td>
<td>“</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>Tot-P</td>
<td>“</td>
</tr>
<tr>
<td>Total potassium</td>
<td>Tot-K</td>
<td>“</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>“</td>
</tr>
<tr>
<td>Sulphur</td>
<td>S</td>
<td>“</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>“</td>
</tr>
<tr>
<td>Soil improvement and physical characteristic</td>
<td>Name</td>
<td>Units</td>
</tr>
<tr>
<td>Organic substances</td>
<td>-</td>
<td>heat loss in % TS</td>
</tr>
<tr>
<td>pH</td>
<td>-</td>
<td>“</td>
</tr>
<tr>
<td>Dry substance content</td>
<td>TS</td>
<td>weigh percent</td>
</tr>
</tbody>
</table>
**Demands on the plant** consist of three questions, which should be answered by the biogas and composting plants:

- What are the plants doing and how?
- How do they know that they are doing it in the right way?
- What do they do when something is going wrong?

That means that the production plant has to have a quality system, that is some documents, which answer three questions above. These documents include:

- map of the whole plant;
- kinds of waste, which come to the plant (all waste should be source-separated and it is not allowed to treat sewage sludge; human body residues; Category 1 material and Category 2 material, except of milk and milk products, manure and digestive tract content);
- contracts with suppliers;
- documents where all process stages are described;
- documents that describe measurements (temperature, moisture, etc.), which are taken during the process;
- documents, which describe how samples of the product are taken and how the analysis of them is provided;
- documented plans about what to do in a case of some damages of plant’s equipment (for instance, about the availability of some extra equipment or even whole plant);
- documented plans about what to do in a case of bad quality product (incinerate it, once more digest or compost, sell without certificate, etc.; separation of good and bad products should be guaranteed and proved in the plants);
- documented plans about how to avoid some damages (for example, to implement new equipment for protection from rats and birds, etc.).

One of the main requirements for composting and biogas plants is that they have to ensure proper hygienisation during the process to avoid an existence of pathogenic organisms in the finished product. It has to be done in the separated hygienisation unit during 1 hour at 70°C (in case of using animal by-products) or at 65°C during 1+1 week with at least one turning, or at 55°C during 2+2 weeks with at least one turning (without any animal by-products) [40].

As for now it is allowed to compost just kitchen waste (from kitchens of schools, institutes, hospitals, restaurants, etc.) and it is illegal to use animal by-products and supermarket and industrial waste for composting, when you want to get the certificate. These not kitchen wastes can be treated in biogas plants. All biogas and composting plants have to know what kind of organic waste they can use for the treatment.

When all these requirements will be achieved, the product can be considered as unpolluted and good quality, and can be awarded with a certificate, which allows for biogas and composting plants to attract more customers, to sell products easier and for higher price, to use the product for farmers’ purposes as fertilizer for arable lands.

The certification is voluntary and is based on the principle of the transparency to the customer. This is achieved by careful documentation and control of various environmental- and quality aspects. To gain the certification, the producer must pass an initial “qualification” year, during which routines and procedures are checked and samples are taken on a regular basis. The producer receives support, advice and training during this period. A certificate is issued once the requirements of the qualification year are fulfilled. The plant is then inspected once or twice a year to ensure that good practices are maintained. As was mentioned, the inspection and certification services are undertaken by SP Swedish National Testing and Research Institute [41].

Thought quality certification for products is not a compulsory requirement for biogas and composting plants, but it has become increasingly important for companies to be able to show a
clear environmental direction in their activities. In addition, environmental pressure from customers, public authorities, sources of finance and other sectors of society is growing. Some companies see these elements as an opportunity to create a clear environmental profile.

Quality systems are used more and more often as an efficient means of managing and organising companies. Most EU directives now specify the use of quality systems as a means of assuring the fundamental requirements in the directives.

Product certification is the traditional certification, confirming certain required characteristics or properties of a product, requirements that are set out in standards or that are specified by public authorities or in voluntary specifications [42].

The companies and municipalities in Sweden, which already have quality certificate for their products, are:

- Kalmar Vatten och Renhållning AB
- Kristianstads Renhållnings AB
- Laholms Biogas AB
- Nordvästra Skånes Renhållnings AB (NSR AB)
- Linköping Biogas AB
- Uppsala Kommun

The first approved certificate was presented to the Linköping biogas plant in early 2003. Still there are no composting plants in Sweden, which have quality certificate, but some of them are doing their qualification year now to be able to get this certification. They are anonymous but, it’s known for the SP, they all have BIODEGMA composting system for the biotreatment of organic waste (see chapter 6.1.3).

3.4. Legislation in Ukraine

Contrary to Sweden, legislative system in waste management is not very good developed in Ukraine. Ukrainian legislation about waste consists of such laws as “About protection of the environment”, “About ensuring sanitary and epidemiological well-being of population”, “Law about waste”, “About treatment of radioactive waste”, “About metal scrap”, Code of Ukraine about mineral wealth, and several other normative-legislative acts [43]. There are no concrete laws, rules and regulations in Ukraine about handing and treatment of organic waste.

The “Law about waste” was adopted on 5 March 1998 in Kyiv. It covers almost all types of waste and defines legal, organizing and economic foundations of activity, which is connected with prevention or reduction of scope of waste creation, its collection, transportation, storage, treatment, utilization and removing, rendering safe and disposal, and also with turning away bad impact of waste from environment and people health on the territory of Ukraine [43].

This Law describes:

- definition of different terms connected with waste;
- main tasks, principles and directions of state policy in the waste handling sphere;
- relations of proprietary rights on waste;
- who are subjects in the waste handling sphere, and their rights and obligations;
- competence of organs of executive power and organs of municipal government in the waste handling sphere;
- how to provide state registration, monitoring and informing in the waste handling sphere;
- actions and requirements concerning prevention or reduction of waste creation and handling the waste in ecologically safe way;

10 All text is taken from the reference 43.
- economic assurance of actions concerning utilization of waste and reduction of scope of its creation;
- infringements of the law in the waste handling sphere and liability for them;
- international cooperation in the waste handling sphere.

The main tasks of the “Law about waste” are the following:
- definition of the main principles of state policy in the waste handling sphere;
- legal regulation of relations concerning activity in the waste handling sphere;
- definition of main conditions, requirements and rules concerning ecological safe waste handling and also system of actions connected with organizing-economic stimulation of resource-saving;
- ensuring of minimal waste creating, extension of its using in economic activity, prevention bad impact of waste on environment and health of human being.

The main principles of state policy in the waste handling sphere are priority protection of environment and people health from bad impact of waste, assurance of safe usage of raw materials and energetic resources, scientifically well-grounded agreement of ecological, economic and social interests of society concerning creating and usage of waste with aim of ensuring its sustainable development.

The main directions of state policy, in order to achieve the realization of tasks and principles stated in the “Law about waste”, are the following:
- assurance of proper collecting and removing of waste, and also following the rules of ecological safety in waste handling;
- reduction to a minimum of the waste and decreasing of its danger;
- assurance of integrated usage of raw materials;
- assistance to the greatest possible utilization of waste by means of straight repeated or alternative usage of resource valuable waste;
- assurance of safe removing of the waste, which is not subject to utilization, by means of development of corresponding technologies, ecological safe methods and actions of waste handling;
- organization of control for places or objects of waste disposal in order to prevent its bad influence on environment and people health;
- realization of system of scientifically technical and marketing researches in order to uncover and define resource value of waste with aim of its effective usage;
- assistance in creating objects for waste handling;
- assurance of social protection of workers, engaged in the waste handling sphere;
- compulsory accounting of waste on a basis of its classification and system of passports.

This law could be a basis for creating new deeper and more purposeful rules for each kind of waste, in particular for organic waste.
4. Biological treatment of organic food waste

Today the use of biological treatment methods, such as composting and fermentation, to turn organic waste into a valuable resource is expanding rapidly in many developed countries, as landfill space becomes scarce and expensive, and as people become more aware of the impacts they have on the environment. Utilizing organic waste by these methods is a big part of the plan to minimize waste overall and to divert these wastes from landfill and from incineration as well.

This chapter includes a theoretical explanation of what are the composting and fermentation as biological treatment methods, how they can be provided (under what conditions), and what kinds of wastes can be used for the treatment by these two methods.

4.1. Composting

Composting is the aerobic biological degradation process of transforming biodegradable organic materials, such as garden and food waste, into an earth-like matter called compost. Insects, earthworms and micro-organisms (bacteria) collaborate in aerobic conditions with less than 55% moisture content, transforming the organic material into compost. During the composting process there are less emissions of greenhouse gases to the atmosphere as from landfilling, and, in addition, composting generates a product useful in agricultural and horticultural applications. Compost is a fertilizer with a long-term effect for improving the nutrient content and is therefore used as a soil improver in gardens, parks and landscapes, and also is used for land restoration and landscaping, were it is used as mulch [4].

Composting is the natural way of recycling that goes on continuously in nature. Small-scale household composting was carried out for many years and large-scale composting schemes, using organic waste collected from parks, and household garden waste collected from civic amenity sites, derive benefits from economies of scale.

Composting removes a large part of the organic biodegradable waste from the waste stream and in this way helps to fulfill the obligations placed on member States of the EU in meeting the requirements of the EC Waste Landfill Directive (1999), which seeks to reduce the amount of biodegradable waste sent to landfill to 75% of the 1995 levels by 2006, 50% levels by 2009 and 35% of 1995 levels by 2016 [20].

Since composting depends on microorganisms, the following conditions for the microorganisms should be maintained:
- Air – since the composting is aerobic process, a lot of air passageways should be into the compost; in an opposite way, anaerobic microorganisms will take over the pile and as a result, the bad odour will occur.
- Water – the compost should be wet enough for proper work of microorganisms (but not too wet to avoid anaerobic conditions).
- Food – there are two types of food that composting microbes need:
  - “Browns” (or carbon) are dry and dead plant materials such as straw, dry brown weeds, autumn leaves, wood chips, cuttings, sawdust, vegetarian animal droppings, hair, etc. They are the source of energy for the compost microbes since they are based on sugar molecules and have a lot of carbon in them. And often they need to be moisturized before they are put to the composting system.
  - “Greens” (or nitrogen) are fresh and often green plant materials such as green weeds from garden, kitchen fruit and vegetable scraps, green leaves, grass clippings, coffee grounds and tea bags, fresh horse manure, flowers, breads, crushed egg shells, etc. They have more nitrogen in them what is a protein source for the composting microorganisms.
A good mix of “browns” and “greens” is the best nutritional balance for the microbes. This mix also helps with the aeration and the amount of water in the pile. “Browns”, for instance, tend to the bulky waste and promote good aeration. “Greens”, on the other hand, are typically high in moisture and balance out the dry nature of the browns [44].

The composting process involves a number of stages. The initial stage involves collection of the waste as source-segregated waste by householder, where segregation of the biodegradable fraction is made through kerbside collection or “bring” schemes. Pre-processing of structure material – “green waste”, i.e., garden waste from parks and civic amenity sites may only require shredding or pulverization. Source-separated organic waste would require a greater degree of pre-processing to remove contaminants and poorly segregated wastes. The input biodegradable waste is delivered to a reception and storage area prior to shredding and homogenisation. This process reduces the size of the waste and produces a more homogenous product for composting. The separated organic fraction may be shredded or pulverized to give a size range of between 1 and 10 cm² depending on the type of waste.

The composting process is aerobic and consequently relies on a plentiful supply of oxygen. Regular aeration is required to maintain aerobic conditions. The composting process may be characterized by three stages. The first stage is characterized by increasing temperatures and involves a high rate of microbiological activity. Simple carbohydrates and proteins are readily biologically degraded by mesophilic microorganisms, followed by thermotolerant and thermophilic microorganisms as the temperature rises above 45°C. The second stabilization stage involves biodegradation of the waste by thermophilic microorganisms and is an exothermic process so that temperatures in the compost pile can reach up to 70°C. The high-temperature stage involves the thermal destruction of weed seeds and pathogenic microorganisms. The compost also includes a third maturation stage and is characterized by lower temperatures. The maturation stage involves further biodegradation of the intermediate compounds and may take several weeks for completion.

The final stages of composting would be processed such as sieving and grading to remove un-composted materials and contaminants such as glass, plastics and metals and then size reduction and screening.

The main factors influencing composting and speed of decomposition are listed below:
- Suitable oxygen content to maintain aerobic conditions – 18% as minimum.
- Temperature – in the range of 30-35°C.
- Moisture content – optimal is 40%; below it – biodegradation is significantly reduced; above it – anaerobic conditions are occurred since moisture occupies intraparticle spaces.
- pH range of the waste material – optimal is 5.5-8; bacteria prefer a near-neutral pH, whereas fungi develop better in a slightly acidic environment.
- C:N ratio of the waste material – optimal is about 25 in the starting waste material; higher values resulting in a slow rate of decomposition; lower ratios resulting in nitrogen loss.
- Size range of waste material – shredding of the starting waste material increases the surface area and results in enhanced rates of composting [20, 30].

Since the composting process is a biodegradation process it consequently leads to the formation not only of compost, but other products which may require control and treatment. Such products are leachate and gaseous emissions. Leachate may form in cases of high moisture content and it is allowed to collect in channels and is discharged to sewer or is treated on site depending on the level of leachate generated. Gaseous emissions from the composting process consist mainly of volatile organic compounds and NH₃ and are often malodorous and potentially toxic.

A key element of the production of compost from biodegradable waste is the issue of the quality of the final end product in relation to compost derived from traditional non-waste sources, which are well established in the market place. The proposed EC Biological treatment of Biowaste Directive
(2001) includes a proposal for the establishment of standards for two classes of compost and one for stabilised biowaste. The compost standards relating to quality and the stabilised biowaste relating to a lower quality product are only suitable for those applications not involving food and fodder production, such as landscaping, road construction, golf courses and football pitches. The proposed standards are set out in the Table 4.1. The standards may be compared with the concentrations of heavy metals in compost derived from different waste sources shown in the Table 4.2 [20].

<table>
<thead>
<tr>
<th>Component</th>
<th>Compost class I</th>
<th>Compost class II</th>
<th>Stabilised biowaste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impurities &gt;2 mm</td>
<td>&lt;0.5%</td>
<td>&lt;0.5%</td>
<td>&lt;0.3%</td>
</tr>
<tr>
<td>Gravel and stones &gt;5 mm</td>
<td>&lt;5%</td>
<td>&lt;5%</td>
<td>-</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.7</td>
<td>1.5</td>
<td>5</td>
</tr>
<tr>
<td>Chromium</td>
<td>100</td>
<td>150</td>
<td>600</td>
</tr>
<tr>
<td>Copper</td>
<td>100</td>
<td>150</td>
<td>600</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Nickel</td>
<td>50</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>Lead</td>
<td>100</td>
<td>150</td>
<td>500</td>
</tr>
<tr>
<td>Zinc</td>
<td>200</td>
<td>400</td>
<td>1500</td>
</tr>
<tr>
<td>Polychlorinated biphenyls</td>
<td>-</td>
<td>-</td>
<td>0.4</td>
</tr>
<tr>
<td>Polynuclear aromatic hydrocarbons</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 4.2. Heavy metal composition of compost from different waste sources (mg/kg dry matter) (Hogg et al 2002) [20]

<table>
<thead>
<tr>
<th>Component</th>
<th>MSW compost</th>
<th>Biowaste compost</th>
<th>Green waste compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>4.5</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Chromium</td>
<td>122.0</td>
<td>28.5</td>
<td>45.6</td>
</tr>
<tr>
<td>Copper</td>
<td>161.8</td>
<td>95.9</td>
<td>50.8</td>
</tr>
<tr>
<td>Mercury</td>
<td>1.6</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Nickel</td>
<td>59.8</td>
<td>23.8</td>
<td>22.4</td>
</tr>
<tr>
<td>Lead</td>
<td>318.1</td>
<td>85.5</td>
<td>87.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>541.5</td>
<td>288.5</td>
<td>186.4</td>
</tr>
</tbody>
</table>

The composting stage involves the biodegradation of the sample under aerobic conditions and therefore requires aeration of the waste. Aeration is achieved by several methods and as these increase in sophistication and control of the process, they also increase in cost. Such processes include the “windrow” system, aerated static piles, in-vessel systems and vermicomposting [20].

4.1.1. Windrow composting

The “windrow” system involves the biodegradable waste being piled into elongated conical heaps about 2 m high, about 3-4 m in width and 50 m in length (Figure 4.1). The waste is turned periodically by mechanical turning. Turning rates vary from one turn per day in the early stages of composting to one turn per five days towards the end of the process. The turning process serves to introduce fresh air and release trapped heat, moisture and not fresh air. The windrows are usually placed on a gravel bed to aid the collection of any leachate that may be formed. Windrows would normally be arranged in rows and the mechanical turning vehicle moves up and down each row turning the waste, thereby periodically fully aerating the pile.

4.1.2. In-vessel composting

In-vessel systems allow closer control of temperature, moisture, aeration and waste-mixing rates. These include containers, silos or towers, enclosed halls, tunnels, rotating drums or reactor tank system. Containers are usually small-scale systems for food processing, and catering wastes operating on a batch system. Silos or tower systems are vertical units operating on a continuous basis, where the biodegradable waste is fed to the top of the silo and composting takes place as the waste moves down the tower. The compost is collected at the bottom of the tower after several days’ duration, followed by a maturation stage. Composting in enclosed halls involves large floor areas where composting takes place inside the purpose-built composting building. Tunnel composting systems are large-scale systems which may be either batch or continuous and may also involve some form of mechanical agitation. Rotating drum systems involve the waste being placed in a long rotating drum, typically 3-4 m in diameter and 50 m long, combined with forced aeration. The air passes through the rotating drum while the waste is continuously stirred and tumbled. Residence times in the drum are typically only several days and would require a subsequent maturation stage to reach completion of the composting process. Figure 4.2 shows a typical rotating drum composter and reactor tank composter. In the reactor tank composter the waste is stirred by a series of augers, which are perforated and allow air to be blown into the composting waste pile. The augers are located on a stirring arm.
4.1.3. Aerated static piles

Forced aeration systems involve air being blown or sucked through the pile of composting waste by fan. The compost pile is located on an aeration block and remains undisturbed. Air is distributed via a perforated pipe covered with a porous base material, which is usually finished compost, which acts as a filter and even distributor of the air. The waste pile for composting is constructed over the filter and perforated pipe. Typical forced aeration systems have pile heights of 2-3 m, or 2-6 m in width and up to 30 m in length (Figure 4.3). The air is passed through the pile either continuously or periodically. If the air is drawn down through the pile, the odours from the compost are contained in the system, allowing for control and treatment if required. Where the air is blown up through the compost pile, this serves to transfer the heat from the inner pile to the outer regions.

![Figure 4.3. Schematic diagram of forced air system for aeration of compost](image)

4.1.4. Vermicomposting

Vermicomposting is the composting of biodegradable waste using selected species of earthworms. The process takes place in long troughs in which the temperature is kept below 35ºC. The vermicomposting process relies on the earthworms to mix, aerate and fragment the waste, combined with the biodegradation process of the microorganisms.

4.2. Anaerobic digestion (fermentation)

Production of biogas from the remains of dead plants and other organisms is a natural biological process in many ecosystems with a poor oxygen supply, for example in wetlands, rice paddies, lake sediments, and even in the stomachs of ruminating animals [41].

Anaerobic digestion has been used to treat sewage sludge, animal manure and agricultural wastes for many years and has also been developed for municipal solid waste and industrial waste.

*Anaerobic digestion* is the biological degradation of the organic components of the waste by different groups of microorganisms, which thrive under anaerobic conditions. Anaerobic digestion takes place in an enclosed controlled reactor in slurry of the separated organic waste. The biodegradation of the waste produces a product biogas, which is rich in methane and carbon dioxide. The generated biogas can be used directly as fuel, or upgraded to a higher quality gaseous fuel or chemical feedstock. In addition, the solid residue arising from anaerobic digestion can be cured and used as a fertilizer or as a soil conditioner.

The anaerobic digestion of biodegradable waste includes several steps. The biodegradable fraction of the waste requires separation from the other components of the waste. Source separation using kerbside or bring systems to civic amenity sites, or mechanical separation, may be used. The biodegradable fraction is delivered to a reception area and stored prior to processing. Pre-treatment involves the removal of contaminants and homogenisation of the waste to aid efficient anaerobic digestion, which also protects the down-stream process. The main stage of anaerobic digestion involves heating and mixing the waste and generates a biogas consisting of methane and carbon dioxide. The methane is combusted to produce energy, which provides heat for the anaerobic digestion process and also for export to provide heat and power. Some part of raw gas from biogas plants can be upgraded to vehicle fuel. The advantage of biogas compared to fossil fuel is that the
vehicle emissions are much less hazardous to health and the environment, and biogas is CO₂-neutral. Liquid digestate is a quick working fertilizer, which can be substituted for artificial fertilizer in agriculture. The anaerobic digestion also serves to stabilize the waste and also to disinfect and deodorize it. Post-treatment involves removal of further contaminants, and further stabilization takes place through composting of the residue to produce a composted product [20].

*There are the next three stages of the anaerobic digestion process’s main stage:*

1. The initial stage involves the hydrolysis and fermentation of the large molecules such as cellulosic, protein and lipid compounds, which are in the waste, to smaller ones with the help of enzymes secreted by microorganisms, the facultative anaerobes, which can tolerate reduced oxygen conditions. The breakdown products are used by several kinds of bacteria that ferment them to so-called volatile fatty acids in the process of fermentation. Acetic acid, butyric acid, propionic acid, valeric acid and capronic acid are examples of fatty acids formed in this step. Apart from these acids, hydrogen gas, carbon dioxide and some alcohols are also produced during this stage.

2. The second stage is the acid stage where fatty organic acids, formed in the previous stage, are converted by acetogen microorganisms to acetic acids, acetic acid derivatives, carbon dioxide and hydrogen. Of all the products formed during the first stage, only acetic acid, or hydrogen and carbon dioxide can be directly converted to methane. This degradation step is called anaerobic oxidation and it can only proceed if the hydrogen pressure of the process is very low.

3. The final stage is the main methane gas forming stage. Here the methane-generating microorganisms, the methanogens, generate methane and carbon dioxide from the organic acids and their derivatives, generated in the earlier stages. There are two classes of microorganisms, which are active in the methanogenic stage, the mesophilic bacteria, which are active in the temperature range 30-35°C, and the thermophilic bacteria active in the range 45-60°C. This stage is the main gas generation stage of anaerobic digestion with the gas composition generated at approximately 60% methane and 40% carbon dioxide. Ideal conditions for the methanogenic microorganisms are a pH range from 6.8 to 7.5 [20].

The main factors influencing the anaerobic digestion are the following: pH range, temperature, nutrient level, C:N ratio, mixing, etc. They should be controlled to maintain maximum activity of microorganisms.

Anaerobic microorganisms are active within a broad temperature range, from psychrophilic conditions (optimum 15-30°C) via mesophilic (optimum 35-40°C) to thermophilic conditions (optimum 55-65°C). In general, the higher the temperature – the faster the process. Temperature also influences the rate and degree of degradation of different organic contaminants, which will in turn affect the composition of the residue. The optimal temperature for biogas processes varies, for example, depending on the nature of the substrate. Usually, biogas processes are either mesophilic (37°C) or thermophilic (55°C) [41].

Thermophilic processes are generally more effective than mesophilic. However, they are also more sensitive to disturbances. Mesophilic processes currently dominate, although thermophilic processes are becoming more common as knowledge improves on the best way to manage them.
Products obtained after the fermentation

The resulting products from the fermentation of organic waste are digestate or biomanure and biogas. Biomanure is rich in plant nutrients and its high content of organic matter also makes it a valuable soil conditioner for soils of low humus content and poor structure, for example compacted clay soils. The digestion residue can replace the use of manure in farms without livestock, thereby decreasing the need for commercial fertilizer. The main use of biogas is an energy source for the production of heat and electricity. After some pre-treatment, biogas can also be used to supply gas grid. Biogas is classified as a cleanest fuel on the market and may be used as a vehicle fuel, in exactly the same way as natural gas. Production from a biogas plant does not always correspond to the local demand, which varies considerably during the year. Consequently, large amounts of biogas must be flared off each year.

Without a doubt, heat production is the simplest and commonest use of biogas. For this purpose, pre-treatment normally just involves the removal of water. Gas boilers for heat production exist at biogas plants, and the gas is frequently used for heating of buildings and households located nearby. Biogas is a local fuel, which is predominantly used in the vicinity of the production plant (because of limited costs), although heat produced in excess may be transported to remote localities either directly via pipelines or indirectly via district heating networks.

The combined production of power and heat is a common alternative to heat production alone. Here, the energy contained in the gas is most effectively utilised. The pre-treatment includes drainage or drying to remove water vapour. In addition, the gas must be separated from particles and certain corrosive components such as hydrogen sulphide and chlorinated hydrocarbons. The split between the amount of electricity and heat produced is determined by the design of the plant, but the normal value is about 35% electricity and 65% heat with a total efficiency, that is the amount of useful energy as compared to energy originally supplied, of about 90% [41]. The heat and electricity produced during the process partly is used for the running the plant.

Biogas can also be used efficiently as a fuel. As it is already a gas, air can be more precisely mixed with the biogas, resulting in a more complete combustion then when solid or liquid fuels are used. Due to the low content of sulphur in the biogas, a low exhaust temperature can be used, leading to a high total efficiency. Producing vehicle fuel from biogas is relatively expensive, since it requires pre-treatment plants as well as infrastructure development, including gas-driven vehicles and filling stations. However, the environmental advantages of biogas, especially when it replaces petrol or diesel, mean that its use as a fuel is becoming increasingly important.

Biogas is upgrading by removing carbon dioxide. This increases the energy content, which enables longer driving distances for a given volume of gas in the vehicle tank. The removal of carbon dioxide also ensures a constant gas quality in terms of the calorific value.

The remaining residue from the fermentation process consists of undigested organic material as well as inorganic material such as metals and minerals, and newly formed biomass (i.e. microorganisms that grew during the digestion process). This anaerobic residue is very nutrient rich and will also provide soils with fresh biomass and humus. However, the residue cannot be used as a fertiliser if it contains disease carrying or pathogenic organisms, heavy metals, hazardous organic compounds or pollutants visible to naked eye, such as plastic. In general, contaminated raw material will result in a contaminated end product. Thus, careful source sorting is essential for a successful result.

The nature of the digested residue varies considerably depending on the raw material used. This, in turn, determines, whether the residue is suitable as a fertiliser on arable land, or if it is better suited for combustion. Digestion residues from biogas plants may be classified into several different categories:
- Industrial wastewater normally requires more treatment after an initial anaerobic digestion step. The composition of industrial wastewater is quite variable, so it may sometimes need additional treatment in a municipal wastewater plant.
- Sewage sludge for municipal treatment plants is normally dewatered after anaerobic digestion, to obtain a somewhat drier product, which takes up less space, both during storage and also in the case of landfill deposition. Sewage sludge usually has high phosphorus content, which is valuable in terms of plant nutrition. However, very little sludge is used as a fertiliser due to the relatively large content of heavy metals.
- Biomanure is a product obtained from biogas plants treating relatively clean, unpolluted materials such as manure, source sorted organic waste or agricultural crops. The biomanure is intended for use on agricultural land and has a nutrient content and consistency similar to that of liquid manure, such as cow and pig slurry. The concentrations of pollutants are generally very low.
- Soil conditioners are made out of relatively dry anaerobic residues that are mixed with topsoil, sand, wood chips, bark, etc. soil conditioners can include most kinds of anaerobically-digested organic residues, although some may require pre-treatment such as dewatering or composting. Products based on biomanure may also be suitable as fertilisers on arable land, although the nutrient content may need to be optimised by using additives. Products based on more contaminated raw materials are more suitable for use in construction works or as a cover material in landfills.
- Landfill products usually remain permanently in the landfill in which they were initially deposited. However, with new techniques for deposition of the waste, the residue may in some cases be recovered and used as a soil conditioner or as a construction material [41].

There are several systems of anaerobic digestion:
- **Dry continuous digestion** – the waste is fed continuously to a digestion reactor with a digestate dry matter content of 20-40%. Both completely mixed and plug-flow systems are available, with plug-flow systems relying on external recycling of a proportion of the outgoing digested waste to be mixed with the incoming waste feedstock in order to initiate digestion.
- **Dry batch digestion** – the waste is fed to the reactor with digested material from another reactor. The reactor is then sealed and left to digest naturally. Leachate derived from the biodegradation process is collected from the bottom of the reactor and recirculated to maintain uniform moisture content and redistribute nutrients and microorganisms. When digestion is complete the reactor is opened, unloaded and refilled to start the batch process again.
- **Leach-bed or sequencing batch process** – the process is similar to the dry batch process but the leachate derived from the biodegradation of the waste is exchanged between established and new batches of waste to facilitate start-up of the biodegradation process. After methanogenesis has become established in the waste, the reactor is uncoupled and reconnected to fresh solid waste in a second reactor.
- **Wet continuous digestion** – the waste is slurried with a large proportion of water to provide a dilute (10% dry solids) waste feedstock that can be fed to a conventional, completely mixed digester. Effective removal of glass and stones is required to prevent accumulation in the bottom of the reactor. When used for Municipal Solid Waste (MSW) alone, filter pressing of the wet digestate to recover liquor to recycle for feed preparation is required, to avoid generating an excessive volume of diluted digestate for disposal. Alternatively, the process can be used for codigestion with dilute wastes such as sewage sludge.
- **Multi-stage wet digestion** – there are also a range of multi-stage wet digestion processes where MSW is slurried with water or recycled liquor and fermented by hydrolytic and fermentative microorganisms to release volatile fatty acids, which are then converted to gas in a specialist high-rate industrial anaerobic digester (IEA Bioenergy 2001) [20].

**Batch processes** are those in which the raw material is added at the start of the digestion process with no further addition or removal of material. The material can be mixed to a greater or lesser extent. Batch processes are often used for the treatment of solid material (for example in landfills).
Continuous processes are supplied with new material during the process either as a continuous flow or in smaller amounts during short feeding intervals (semi-continuously). This technique is of the applied to substrates that can be pumped, and is the technique used for digestion of sludge at sewage treatment plants. The extent of mixing can vary, but a “total mixing” using rotating mixers is commonest.

One-phase process: this is technique used most frequently, where all degradation steps take place in one vessel, often accompanied by some degree of mixing.

Two-phase process: the process is divided into a first stage of acid formation followed by the second step when methane is produced. This enables separate optimisation of the two steps, normally using two digestion chambers. Biogas is formed in both stages, although most will be produced in the second phase. The method is particularly suitable for wet wastes from the food industry. In a two-phase process, the acid-rich leachate, produced in the first step, is fed to the methane-producing step at given time intervals [41].
5. Sorting of the organic food waste

Sorted waste is the main pre-requisite to biological treatment of waste. It is important that it should be done in a good way in order to get not only the success in the recovery and utilisation of sorted waste categories, but also to get a clean and good quality product from biogas or composting plant.

Food waste, which is handled in composting and fermentation plants, comes from kitchens of households, schools and institutes and also from restaurants, supermarkets, food industry, etc. As a rule, specific waste from large industries is managed where it is produced. This waste is often homogeneous and therefore seldom needs to be sorted. Contrary to it, household and similar waste has to be sorted before they get to the biotreatment plant. There are several methods of sorting the organic waste, which are described in this chapter.

5.1. In Sweden and the Södertörn area

Sweden is one of the leading countries where the sorting of waste is spread very much. In Sweden packaging materials and newsprint are collected by the producers, in accordance with the law of producer’s responsibility. Also there are, in some areas, the collection systems for the following separate fractions: compostable waste (organic waste), waste to energy (combustible waste), waste to landfills and hazardous waste. Hazardous waste is collected in special collection points, and other three fractions are collected in different containers and then are treated by biological treatment methods, incineration or go to the landfill.

Since this Thesis Work is focused mostly on food waste then the different sorting methods for food waste used in Sweden will be described below.

The largest amount of waste in Sweden is generated by industry. As was mentioned above, food waste from restaurants, big supermarkets and food industry is always sorted by fractions at the source and is homogenized and it, as a rule, doesn’t need to be sorted. They are delivered to composting or biogas plants by special trucks such as showed on the Figure 5.1.

Household waste also takes a big part in a stream of organic waste in Sweden. They are not homogenised as industrial waste, and, that’s why, the main attention should be focused right on them.

A lot of work has been done in Sweden concerning sorting of household waste. Municipalities have increasingly organized regional usable waste collection points, which usually consist of separate bins for organic waste, for glass, paper and cardboard, liquid packaging board, small metal items.
and clothes and shoes. They are usually constructed and maintained by the municipalities or regional waste management companies [46]. The municipalities have the formal responsibility for collecting the household waste in Sweden. The municipalities collect about 40% of the household waste in the country with their own employees. Private contractors, by order of the municipalities, collect the remaining quantity [21]. All municipalities have assumed responsibility for informing households about waste management and source sorting the waste. Several information channels are used to reach households and other customer groups. Brochures, customer magazines, websites, newspaper and television advertisements, information in schools, open-house activities and evening meetings with different customer segments are just some examples of modern information channels. The traditional printed channels are still the most important for information on waste. Websites are used by only a few per cent yet by households to look for information on waste. Surveys have shown that the households prefer to receive information about all waste via the local authority [4].

Adjustment of collection work to the new legislation on waste is being done on the basis of local conditions in the municipalities. Bins are still the most common way to collect household waste. A number of local authorities have introduced systems with optical sorting of different-colored bags. This makes it possible to distinguish different types of waste when recycling source-sorted food waste. Other municipalities have chosen to have a special container for biological waste with holes for ventilation [4].

Different types of refuse trucks are used for the collection of household waste. The trucks are equipped with compactors for reducing the volume of the waste material. Collection of household waste in residential areas with single-family houses is normally carried out once every second week. In residential areas with multi family houses the waste normally has to be collected once a week. During the last few years it has turned out to be more common with refuse trucks equipped with different compartments, so that one and the same truck can collect waste that has been sorted out in different fractions by the households. Combustible waste can for instance be separated from organic waste. Several different transports for picking up different kinds of household waste can thus be avoided. An alternative version is that the households sort the waste in bags of different colors. The garbage bags can then be mixed in the same truck. Optical sorting in large central sorting plants carries out separation of bags with different waste fractions. Traditional back-loaded trucks as well as side-loaded trucks are used for transportation of household waste. When designing new vehicles, the working environment factors are highly considered, including efforts to avoid heavy lifts. The households are to an increasing extent responsible for transporting their bulky waste to special recycling centers. Only some municipalities are still offering collection service at private houses [21].

Households pay the cost of waste management in municipalities, as they are regarded as waste producers and waste holders. Certain municipalities have established waste collection fees that are scaled, in order to provide incentive for residents to sort waste more efficiently and minimize the amount of waste produced. They can take care of some of their domestic waste themselves, provided it is in an acceptable manner, such as by composting [18].

The examples of sorting systems, which are used in Sweden, are source sorting at households, optical and vacuum sorting systems.

5.1.1. Source sorting

The collection and treatment of household waste, including collection at recycling centres, are financed by a fee paid by the households. The fee is compulsory and is in most cases dependant on the amount of waste delivered by each household. Funding for financing treatment of packages and other products covered by producer responsibility is raised through an increased price for the product when it is sold the first time. Costs for taking care of waste from the industry and other waste producers have to be covered by the company producing the waste [21].
People in Sweden are aware and are ready to sort the waste even when the source separation system with separate collection of compostable household waste causes increasing costs for household waste management with about 20% compared to a conventional system. A household in a single-family home pays on average just under SEK 1 300 per year for fortnightly collection. This sum includes relevant waste tax. Taxes amount to SEK 370 per ton of deposited waste. The corresponding fee for a household in a multi-family house, calculated on the basis of a 70 m² flat, is just over SEK 700 per year for weekly collection. Calculated per person regardless of the form of housing, this means that the cost for waste collection and treatment is about SEK 500 per year [4]. There is also a tax on landfill, which is paid by the companies which bring their waste to the landfill. And there are suggestions for taxes on incineration of waste, but they are not implemented yet.

To compare costs on different treatment methods we can use the Table 5.1.

<table>
<thead>
<tr>
<th>Treatment method</th>
<th>Amount SEK per ton of waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill</td>
<td>650–1,200</td>
</tr>
<tr>
<td>Incineration</td>
<td>200–500</td>
</tr>
<tr>
<td>Biological treatment</td>
<td>400–1,000</td>
</tr>
</tbody>
</table>

The source sorting is very important because:
- the waste becomes part of the natural cycle instead of putting a strain on the environment;
- natural resources are preserved for the future generations;
- there is a possibility to recover methane, which can be used to heat buildings (district heating);
- there is a possibility to produce a soil improvement agent that can be used in agriculture, etc.

There are two types of source sorting the organic household waste in Sweden.

1. The first one is when all organic compostable wastes are put in plastic bags (plastic-bag collection system). These wastes are the following: food remains, peelings from fruit and vegetables, offal from meat and fish, bread, coffee grounds, teabags, waste from flowers and wet kitchen roll.

Two types of plastic for the bags, which are used for collection of the waste, are:
- The first one is when the colored plastic of two or three colors is used for bags for waste. Organic compostable waste is put into the black or green bags. Other waste that is left after separation of hazardous, electronic and recyclable waste should be put in white or other plastic bags. These two kinds of bags must be properly knotted so that nothing can fall out. Then all bags are thrown in the refuse chute or dustbin. Then these bags go to the optical sorting and after that bags with food waste go to a crusher-opener and are composted or digested, and other ones are incinerated or landfilled.

Such sorting system is used in the treatment plant in Borås kommun, TRAAB and Falun treatment plant.

- The second one is when special kind of plastic can be used for bags for compostable waste. Such plastic bags are easy to compost and are not needed to be opened for the biotreatment.

SRV återvinning AB in Huddinge treats food waste in such kind of bags.

2. The second type of source sorting is when all organic household wastes are put into the paper bags. Such collection system is called paper-bag collection system, that means that the waste
is kept in the kitchen in specially treated paper bags in a wire rack (Figure 5.2). The household instructions for separating waste state that the following food waste is allowed to be put into the bag: food leftovers, remains from food processing (e.g. fruit- and vegetable peel, meat-bones and fish remains), bread-scraps, coffee grounds, coffee- and tea filters, wilted flowers, pot plants and earth from re-potting, kitchen-roll paper and also popcorn, sweets and chocolate. Outdoors, the waste is kept in ventilated brown plastic bins (130 litres), which are emptied every other week or, sometimes during the summer time, every week. A 140 l bin with holes, which is used for single-family houses, costs 400 SEK and a 240 l bin with holes, used in multi-family houses, costs 500 SEK [5]. Waste from institutional kitchen is handled in the same way as household waste.

Figure 5.2. Paper-bag collection system: paper bag for keeping organic waste in the kitchen and ventilated plastic bins [45, 47].

Some municipalities (for instance, in Helsinborg) have a system with 2 bins with 4 different fractions in each bin. The households sort out the different packaging materials, organic waste and residual waste (Figure 5.3).

Figure 5.3. Bins which are used for different fractions of waste [45]

After delivering to the composting or biogas plant, the paper bags are ripped open in a scoop with screws that cut the waste in pieces. The green waste is shredded separately and mixed with the food waste. Or the waste is put in a mixer-wagon that opens the bags and mixes the waste with water before putting it through a screw-press. The dry fraction is then mixed with garden waste (with a “blandningsskopa”).

Such source sorting system is used for sorting the waste, which are delivered to Västerås fermentation plant, Karlskrona composting plant, Luleå composting plant, NSR AB (Helsinborg), etc. for treatment.

5.1.2. Optical sorting

Optical sorting (OptiBag) is a system developed for treatment of waste from households, restaurants and other similar types of waste, which are put in coloured bags (Figure 5.4).
The households do the sorting into the correct bag. At the household the waste is sorted into 30 litres bags or normal plastic bags from shops. Organic waste from restaurants is sorted into 60 litres plastic bags. Other fractions with lower density can be sorted into bags with a volume up to 125 litres. The bags are dumped into existing waste chutes or recyclable trashcans. They are transported in existing waste trucks and dumped into a receiving pit. And then they go to the optical (OptiBag) system for the sorting [48].

The system is based on a video system that recognise the colour of the bag passing a sensor. If a bag with the right colour (for example green or red) passes the sensor a signal tells the pusher unit to push the bag down to a lower conveyer. This conveyer transports the bag to a compost or fermentation plant, container, bale press or to further treatment (Figure 5.5).

Bags with a deviation from the chosen colour/colours are ignored and pass through the pusher unit and will, if it does not fulfill any of the colour requirements for any of the fractions, eventually fall of the end of the conveyer. Normally it will be collected for further transport to landfill or incineration. Any waste, which is not "bagged", finds its way here also. Each colour corresponds to a fraction and the system has a capacity to handle 6-7 fractions or even more. A system with two fractions work with one "decided" colour and "other" colours, and a system with three fractions work with two decided colours and "other" colours, and so on.

![Figure 5.4. Coloured bags with the waste used in optical sorting [48]](image)

**Figure 5.5. The schematic technological scheme of OptiBag sorting system [49]**

*The main advantages of optical (OptiBag) sorting system are the following [48]:*
- The optical (OptiBag) system is designed to demand a minimum of changes in the existing collecting routines and to have a minimum of risk for rats, mould fungus and other health risks.
- The sorting is already done at the household or restaurant. The needed effort for this is minimal and in no cases bigger than for any other system. The customer is well motivated and the quality of sorted material is high.
- Expensive investments in special waste houses, extra trashcans, etc is not necessary.
- The optical (OptiBag) system works as well in cities, residential areas as on the countryside.
- The possibility to increase the number of fractions is easy to do. No extra trashcans are needed.
- By offering the end customer a system that is easy to adopt to and which does not demand any major extra effort, gives a high quality of sorting.
- Those end customers that can’t, or refuse to sort their waste, normally use plastic bags from shops or no bag at all. This material and bags is refused by the pusher units and delivered to landfill. They will therefore not pollute the fractions that have been given priority.
- Very good conditions and health care for workers.
- Experience has shown a high acceptance from the citizens.
There are several biogas and composting plants in Sweden, which use optical sorting system. Several of them are explained below.

**TRAAB, Falun and Borås** have such system, where the three fractions (compostable, combustible and fraction to landfill) are collected in plastic bags of different colours. All bags are collected in a conventional truck and are taken to an optical sorting plant. In Falun black bags are used for organic waste, the red ones for waste to energy and the white ones for waste to landfill. In TRAAB green bags go to the fermentation plant, red to incineration and grey and other bags – to the landfill. They treat approximately 20 000-30 000 tons waste per year: 25% of biomaterial, 55% of combustible waste, and 20% waste to landfill. TRAAB’s investment costs for OptiBag sorting system were 20 million SEK in 1999 [50]. In Borås they have two kinds of bags: black – for compostable waste, and white – for waste to incineration (Figure 5.6).

![Plant for optical separation of black and white bags in Borås City](image)

**Figure 5.6. Plant for optical separation of black and white bags in Borås City [51]**

The OptiBag system shows high purity of organic waste from single houses as well as from apartment blocks. As functional purity it can, according to investigations in the city of Borås, be classified as “purity high enough to produce compost acceptable for sustainable agriculture use” (Andersson et al 1997) [51].

**Telge Återvinning AB** in Södertälje also uses this OptiBag sorting system. The households sort out their waste at home and put food waste in plastic bags of special green colour (Figure 5.7), which is recognizable by the optical machine, and other wastes are put in bags of other colours. These specific green bags are spread among the households for free by the company. Also Telge Återvinning supplies the households with the relative information how to sort the waste, how to use the bags, which waste is allowed to be in the green bags, etc.

![Green bag for collecting food waste used at Telge Återvinning AB in Södertälje](image)

**Figure 5.7. Green bag for collecting food waste used at Telge Återvinning AB in Södertälje (picture made by Halyna Kosovska)**

Telge Återvinning refuse-collection trucks take all bags from households’ bins or chutes and transport them to the reception unit – Tveta recycling facility. From this collection unit the wastes go up on a conveyer and then they are divided and go on three parallel conveyer belts. On the ways of these belts three optical sensors stand. The bags pass these sensors and it sends a signal to the removal arm, which pushes green bags out of the belt, other bags continue to go on the belts further and they are collected in the containers for residual waste. Green bags are transported to a bag opener and crusher and then food waste is collected in the containers for the organic waste (Figure 5.8).
This sorting system is quite good and it has a lot of advantages, as was mentioned above: it sorts the bags of different colours very quickly, without any mistakes and there is no necessity in a high quantity of workers, etc.

But there are also some disadvantages of the optical (OptiBag) sorting system:
- it is comparatively expensive; Telge Återvinning AB paid 30 million SEK for the building of OptiBag sorting facility [52];
- the bags with organic waste should be of a certain specific colour (green – at Telge Återvinning AB), because in other case the bags will not be recognized by the optic machine;
- if bags are not knotted in the right way, the organic waste could be out of the bag and won’t be recognized as the food waste, etc.

The investment costs in optical sorting system depend on the capacity of receiving bunker, sorting capacity ton/hour, number of fractions, distances of automatic transport and treatment of the material.

Some example of costs without building and road-work:
- one line OptiBag plant (5 ton/hour), receiving capacity 50 m³, three fractions of waste, sorted waste goes directly to containers without treatment cost about 5-6 million SEK;
- three lines OptiBag plant (15 ton/hour), receiving capacity 100 m³, three fractions of waste, transport to double container places, bag-opener for bags with organic waste, screeners, compaction containers etc. cost approximately 25 million SEK [53].

5.1.3. Vacuum sorting system

Vacuum sorting system (Envac system) is centralised sorting system, which is mainly good for density-populated areas. This underground waste transportation system consists of a pipe network connecting waste inlets, placed outside or inside the buildings in the area with the collection terminal. The terminal is often located outside of the residential centre in an area easily accessible for container trucks.

Fans create an under pressure in the system that sucks the waste away in the underground pipe system at a speed of about 70 kilometres per hour. The entire process is fully automated using
electronic control systems that monitor and regulate operation [54]. All manual handling of waste bags and waste containers has been eliminated.

The content of the pipes passes through a cyclone, which separates the waste from the air that carries it. The air is then filtered through various dust and odour filters, and then released into the open air.

The system offers a complete solution for solid waste in mixed urban areas. Households, offices, entertainment and shopping areas are all connected to one waste collection system.

There are two types of such sorting system: central waste suck and mobile waste suck.

**Central waste suck system (stationary system)** consists of a fully enclosed vacuum system, which means getting rid of foul smelling, dirty refuse collection rooms and containers in the streets. No one needs to come into contact with refuse sacks or containers. The waste is thrown into a normal inlet, either indoors or outdoors. Sorting at source is handled by using one inlet for each fraction.

In principle, the system consists of a number of collection points, linked together by piping that transports the waste to a central collection station (Figure 5.9). When a refuse bag is deposited into an inlet, it is temporarily stored in a chute on top of a discharge valve. All the full inlets connected to the collection station are automatically emptied at regular intervals. The control system switches on the fans and a vacuum is created in the network of pipes. An air inlet valve is opened to allow transport air to enter the system.

One by one, the discharge valves below each of the chutes are opened and the refuse bags fall down by gravity into the horizontal network of pipes and are sucked to the collection station. The refuse enters the collection station via a cyclone that separates the refuse from the air. The refuse falls down into a compactor, which compacts the refuse in the hermetic container. The transport air then passes through dust and deodorant filters and a silencer.

The system is ideal for separating waste for recycling, in which case there is an additional inlet and container for each category of refuse. The control system directs a diverter valve to transport each category of sorted waste into the correct container.

When the containers are full, normal trucks collect them for emptying for further transportation to incineration facilities, composting or biogas plants or landfills [55].

In the **Mobile waste suck system** the waste is deposited in storage tanks, which are regularly emptied via special docking stations into vacuum-equipped vehicles.

For those who live or work in the area, the mobile system is used in just the same way as the previous stationary version. The refuse bag is put into an inlet, which may be located indoors or
outdoors. The bags are temporarily stored in a closed tank, the size of which is adapted to the amount of waste generated by the building occupants (Figure 5.10).

The storage tanks are linked to docking points via a network of pipes. The docking points are placed so that the vehicle collecting the waste does not need to drive into yards, etc. The system is most often dimensioned for emptying once or twice a week.

The vacuum truck has the same function as a central waste suck collection centre, collecting the waste through a pipeline system. The driver of the vacuum truck manages the entire emptying process by connecting to the docking point. As in the stationary vacuum system, the waste is compacted and dust and odours are filtered out of the air.

The mobile system is primarily recommended for small residential areas.

This mobile system can easily be adapted for sorting at source. In such cases, an additional chute and storage tank are installed for each waste category. The truck empties the various categories separately [55].

5.2. In Ukraine and the Yavoriv Region

Since the waste management system in Ukraine is almost undeveloped, there is no sorting of the household waste in Ukraine.

More than 10-15 years ago it was common for people to collect paper and glass waste at home and then they could bring it to special centres, where people left these kinds of waste and got some money back for it.

But now it is almost unusual for ordinary people to do this, since it takes time and efforts and doesn’t bring almost any benefit. There are no incentives for people to sort the waste; there are no regulations to do this; there are almost no recycling plants in Ukraine; there are no treatment methods, which would require the sorting of waste and people are not so aware to take care of the environment.
6. Biological treatment of organic food waste in Sweden and the Södertörn area

Sweden is one of the leading countries in using biological treatment for handling the organic waste. There are a lot of composting and fermentation plants, which provide treatment of organic waste using different methods of biotreatment. This chapter will describe biological treatment methods used in Sweden, their advantages and disadvantages, investment and treatment costs of using the methods, experiences of plants from using them, etc.

6.1. Composting methods used in Swedish plants

Composting of organic waste is a very common method of biotreatment. There are several types of composting systems in Sweden, which are described below. The information about methods is written mainly from two points of view: the company – which produces the equipment for composting (information is taken from the home pages or advertisement brochures of the company or through the interview of the company representatives); and the plant – which uses this equipment (information is taken through the interview of the people who work at the plant or from the brochures of the plant). This is a good way to have more or less adequate information about the methods and to make a better comparison of these different methods.

6.1.1. Open composting

Description of the open composting system
Most of the composting plants in Sweden still have an open (or windrow) composting system for the treatment of organic waste. It is the simplest composting system, which does not require a lot of investment costs and is easy in handling the waste.

Source sorted organic household waste or food waste from kitchens of schools and institutes, from restaurants and big supermarkets, which are put into plastic or paper bags, are brought to the composting plant. In some plants the bags are crushed and the remains of the bags are then screened out in a large horizontal drum with holes. At some other composting plants bags are opened and cut in a scoop with screws. At the SRV in Huddinge a special kind of plastic bags are used, which are easy to compost, so they do not need to be opened. The food waste is mixed with the garden and park waste that was crushed to small pieces (Figure 6.1).

![Figure 6.1. Organic and garden waste used for composting at the SRV återvinning AB in Huddinge (pictures made by Halyna Kosovska)](image)

In the Appendix 4 you can see almost all composting and fermentation plants, which exist in Sweden now (autumn 2005) with the short characteristic of the companies, which I managed to contact.
Mixed food and green waste (the optimal is – food waste: green waste=3:1) is put into long piles, known as windrows (Figure 6.2). It takes from 7 months to 1.5 year to get ready compost. During this time special machines are used to return the piles one time a week or one time a two weeks (Figure 6.3). This is done to maintain aerobic conditions in the pile [5].

When the compost is ready, sieving machine is used to separate uncomposted material (such as glass, plastic, metal things, etc.) from compost (Figure 6.4). The compost is mixed with soil or sand (this is done in the composting plant or is sold to some other companies which do this) and then is used as a soil improver or in the construction industry. The separated residue is brought to the incineration plant (before 2005 it was allowed to put this residue the landfill, but not any more).

The advantages of the open (windrow) composting are the following:

- it is cheap, most available and simple method of biotreatment of the organic waste;
- there are reduced construction and operating costs;
- flexible management;
- it needs less machine for treatment what results in low maintenance levels;
- it is possible to get the final product of good quality.

The disadvantages of the open (windrow) composting are the next:

- it is difficult to monitor and prove moisture, pH, temperature, and contaminant concentrations in the pile;
- there is the problem with odour during the composting process;
- the duration of composting process is long (the longest in comparison with other methods);
- it is almost impossible to get approval from the SJV and get the quality certification for the product from SP and RVF.

The plants in Sweden, which use open composting system:\n
- Alingsås kommun (Alingsås)
- LSR (Landskrona)
- Ludvika kommun (Ludvika)
- MERAB (Eslöv)
- Mossvägen Falköpings kommun (Falköping)
- Nårab (Klippan)
- Uppsala kommun (Uppsala)
- SRV återvinning AB (Huddinge)
- Sysav (Malmö)
- Västblekinge Miljö AB (Mörrum)
- Västerås Renhållningsverk (Västerås).

There are could be some other companies with open composting system, since I couldn’t contact all biological treatment companies in Sweden. Short information about these companies is in the Appendix 4.
For example, in *Alingsås kommun* they use open composting without preceding of anaerobic digestion. Cured compost is available for the public for free. Some is used within the municipal activity (parks, flower beds etc.).

Alingsås kommun have a permit from the county administrative board (Länsstyrelsen, Västra Götaland) for the composting facility. It allows composting of almost 10 000 ton/year of park- and garden waste, easily biodegradable organic household waste (the annual limit for this kind of waste is 2 000 ton/year), horse manure and similar waste.

In their municipality, the inhabitants have an obligation to separate waste for composting. The households use bags made of cornstarch and put these in a bin for compost. The households are allowed to put all sorts of leftovers (scrap of food), coffee grounds and filters, ashes (not from tobacco), bones (from chicken, meat, and fish), flowers and soil, garden waste in bags, kitchen paper and napkins, in the bin for compost.

Composting facility in Alingsås kommun is located within the disposal facility. At the disposal facility the staff manually separates waste that is not biodegradable. No extra equipment for the composting facility is necessary; they use the same that they have for the disposal facility. The only problem for them is odour that occurs when the compost is turned. Some neighbours sometimes complaint about it.

There are a lot of composting plants in Sweden, which operate at the similar way as in Alingsås kommun. There are also several plants, which use unsorted organic waste: Västblekinge Miljö AB (Mörrum) and Ludvika kommun (Ludvika). They have less smell during the composting process than when using sorted organic waste [57]. Also there are some plants, which handle only garden waste without mixing them with food waste: LSR (Landskrona); Sysav (Malmö). These plants are not going to get the certificate or approval since their compost is not used for the agricultural purposes.

All these companies have the odour problems when return the piles during the composting process and don’t have any certification and approval from the corresponding organizations.

6.1.2. Ag-Bag composting system

*Ag-Bag composting system from the “company-producer” point of view*

The Ag-Bag composting system was established in Sweden in 2001 within the company Componordic System AB, which is family-owned company founded in 1997.

According to the information on the Ag-Bag’s home page and the Componordic System AB brochures, the Ag-Bag is an effective and environmental friendly system for composting. This method is good for storage (for example, during temporary interruptions or revision of incineration of waste), hygienisation of materials and extraction of methane gas. This composting system can process large amounts of organic materials (between 25 000 to 100 000 tons of organic material per year) and includes a mixer wagon that weighs the material, opens bags and blend it with the structure material. The system consists of a contained process and a closed composting reactor which only emits heat, water and carbon dioxide without any odour and leakage [30]\(^{14}\).

The benefits with this system are: low initial capital costs (the only requirement is a hard-packed surface); low cost of labour; flexible localization (mobile) and processing volumes; it is a continuous batch system; it takes just 2-3 month to get odour-free and humus-like end product and because of that short period of time the site can be used 3-4 time/year; and minimal disturbance of the surroundings (contained process).

\(^{14}\) All information about Ag-Bag composting system is taken from the reference 30 except of special notes.
Also this system minimizes or eliminates: birds, flies and rats; reduces odour and leakage to groundwater; is weather independent; needs reduced site area and reduced cycle time; has more effective workload and reduced time-consumption; no unnecessary transports is needed; does not require a secluded location; no large and nonflexible investments.

*Parameters, which are maintained during the process (depending on the waste composition):*

- Moisture content: 45-55%
- C/N ratio: 20-40
- pH: 6.5-8.5
- Oxygen: 10-20%
- Fraction (particle size): 5-10 cm
- Compost cycle: 8-12 weeks
- Curing: 4-6 weeks

*Possible feed stocks which can be used in the process:*

- Straw
- Horse manure
- Paper waste
- Cardboard waste
- Household waste
- Grass clippings
- Food waste
- Fish waste
- Contaminated soils
- Woodchips
- Leaves
- Sludge
- Sawdust

*Flowchart for Ag-Bag composting:*

- Household, restaurant, catering
- Transport
- Reception
- Pre-treatment
- Hygienisation (10 days)
- Composting (2 month)
- Curing (1-6 month depending on what the compost will be used for)
- Screening
- Possible hygienisation (70°C) in a mixer wagon (additional security)
- Ready compost

*The process*

The composting process takes place under control conditions in an Ag-Bag composting system. A plastic bag of 60-75 m in length and 1.5 - 2.7 m in diameter which can be filled with 80 – 320 ton of waste (Figure 6.5). The filling capacity is between 60 – 200 ton/h.

Before the process starts, waste should be correspondingly prepared. For that purpose the next equipment can be used.

- **BIGA Vertical Mixer Wagon** – a very powerful mixer wagon that receives, weighs, cuts, divides, mixes and transports the material in a fast and simple way (Figure 6.6). The Vertical Mixer Wagon can be used as a reception device for sort out household waste. A digital weighing system with 6 different weighing programs, weighs the material. The large augers with serrated cutting knives cut the bags and mix the waste quickly and efficiently. The material is thereafter transported to the location of the structure material. The weighing system registers the exact amount of structure material for a god compost mix. The material is transported to the compost site while blending. When the material is composted, the mixer wagon can be used to transport the material while blending to the curing site. The 3 m high adjustable belt conveyor has 3 m unloading capacity. This Vertical Mixer Wagon can also be used when handling sludge, ashes...
and contaminated soils etc.

- **Dutch Oven System BV** – an infrared system for heating of different amounts and capacities (Figure 6.7). An infrared system is a very good and reliable way to achieve hygienisation by heating the material to 70°C for 1 h (category 3 materials) or hygienisation of soil improvement materials. Dutch Oven Systems infrared heat can be used in combination with the BIGA mixer wagon because the material is mixed while heated and all the material gets heated at the same time. The temperature is regulated by an infrared heat temperature monitor. Heating the material to 70°C while mixing for 1 h, results in a thoroughly heated material. Soil-improvement materials can also be hygienised through this system. Frozen materials such as household waste during winter can be defrosted and mixed with structure materials for composting. This makes inappropriate storage of waste during cold seasons avoidable.

**Operation**

The Ag-Bag composting method is fast and simple to operate. The feed hopper of the machine is filled with mixed compost material and the hydraulic ram pushes the material through the tunnel into the bag, attached to the machine (Figure 6.8). The hydraulic ram is operated by a remote control and returns automatically to start position, which leaves the feed hopper empty to be filled again after about 60 seconds. The machines can have one or two aeration channels through which the perforated aeration pipe is fed into the composting bag at the same time as the compost material is fed into it. With a well balanced mix of compost material this construction will result in an odour and leachate free composting process. Since the Ag-Bag system is a closed and static system, it is important to have a right proportion between water and air space from the very beginning in the mixture. Practice experiences have shown good aeration conditions in the bag if one third of the mixture consists of wood chips with a length of 1-15 cm. The Ag-Bag works well if the water content in the mixture is about 50%. The time for the biological treatment in the Ag-Bag is about 14 weeks. The final part of the composting can be for 1-2 month in heaps (open composting) where aeration is possible. After the material has passed through the sieve the wood chips can be reused. There is a ventilation system in the bag and the fan can be regulated to suit the degradation rate in the process. It is also possible to control the air transport in the bag by changing the valves by manual [58].

**Figure 6.7. Infrared system for heating the waste used in Ag-Bag composting system [30]**

**Figure 6.8. Loading the plastic containers of Ag-Bag composting system with the waste by feed hopper [30]**

*There are two models of Ag-Bag Environmental Composting System:*

- The Ag-Bag Environmental Composting System **CT5** is developed for smaller and medium-sized sites. The CT-5 cooperates with composting bag, 1,65 m Ø x 60 m and has a storage capacity of 70-80 tons.

- The Ag-Bag Environmental **CT8** Composting System is developed for medium-sized and large sites. The CT-8 cooperates with the composting bag, 2,40 m Ø x 60 m, which has a storage capacity of 160 tons, or 2,70 m Ø x 75 m with a storage capacity of 300 tons.
**Investment and treatment costs for using the composting system**

The cost for Ag-Bag composting system mainly depends on the amount of waste for treatment, since that defines the amount and size of plastic containers, amount of fans, etc.

The estimation cost for buying of CT8 300 or CT8 160 ton (system for medium-sized and large sites) is the same [59]:
- 1 350 000 SEK for CT8 machine;
- 18 000 SEK for the fan;
- 755 520 SEK for the mixing machine.

The price for bag in these two types of machine differs from each other:
- for CT8 300 ton the price for bag including pipe, valve and connector is 17 000 SEK;
- for CT8 160 ton the price for that is 15 000 SEK.

But treatment costs, using different bags, differ\(^\text{15}\):
- for CT8 300 ton:
  - for 7 000 ton/year – 199 SEK/ton;
  - for 14 000 ton/year – 162 SEK/ton;
  - for 28 000 ton/year – 143 SEK/ton;
  - for 42 000 ton/year – 137 SEK/ton;
- for CT8 160 ton:
  - for 7 000 ton/year – 236 SEK/ton;
  - for 14 000 ton/year – 199 SEK/ton;
  - for 28 000 ton/year – 180 SEK/ton;
  - for 42 000 ton/year – 174 SEK/ton

So, the processing of larger annual quantities of material is more cost effective than the treatment of smaller quantities. Increasing of site capacity decreases the treatment costs per tone.

**The plants in Sweden, which use Ag-Bag composting system**\(^\text{16}\):

- Telge Återvinning AB in Södertälje – began to use the Ag-Bag CT 8 system in 2001.
- Ragn-Sells AB in Bro – began to use the Ag-Bag CT 5 system in 2001.
- The municipality of Borås – began to use the Ag-Bag CT 5 system in 2002.

I have visited the company Telge Återvinning AB in Södertälje and talked to Annette Ovland. This composting plant started to treat organic waste from households, restaurants, supermarkets and food industries, and also green waste from parks and gardens in a biological way in 2001. They use the Ag-Bag composting system and also the OptiBag sorting system (see Chapter 5.1.2.).

Source sorted waste (different kinds of waste are put in the plastic bags of different colours), which comes to the plant, is sorted in the OptiBag sorting system, after which all wastes are divided into two separate groups: organic waste in green bags and other kinds of waste in other bags.

These other wastes are collected in the containers and are then put in some big holes on the plant’s territory for several years (about 3-5 years). The company has an one full hole and another new one where they started to put the waste in (Figure 6.9). During these years the methane is created in these holes and is collected. After these several years Telge Återvinning is going to dig out these bags and then incinerate them or compost, but until now they haven’t done anything with these waste [52]\(^\text{17}\).

\(^{15}\) More detailed information about these investment and treatment costs are in the Appendix 5.

\(^{16}\) The short information about these companies is in the Appendix 4.

\(^{17}\) All information about Telge Återvinning AB in Södertälje is taken from the reference 52.
Green bags with the organic waste are opened and crushed with the special equipment and are then collected in the containers for the organic waste. They are mixed manually with crushed green waste in proportion 70% of organic waste and 30% of green waste (Figure 6.10). They have approximately 15 000 t/y of organic waste and about 5 000 t/y of green waste. Telge Återvinning AB doesn’t have a Vertical Mixer Wagon, which is suggested by the Componordic System AB for the mixing of waste. They also don’t have Dutch Oven System BV, which serves as hygienisation unit. They try to maintain 65°C for a long time during the fermentation and composting stages inside the bags to hygienised the waste.

To fill the bags with mixed waste Telge Återvinning AB uses special loader (feed hopper), which is suggested by the Componordic System AB (Figure 6.11). Waste is given from the top of that machine and hydraulic ram inside the machine pushes the material into the bags. The hydraulic ram is operated by a remote control and returns automatically to start position. After that the space inside the feed hopper is empty and is ready to be filled with another portion of waste. The machine also has two aeration channels with the perforated aeration pipes, which are put into the bags (one is in the bottom and another is in the top) together with the material for composting. One bag can contain about 300 tons of waste.

When bags are filled, at first a fermentation process inside the bags takes place (it is done for 1-4 weeks depending on how much gas is generated), and then Telge Återvinning AB adds air through the pipes by fans – this is the composting stage. This stage lasts about 16-20 weeks. So, the whole process inside the bags takes about 17-24 weeks. After that the bags are cut and composting material is taken from them and put into the piles (windrow composting) for further maturation stage. Bags should be changed after each time of composting (one bag can be used for the composting process only one time).

During the composting stage in the bags, Telge Återvinning AB provides measurement of temperature of the material. It is done manually with special devices several times a week. If something is wrong with the temperature they can give more air to the bags to regulate it. Air can be supplied by fans through the perforated aeration pipes inside the bags or trough the blue openings which are spread on the each bag (Figure 6.12). Together with the necessary temperature, they are also trying to maintain the necessary moisture of the composting material. Manual mixing the waste allows them to do that since they can control the quantity of green waste and organic waste.
waste, which should be put to the mix. For instance, when they have too wet organic waste, they can put more green waste than usual (30%) or vice versa.

When the compost is ready, other companies are responsible for sieving it (to separate plastic and other materials from the compost); Telge Återvinning AB doesn’t do it by itself.

Leachate, which they get during the composting process and landfilling (which they also have on the site), is cleaned in special ponds, where the heavy metals and other contaminants are taken away, and then clean water is collected in a closed ditch from where is used for the irrigation of trees [49].

The advantages of the Ag-Bag composting system are the following:
- it is comparatively cheap method (it cost about 1 million SEK for Telge Återvinning AB to buy the machine (loader) and each bag costs about 10 000 SEK);
- this system is easy in work, easy to follow the process;
- there is the possibility to make own mix of waste (the quantity of different wastes, which go to the mix, can vary if necessary);
- the composting process in bags is faster then windrow composting;
- there is less odor problems than during the open composting.

The disadvantages of this system are the following:
- difficulties with hygienisation process – difficult to prove the quality of the hygienisation, difficult to hygienize the whole material equally;
- difficult to spread the air evenly in whole material;
- bags cannot be used more than one time;
- it is difficult to mix the material during the process;
- the fans are too small to supply a good aeration of the composting material;
- the measurement of temperature, moisture, etc. in the bags is done just a few times a week and it is done manually without any automatic devices;
- the bags often become broken and there are a lot of holes which could be done by birds;
- a lot of birds on the site area;
- system can not be considered as a really closed;
- there are complaints from inhabitants about the smell and leachate water around the composting site.

Telge Återvinning AB doesn’t have any certification and, I think, it will be very difficult to get it using this kind of composting system, since it is very difficult to prove that they have really very good hygienisation of materials, that they have necessary conditions inside the bags, that they have proper mixing the organic waste and structure materials, that they have materials in size of no more than 12 mm, etc.

6.1.3. BIODEGMA composting system

BIODEGMA composting system from the “company-producer” point of view

BIODEGMA concept is bought from and built by a German company called Biodegma. It was the first company, which used semi-permeable (Gore-tex) membranes as the enclosure for the composting of organic waste.

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18 All text is taken from the reference 60 except of special notes.
According to the BIODEGMA home page and the company brochures, the advantages of this system are combined with advantages of open windrow composting and main advantages of a closed rotting system:

- no or limited treatment of exhaust air is necessary;
- reduced construction and operating costs;
- less machine intensive resulting in low maintenance levels;
- flexible management;
- consistent site operation;

and

- reduced odour emissions;
- reduction of spore emission with regard to the surrounding environment;
- the simple modular design of the system allows an enlargement of the plant’s capacity at any time [61].

Beside functional advantages, the economical aspects are one of the major decision criteria:

- modular design without complex and susceptible to faults conveyor technique allows low investment and operation costs;
- flexibility to cope with future changes in legislation;
- low energy costs since exhaust gases don’t have to be treated;
- low maintenance and repair costs, high availability [61].

System description
The delivered waste is unloaded into the delivery and processing area where a first visual inspection takes place. Larger disturbing materials like metals or plastic bags filled with municipal solid waste will be removed. The incoming kitchen waste is mixed with approximately 25-30% green waste by using the wheel loader.

Modules are also loaded using the wheel loader. The modular design of the system allows treating capacities between 5 000 – 40 000 t/y.

Intensive phase of biodegradation process takes place under closed roof of the modules and the retention time for this is 3 weeks. During this time controlled and aerated climate is maintained inside the composting-modules. This is closely monitored by temperature probes and the computer system to ensure complete hygienisation of the composting material.

Modules are the main unit of the BIODEGMA composting system, where intensive phase of biodegradation process takes place. The layout of this composting system can be visualized as is shown on the Figure 6.13.

Figure 6.13. The scheme of modules used in the BIODEGMA composting system [60]
Each composting module has a capacity of 250 m³ -280 m³ and is covered with the aluminium construction with an integrated breathable watertight semi-permeable membrane. The system uses GORE-TEX membranes (Figure 6.14). With a low weight of less than 450 g/m², the membrane is permeable to very fine water vapour, but prevents any extensive escape of fungus spores. Because of the special characteristics of the laminate, the composting material can breathe without getting excess moisture from rain from outside which reduces quantity of leachate water required for disposal. The emissions of odour intensive products from the composting process into the surrounding environment are greatly reduced in the modules with these membranes, since the main component of the odorous substance is dissolved in water. The cover protects the material from drying out. In addition it provides a constant and controllable microclimate within each composting module, in which it keeps the optimal conditions for the composting material. The area between the surface of the composting material and the semi-permeable cover also serves as insulation, so even the edges of the compost material maintain the required temperature and are hygienized.

Each module in its concrete floor surface has also the four long channels integrated to the drainage and the aeration pipes. This aeration system, which is separated for each module, consists of:

- **Radial ventilator** – the ventilators are set up behind the back wall of the modules in a ventilator station. Air is blown into the composting material through a continuous pressure in the aeration pipes made by the ventilators. Each ventilator supplies sufficient air quantities in order to avoid the uncontrolled heating of the material and has an electrical installation of 1,6 kW.

- **Air distributor** – the construction of the air distributor prevents high-pressure loss during air introduction. Air is evenly distributed through the openings with reduced pressure loss into the individual aeration pipes. An added rectifier results in the reduction of air escaping from the fan. Air distributor and rectifier are made of high grade steel.

- **Aeration pipe** – the aeration pipes are produced from polypropylene and are designed to continuously supply the composting material inside the modules with oxygen. With the increasing distance from the fan, the entire diameter of the pipe increases to ensure even-air distribution along the length of the module in a clearly defined relationship.

- **Combined interval-temperature control (PLC)** – the aeration unit is supplied with PLC in order to regulate the fans by a programmable maximum temperature according to the time of composting. An additional minimum fan interval, dependent on the respective material structure, is also given. The temperature is continuously measured in the core and rim area of the composting body. The relevant composting parameters, water content and temperature are recorded and stored by means of the temperature regulator. Every module is regulated separately, with adjustment to the respective composting conditions.

This type of construction allows simple charging/discharging by the wheel loader; drainage of the composting material; protection of the aeration pipes; simple cleaning routine; no restriction of the aeration of the composting material; controlling the conditions in each module separately.

After intensive stage, the curing stage of composting follows and the material is placed either into open curing modules and aerated or in open windrows with regular turning. The open curing modules are exactly the same as the intensive compost modules. Depending on the nature of the material being composted, the material can be moistened if necessary using the collected leachate or other suitable liquid. The material stays in the curing modules for another 3-4 weeks.

After a total of 6-7 weeks the material is transposed to the maturation area. The maturation takes place in open windrows. Retention time for this stage is 8-12 weeks. During this time the material has to be returned 3-4 times. The water content has to be adjusted if necessary.
After the maturation stage the material can be screened with a 10/15 or 25 mm screen. The screen should have a magnetic roll at the end of the conveyer belt for the fine fraction and a wind sorter. After removing plastics and metals the sieved overflow can then be reused in the maturation or if necessary as structure material for the intensive stage. The sieved material can be used as finished compost material and goes to the storage area.

**Leakage water and odour emissions**

Since the intensive composting process is covered, the leachate water can be collected in a tank separately from the rain water and can be reused to add moisture during the curing phase, if necessary. Combined with the controlled pressure aeration, the quantity of leachate water is less than in some other systems. The odour is reduced by the semi-permeable cover and 90% reduction of the odour emission can be guaranteed.

**Pathogens and industrial safety**

The composting system is suitable to produce hygienic compost. The spores are completely killed during the process in the modules and, as a result, there are no negative worker conditions for employees or the surrounding environment. Since none of the processing procedures takes place in the composting modules, the employees are not exposed to spore contamination. The spore reduction is based on the pore size of the membrane and the development of a moisture film on the surface of the composting material. This moisture film is caused by condensation of the water vapour. During the discharging procedure, when the cover is opened, the moisture film prevents dust formation and the associated bacteria emissions. The wheel loader should be equipped with an S-class filter acclimatized cabin.

**Operational safety**

The operational safety results from the modular design of the system and the simple technology. Even during a possible breakdown, the operation of the entire plant is guaranteed. The modular nature of the system means that there are no constrictions in the process flow, and that is why there is no interruption in the entire plant during an operational problem. The data transmission system allows the continuous monitoring of any operating conditions. If necessary, the composting parameters can be modified by changing the ventilation rates.

**Winter operation**

Under normal Swedish weather conditions (above –5 °C) it is not necessary to warm up the outside air circulated into the rotting material. This is illustrated by the composting plant in Sala (Sweden). During the winter 99/00 the temperature was below -20°C over a period of a few weeks and then composting process ran under normal conditions. Only the pre-composting process (self-heating process, a chemical reaction in the material with temperatures of over 65°C) was started by a space heater (for warming up the air) within 4-5 days. To make the winter operation easier, BIODEGMA is able to provide the specification and detail engineering of a ventilator building at the back of the modules (comparable to Sala). In this station it is possible to warm up air with a space heater if the temperatures are extremely cold, so that pre-heated air is blowing into the pre-composting material. Further it is necessary to use heating cables under the doors and at the door hinges. It has to be ensured that the composting material is not frozen after the changing of the composting modules as there are very few ways to thaw the material and to start the composting process again. Training is provided to operators as part of the commissioning process on the necessary difference in regulation of the airflow during the winter months.

**Investment and treatment costs for using the composting system**

Costs (investment and treatment) depend on many different factors: amount and type of waste for the treatment; density of waste; what kind of works are needed at the plant and what kind of works are already done; how many modules are needed and what kind equipment is going to be implemented; on energy and labour demands, fuel consumption, etc.
Some investment costs, which were estimated for the SRV by BIODEGMA in 2005-11-24\textsuperscript{19}, are [62]:

- For current waste capacity of 14 500 t/y (7 500 t/y of kitchen waste and 7 000 t/y of green waste) the 8 modules are required, so the price is – 7 550 000 SEK (technique for 8 modules) plus 4 429 993 SEK (other works), that is about 12 000 000 SEK;
- For increased waste capacity of 22 000 t/y (15 000 t/y of kitchen waste and 7 000 t/y of green waste) the 11 modules will be required, so the price is – 10 100 000 SEK (technique for 11 modules) plus 6 081 047 SEK (other works), that is 16 000 000 SEK.

In case of using additional maturation stage in open curing modules, investment costs will be the following:

- For current waste capacity (14 500 t/y) the 8 additional open curing modules are needed, so the price is – 8 648 000 SEK (technique) plus 8 376 470 SEK (total civil works), that is about 17 000 000 SEK.
- For increased waste capacity (22 000 t/y) the 11 additional open curing modules are needed, so the price is – 11 515 000 SEK (technique) plus 11 467 778 SEK (total civil works), that is about 23 000 000 SEK.

The plants and municipalities in Sweden, which use BIODEGMA composting system\textsuperscript{20}:

- Affärsverken AB in Karlskrona
- Norrlandsjord & Miljö AB in Luleå
- Nordvästra Skånes Renhållnings AB (NSR AB) in Helsinborg
- Tekniska Förvaltningen in Luleå
- Vafab Miljö in Sala
- Örebro kommun

At Affärsverken AB in Karlskrona the composting plant was built in 2002 and put into operation in October in the same year (Figure 6.15). The plant was constructed to compost biological waste from households, some restaurants and schools, and it has the capacity to treat 9 750 tons/year. In 2004 they treated 3 500 ton of food waste in the BIODEGMA composting system [63]\textsuperscript{21}.

![Figure 6.15. BIODEGMA composting system used at Affärsverken AB in Karlskrona [63]](image)

The plant consists of 9 modules, 5 covered with Gore-tex and 4 open boxes. Behind the modules is the fan house. There is a fan with the capacity of 1.6 kW connected to each box. The roof is opened automatically by a small engine on each module. Each module is 6.5 m x 21 m and is loaded to a height of about 2 m. That means every box holds about 250 m\textsuperscript{3} equivalent to about 150-160 tons.

\textsuperscript{19} More detailed information about investment and treatment costs for BIODEGMA composting system is in the Appendix 6.
\textsuperscript{20} Short description and contact information about these companies or municipalities is in the Appendix 4.
\textsuperscript{21} All information about Affärsverken AB in Karlskrona is taken from the reference 63.
The biological waste from households is collected once every 2 weeks and from apartments and restaurants once every week and is delivered to the reception area. The brown paper bags are ripped open in a scoop with 4 screws that cut the waste in pieces. The green waste is shredded separately and mixed with the food waste. To have a good structure of the compost the food waste is mixed with 25-30 % wood chips. The water content in the mixed compost should be 50-60%.

In each box there are 4 gutters in the floor with perforated air pipes connected to the fan. The air is supplied through these pipes. The gutters are filled with wood chips. When the modules are loaded the floor is covered with a layer of 10-20 cm of wood chips that helps to obtain an even distribution of the air throughout the pile.

The temperature in the compost rises very quickly to about 70°C. The temperature is measured with a gauge placed in the pile in two places: in the core (center) and in the surface. Temperatures and air supply are registered in a computer at the office and the air supply can also be changed at the computer. For each load a report with the temperatures and other data in a diagram is got.

When a covered box is filled the composting process shall continue for 3-4 weeks. This is called the intensive phase. During these weeks the waste is hygienized.

During the intensive stage of the composting process of food waste, smelly odours often arise, for example sulphuric substances and butter acid. Almost all these smelly substances dissolve in the moisture and are brought back to the compost as condense water. The moisture in the air condenses in the ceiling and drops back to the compost by 4 drop strips on each side of the roof, to get an even distribution. If there is an excess of water it is drained off by the gutters to the front drain or the side drain in each box. The leakage water, a few m³ per badge, is drained off to the leakage water system that also takes care about the leakage water from the landfill.

After 3-4 weeks dry parts arise in the compost. The compost has to be re-mixed and is put in an open box for another 4 weeks. The arrangement is similar to the covered boxes including the air supply and the report from the computer. To move the waste several times from one place to another and mix it requires the use of a wheel loader.

After the second phase the compost has to mature for another 5-7 weeks until the compost is stable. During this period the compost has to be turned in the pile at least once a week to aerate it.

The compost is sieved through a 10 mm sieve in a sieving machine. If plastic is sorted out, which may be done with a wind siever, the wood chip residual can be used as structure material over and over again.

As long as Affärsverken AB has space, they will mature the compost for another 10 weeks before selling the compost to customers. They also take samples and send to laboratories to have the content of the compost analysed. So far they have had very good nutrition values: nitrogen (3%), phosphorus (0,3%) and a low content of heavy metals.

The advantages of using BIODEGMA composting system are the following:

- composting of the waste under a semi permeable membrane (such as Gore-tex) inside the modules reduces the problem with odour substantially in comparison to the open composting;
- these membranes prevent escaping fungus spores to the atmosphere and getting rain water inside the modules;
- composting process is almost not dependent on climate conditions since it takes place in an enclosed reactor;
- the temperature (when it is so cold) can be regulated by heating pre-composting material with a space heater;
there is the possibility to control the temperature, moisture and air during the process;
- the possibility to prove the maintenance of hygienisation stage during the required time and at the required temperature;
- the use of electricity is low due to the low energy consumption for the fans.

*The disadvantages for them are the following:*
- odour problems are arising during the moving composting material from intensive stage to the maturation stage and during the mixing process of the not completely composted material;
- it is comparatively expensive composting system.

The investment costs for the BIODEGMA process at Affärsverken AB in Karlskrona were approximately 5 million SEK and the land- and concrete work, including the reception area, cost about the same amount, 5-6 million SEK.

**Norrlandsjörd & Miljö AB in Luleå** signed a contract for the delivery of the composting plant with a capacity of 12 000 t/y in December 2003. They treat about 3 500 metric wet ton waste yearly. The household and industrial waste comes from the regions of Luleå, Piteå and Kalix. Situated in Luleå, this plant is the most northerly of all BIODEGMA facilities. With temperatures ranging from -30°C during winter to >20°C in the summer, the system is therefore faced with very demanding operating conditions. The start-up of the plant took place on September 6th, 2004 [61].

The plant consists of: reception hall; 5 closed modules for 4 weeks treatment; 5 open modules for the next 4 weeks; open asphalt surface for after treatment, approximately 6-12 weeks. They take waste from 6 municipals in north of Sweden. Waste comes from households, restaurants, supermarket and garden waste. Norrlandsjörd & Miljö AB uses shredded garden waste as structure materials in the compost. They follow the regulations for the certification from RVF (SPCR 120) but they are not certificated yet [64].

They are satisfied with this method. As for them, it is a simple technique with a good result and not so expensive equipment compared with other technique. They are so far quite happy with the process as the major disadvantage with the former compost operation – from time to time extremely bad smell in surrounding areas – has totally disappeared.

On the minus side it is a lot of work with wheel loader to move the waste during the treatment time: from reception hall to closed module, then to open module and finally to asphalt surface. Also, although all waste should be source sorted before the treatment, it is still a lot of plastic and other non organic waste, which is a big problem. They have to sieve the waste at least two times during the treatment time to take away this non organic waste. For that they use a drum sieving machine and again they have a lot of work with a wheel loader [64].

The composting plant in Örebro has the facility for treatment of 8,000 t/y of kitchen waste from a source separated collection and an additional 3,000 t/y of green waste. Both collections are from the Örebro region. The waste is delivered into an enclosed delivery area fitted with a bio filter for odour treatment. After homogenisation the waste is treated for 3 weeks in closed BIODEGMA modules, turned and treated for a further 3 weeks in the modules. Construction of the plant was started in September 2003. After a 2-month winter break they started in March 2004. Commissioning of the plant took place on May 12th, 2004 [61].

**At Nordvästra Skånes Renhållnings AB in Helsingborg** they separate food waste into liquid and dry fraction. The liquid fraction is treated by anaerobic digestion for production of biogas. The dry fraction is composted in a BIODEGMA composting facility with forced aeration. They treat sorted waste from households and industries. The food waste comes from the six municipalities in their
region. The NSR AB is satisfied with the method. The only problem is the odour when moving material from closed to open modules. There is also a risk of drying out the material [65].

**At Vafab Miljö in Sala** the plant is similar to ones above. They also have 4 weeks treatment in closed modules with 4 aeration channels, then 4 weeks treatment in open modules, and the rest of time on an open asphalt area. They treat 6 000 tons of organic waste and 2 000 tons of park and garden waste. The treatment costs for them are 350 SEK/ton. As they said, it is twice cheaper than treatment costs in other composting plants, since their plant was built in 1999 and they had (or still have) subsidies from the government. Investment costs were also 50% less than they should be due to the subsidies. Vafab Miljö uses its compost for soil improvement [66].

So, we can come to the conclusion, that all these composting plants, which use BIODEGMA composting system, are satisfied with the method, they almost don’t have any problems with odour during the process, and also they provide the composting process in enclosed reactor, which helps them to control the process conditions. They can maintain the necessary temperature, moisture and aeration, which should be kept during composting to get the product of good quality. From the other side, the system is not cheap and also there are some odour problems during the transportation of the waste from the closed modules to the open maturation stage.

Some or all of these composting plants (who they are known just to the SP) are doing their qualification year (autumn 2005) to get the quality certificate for the compost and also, probably, they will also be able to get the approval from the SJV.

### 6.1.4. RotoCom (bagging) composting system

**RotoCom (bagging) composting system from the “company-producer” point of view**

This is a static composting method in closed plastic bags. It allows controlling the process evolution without turning or mixing the organic material during its transformation. The content of each bag is kept isolated both from the ground and from the environment. According to the company, it’s not necessary to build concrete surface, you can put the composting units also in a field or ground. The process can be successfully applied to any kind of organic material, previously mixed and shredded: vegetable waste, food industry by-products, agricultural waste, bio solids, manure, and urban food waste; as well as yard waste. It is possible to obtain good compost as well as a high quality biological organic fertilizer [67].

If the mixture is very wet or dense, it’s useful to add some brushwood or green waste. During the filling phase, the RotoCom machine places two perforated pipes at the base of the bag for air transit (*Figure 6.16*). The machine works feeding or dumping in a special conveyor that transports the material on a big rotating auger that presses the product inside the bag. The machine goes forward automatically and proportionally to the quantity of feed supplied. The most common diameter in Europe is Ø240 cm. The machine has a capacity to store 80 ton/h with a fuel consumption of 9,5 litre per hour of diesel fuel. RotoCom machine was made in Italy by the company APIESSE s.r.l. [69].

![Figure 6.16. RotoCom machine for loading waste to the plastic bags](image)

For uniform composting, the material is put into the bag at medium or low compaction, maintaining free air space. For example, with an average density of 670 Kg/m3 it is possible to store 3,03 ton each meter or 4,52 m³ of product each meter. The bags are 60 m long with diameter 3,0 m and with storing capacity of 240 tons of waste. The filled bags are sealed and laterally manually cut in different places to let air get out slowly. A fan connected both to the perforated pipes and to a timer, provides forced aeration to the bio-mass. The controlled air flow satisfies the bacterial oxygen
demand for aerobic activity. In this closed environment there is no leakage spreading as the plastic film envelops and isolates its content during the whole period of the thermophilic phase. That step is characterized by increasing of the inner temperature (ideal range = 55°-65°C), loss of humidity and volume. Climatic conditions do not have a big impact on the process, since it is possible during the winter to put covers on the bags, which can maintain warmth. This closed system reduces the odour problems, since it is possible to cover each bag with a flexible porous panel, which is able to capture the eventual smells coming out from the lateral cuts [67].

The high temperatures inside the organic material start during the first four or five days and last about five-six weeks. After a fortnight the oxygen demand decreases and bio-stabilization progressively occurs. It is very important to daily control the thermic level. During the third week, after the measurement of the Biological Oxygen Demand (BOD), it is good to reduce the intervals of forced aeration (less minutes “on”, more minutes “off” on the blower). There is an oxygen measuring system CM36 (Figure 6.17). A special oxygen sensor measures and monitors O₂ content directly in the pile, which is vital for the microorganisms. A temperature probe integrated in the oxygen sensor records the temperature at the measuring point from 0 until 100°C [70].

After about four-six weeks the air supply is stopped and the bags are opened. The half-mature product can be transferred to a pile. Bags should be thrown away after one using, but it is possible to use the perforated pipes more for the following cycles. Volume, humidity, odour are quite less. A period of about four weeks in pile, turning the material sometimes, can improve and homogenize the bio-mass. Total process takes about 8-10 weeks22 [67].

According to the company, the new idea to make compost in such kind of plastic bags was:
- the possibility to use forced ventilation in plastic tube;
- there are no odours or wind and rain problems;
- using of fully recyclable plastic material;
- increasing processing speed in bags in comparison to open composting;
- machine is fully automatic;
- flexibility of the work;
- the absence of fixed structures to compost;
- the absence of turning machines to oxygen the rows;
- with some premixing of material by the loader it is not needed to use a mixer wagon;
- low costs [68, 71].

Investment and treatment costs for using the composting system
According to the estimations of Claes Tech AB in Sweden, the costs are the following23:
- RotoCom machine costs 1 200 000 SEK (or 240 000SEK per year during 7 years);
- One bag (volume is approximately 400 m³) costs 9 000-10 000 SEK;
- One fan costs about 12 000-13 000 SEK, but there are should be also devices for temperature and oxygen regulation;

Treatment cost is about 75-125 SEK per ton depending on many factors:
- filling and emptying the bags – is about 10-15 SEK per ton of material;
- using of RotoCom machine – is about 24 SEK per ton of waste (if amount of waste is 10 000 tons per year);

22 The technological schemes of this RotoCom system are in the Appendix 7.
23 More detailed information about costs for the RotoCom system is in the Appendix 8.
- using bags – is about 40-75 SEK per ton of material [72].

**The plants in Sweden, which use RotoCom (bagging) composting system**

The RotoCom (bagging) composting system is most spread in France. There are almost 30 plants, which operate with that system. Also a lot of plants, which use RotoCom (bagging) system, are in Italy. There is just one plant in Sweden (till November 2005), which uses this system for composting of organic waste – **Borlänge Energi**.

I have talked to Christian Ohlans – the representative of the plant in Borlänge. He said that they have invested about 60 million SEK to build a whole plant. Investment costs for the RotoCom composting system was about 1,5 million SEK. Their treatment costs are about 650 SEK per ton of waste (the price could be for the company, which brings waste and pays for them).

In Borlänge Energi they use box composting together with RotoCom composting system. Organic waste they get from households, restaurants and food industry. The amount of this waste is about 10 000 t/y. Borlänge Energi also treats garden waste which amount is about 2 000 t/y. These wastes are collected at the reception area and are mixed. Then they go to the box composting system, which is inside the building (**Figure 6.18**). This process takes about 4-5 weeks. During this stage it is possible to reach and maintain 60-65°C in the composting material for more than one week. The box composting also allows avoiding problems with odour outside the building, where boxes are situated [74].

After that the composting material is put to the RotoCom plastic bags with helping of special RotoCom loader (**Figure 6.19**). The volume of plastic bags is approximately 300 m³. This stage takes about 14-16 weeks, though, according to the “company-producer” of the system, it takes 5-6 weeks (it could be in case of much warmer climate in Italy in comparison to Sweden). During this time the aeration of the material is done with using the fans (**Figure 6.20**). Inside the plastic bags it is very difficult to reach 65°C in composting material. Borlänge Energi can reach this temperature for a few hours maybe or the temperature 55°C for almost three days, but they don’t need to have it since 65°C is reached in the previous box composting stage [74].

After this stage, plastic bags are cut and thrown away, and composting material is put into the piles (windrow composting) for further maturation stage. The whole process takes about one year to get the ready compost.
Matured compost is sieved in order to separate different kinds of contaminants and then is used as a soil improver or for the construction purposes.

Borlänge Energi has this method already 7-8 months and they are satisfied with the system. They said that this method is cheaper than Ag-Bag composting system (the price for the one RotoCom plastic bag for them is about 7 000 SEK). But they also have smell problems during the process. And also bags can not be reused. They don’t have any certification and approval, but they work to get the SP certificate [74].

According to Claes Anderson, Borlänge’s level of composting is not very high. It could be because of too dense material, depending on too high moisture content or too high bulk density and too little correction of wood chips, etc.

The advantages of the RotoCom (bagging) composting system are the following:
- it is comparatively cheap method (for Borlänge Energi each bag costs about 7 000 SEK) – it is cheaper than Ag-Bag composting system;
- this system is easy in work;
- there is the possibility to make own mix of waste;
- the availability of oxygen and temperature measuring system which allows providing the continuous monitoring of parameters;
- the availability of covers for the bags, which can maintain warmth, so the process could not be very dependent on the weather conditions;
- the availability of a flexible porous panel to cover each bag with in order to be able to capture the eventual smells coming out from the lateral cuts;
- the composting process in bags is faster then windrow composting;
- there is less odor problems than during open composting.

The disadvantages of this system are the following:
- difficulties with hygienisation process – almost impossible to reach the necessary temperature for hygienisation the material;
- difficult to spread the air evenly in whole material;
- it is difficult to mix the material during the process;
- bags cannot be used more than one time;
- the fans are too small to supply a good aeration of the composting material;
- the bags often become broken and system can not be considered as a really closed;
- there is not very sophisticated control of the process;
- there is no mixing machine suggested by the RotoCom system.

So, RotoCom (bagging) composting has not sophisticated control of the process, but anyway it has more control than windrow composting. It is possible to keep some moisture and aeration inside the bag and there are no big odour problems while material is in the bag. Normally it is very difficult to reach hygienisation temperature in all material, but these bags can be provided with insulation cover (it is reusable). And this system is comparatively cheap.

As for the Ag-Bag composting system, it is also will be quite difficult to get the quality certification and approval for RotoCom composting system because of the similar problems in proving the hygienisation stage, the necessary conditions inside the bags, proper mixing the organic waste and structure materials, size of materials of no more than 12 mm, etc.

6.1.5. Rotocom rotary composting system

Rotocom rotary composting system from the “company-producer” point of view
There is another Rotocom rotary composting system, which is mainly used in New Zealand, England and Japan (Figure 6.21). There are no plants in Sweden nowadays using this kind of
composting system. This system is different from the previous one since it has continuous turnover during the composting stages.

Rotocom is an alternative to landfill and windrow composting. The Rotocom rotary system can be used for industry, large companies, local councils and small communities. All organic waste streams can be treated using the Rotocom rotary system including even Animal By-products [76].

**Process description**

Waste is delivered to the processing facility where it is first sorted then shredded to reduce particle size if required and mixed, after that it is put to the vessel. For that purpose the mixer and in-feed conveyor is used (Figure 6.22). A building allows these procedures to be managed without interference from the weather, and also reduce any odorous discharges to the environment.

Waste is processed using a rotary drum horizontal flow reactor (Rotocom), which is essentially a slowly rotating cylinder with a counter-current airflow and the internal features to manage the even flow of biomass through the system. Rotocom rotary system provides a thermophilic (high temperature) composting phase where pathogens and seeds are destroyed, and odours are minimized. Fan forced airflow provides a controlled oxygen environment for aerobic decomposition. Residence time in Rotocom varies with application but is not shorter than four days. Continuous turnover increases the contact with oxygen what accelerates the composting process. In the thermophilic composting phase, volume is significantly reduced to form a commercial compost product of approximately 60% of the original volume.

All process air is extracted from the vessels and processed through enclosed bio-filters where the organic volatile compounds are converted into water and carbon dioxide. After passing through the bio-filters, the cleaned process air is vented to atmosphere. Alternatively, where land area is constrained or on customer preference, chemical scrubbers can be used for odour removal.

After intensive processing in the vessel, the compost is then conveyed into a storage bunker, where it can be moved by truck or front-end loader to cure in windrows before the end usage24 [76, 77].

The centerpiece of the Rotocom composting system is the rotary vessel (Figure 6.23). The outer drum rotates, moving the material inside the vessel through the system. Internal features, such as paddles running the length of the drum and vanes positioned upwards from the central shaft, manage the even flow of biomass through the system. The paddles lift the waste up the side of the vessel and turn it over. As the vessel is filled to around 70% capacity, the central shaft is completely covered by the composting material. As the vessel rotates, lifting and turning over the material, it flows pass these arms, which guide the compost forward, pushing it further down the vessel [77].

24 The technological scheme with the description of a whole process is in the Appendix 9.
There are the following temperature stages inside the Rotocom vessel:
- development of thermophilic temperatures in the materials from ambient 20-40°C – microorganisms begin decomposing the readily available components in the waste;
- thermophilic temperatures (up to 70°C) – period of high temperatures (peak) to ensure complete destruction of pathogens and seeds;
- gradual cooling as organic matter is degraded – 55°C;
- material exits at 40°C [76, 78].

The level of sophistication of the control system varies depending on the requirements of the client, but data logging of temperatures is mandatory and provides confirmation that temperature requirements for pasteurization have been met.

Rotocom units are available in a range of sizes depending on varying volumes of waste and the intended application (Table 6.1.)

Table 6.1. Rotocom vessel sizes offered by ANDAR Holdings Ltd. [77]

<table>
<thead>
<tr>
<th>ROTOCOM™ unit</th>
<th>Dimensions (m)</th>
<th>Working volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC12 (12 m³)</td>
<td>1.6 Ø x 6.0 length</td>
<td>8.4</td>
</tr>
<tr>
<td>RC28 (28 m³)</td>
<td>2.0 Ø x 9.0 length</td>
<td>19.8</td>
</tr>
<tr>
<td>RC54 (54 m³)</td>
<td>2.4 Ø x 12.0 length</td>
<td>38.0</td>
</tr>
<tr>
<td>RC85 (85 m³)</td>
<td>2.7 Ø x 15.0 length</td>
<td>60.1</td>
</tr>
<tr>
<td>RC127 (127 m³)</td>
<td>3.0 Ø x 18.0 length</td>
<td>89.0</td>
</tr>
<tr>
<td>RC159 (159 m³)</td>
<td>3.0 Ø x 22.5 length</td>
<td>113.3</td>
</tr>
</tbody>
</table>

According to the company, the key benefits are:
- High level (complete) of pathogen and seed destruction;
- Avoids leachate and ground water issues;
- Reduces vector attraction (flies and vermin);
- Flexibility of processing;
- Greater degree of process control;
- Space efficiency;
- Range of waste streams able to be processed;
- Enclosed system ensures protection from the climate;
- Eliminates the risk from dust and bio aerosols;
- Consistent level of treatment;
- Low operating and energy costs;
- Low maintenance and labour requirements;
- No compaction of material during processing;
- Odour minimisation and treatment;
- Mechanical reliability;
- Integrated temperature and moisture control system;
- Can be operated for total decomposition or production of consistently high compost depending on throughput and feed material composition;
- Stable process and temperature profile enables different environmental microbes to be active simultaneously in the system;
- Continuous and consistent aeration for consistent oxygen levels;
- Does not dry out or compost unevenly;
- Accurate blending of feeds lead to consistent C/N ratios due to continuous mixing system;
The system can be operated to meet different standards like EU Animal By-products Regulations (2003) [76, 78].

Depending on an amount of waste which is going to be treated, composting plant can contain several Rotocom units (Figure 6.25).

Figure 6.25. A typical composting plant with using Rotocom rotary composting system [77]

**Investment and treatment costs for using the composting system**

Investment costs for Rotocom rotary system depends on many factors such as the number of units supplied, kind of steel (stainless or mild steel) used for the vessel, costs to transport the waste to site and many others. An estimate price for a RC159 machine that will process 5 000 tones waste per year is about 600 000 Euro. Treatment cost depends basically on electricity and lubrication [79].

**Advantages of the Rotocom rotary composting system are the following:**
- Rotocom is a stainless non-corrosive steel cylinder, which operates continuously;
- the vessel is insulated, so all material can reach the temperature 70°C for the hygienisation for appropriate time required by the Animal By-Products Regulations;
- there is continuous measurement of temperature in the system;
- there is the possibility to treat animal by-products;
- time of composting process is reduced substantially; it takes a minimum 6 weeks to get finished compost (7-10 days in Rotocom rotary system, remainder in windrows);
- very rapid losses in organic matter are achieved by during the process;
- the smell during the process is reduced a lot because of using bio-filters and chemical scrubbers;
- there is the possibility to get approval and the quality certification.

**Disadvantages of this system are:**
- it is difficult to prove retention time and temperature when the process runs on a continuous basis and is fed in one end;
- several drums are needed for big amount of waste and it is quite expensive (for example, for 15 000 tones waste per year 3 RC159 machines are necessary);
- it is comparatively expensive system

This system is a quite good method for treatment of organic waste, since it is possible to treat animal by-products and to reach the temperature 70°C to ensure the hygienisation of the material. The smell during the process is reduced a lot because of using bio-filters and chemical scrubbers and because the vessels can be located inside the building, which also helps to reduce odour problems. The time of composting process is also reduced substantially. It takes about 6 weeks to get mature compost. In spite of these advantages, I think this method is quite expensive (the most expensive in comparison to other composting systems described in this report).
I think, it would be possible to get an approval from SJV for this kind of composting since this system can be operated to meet Animal By-product Regulations. And there is also the possibility to get the quality certificate from RVF and SP as well.

6.1.6. VAPO composting system

VAPO composting system from the “company-producer” point of view
VAPO is Finland’s leading supplier of a tunnel composting system for composting plants. VAPO Biotech is a part of Vapo group, a major Finish company.

According to the VAPO brochures, VAPO Biotech system is reliable, efficient and cost-effective for treatment of biowaste, sewage sludge, and other organic wastes. Extensive automation means that plants are easy to operate and require only low manning levels. The tunnel composting plants are flexible in terms of the quantity and type of material they can handle. The method is also effective for processing frozen biowaste. Plant throughput can be increased by adding new tunnels, while existing tunnels continue to operate without interruption [80]25.

The system is closed, and liquid effluents generated during the composting process are collected and treated, and can be recycled. Odours are treated by an ammonia scrubber and then by a VapoClean bio-filter. Therefore the plants can be located near to inhabited areas, according to the company-producer.

Parameters that are monitored and can be guaranteed by the VAPO Biotech include:
- plant capacity;
- absence of pathogenic bacteria and fungi;
- absence of germinating seeds;
- loss of organic matter;
- moisture %;
- exhaust gases (HN₃, reduction %);
- effluents;
- operating ratio and costs;
- final product nutrient level.

Process overview
VAPO plants utilize a batch process housed in totally enclosed tunnels with forced aeration to promote consistent composting. The process is entirely self-contained and fully automatic (Figure 6.26).

Waste reception and pre-treatment
Incoming waste is discharged into insulated reception bunkers. The waste is blended with a bulking agent. This is done in the pre-treatment hall using a loader fitted with a screening bucket, or a fixed mixing unit. A feedstock layer 2-3 meters deep is then built up in the tunnel.

Composting
Composting takes place in closed, reinforced concrete tunnels, which are aerated through perforated hollow-core floor slabs. The process air can either be recirculated from the other tunnels, fresh air from outside, or a mixture of both. Composting conditions are optimized by the process control system. The composting stage takes from 14 to 21 days.

25 The information about VAPO composting system is taken from the reference 80.
Process control and automation
The process is fully automatic. The automation system monitors and controls the volume, temperature, moisture and oxygen content of the air flow into each tunnel separately in order to optimize composting conditions. The automation system can also be controlled by remote control.

Exhaust gas treatment
The exhaust gases are fed through a scrubber, which removes ammonia. A heat recovery unit recovers heat energy generated in the composting process, and this is then used to heat either incoming air or the plant facilities themselves. After the scrubber, the exhaust gases pass through a VapoClean bio-filter, which removes malodorous gases and any remaining ammonia.

Screening and post maturation
When the material is removed from the composting tunnels it is first screened and then put in windrows outside for post maturation. This takes 3-6 months, after which mineral soil and nutrients can be added, if required, to the mature compost to produce growing media.

Figure 6.26. The example of the technological scheme of composting plant with using VAPO composting system [80]

I have met with the representative of Vapo composting system (Timo Valkeinen from the VAPO Biotech Company) and talked about the system. There are no composting plants in Sweden yet, which use VAPO composting system, but the VAPO Biotech is now offering one to Gävle. Since VAPO Biotech is a Finish government owned company, it is understandable, that there are a lot of composting plants in Finland, which operate with this composting system. Actually, there are 14 such composting plants and the oldest one has been operating since 1996. During such a long period of working there are no complaints from the workers or inhabitants living close to the plant about smell and other different things [81][26].

The plant can treat organic household waste as well as sewage sludge with using of bulking materials such as green waste and wood chips for the household waste and peat in case of treating the sewage sludge. There are two entrances for the trucks, which come with these two different kinds of wastes. The place in front of entrance for household waste is heated; this is so the trucks don’t slide into the doors.

Inside the plant has two separate sections where sewage sludge and household waste are collected. The household wastes are source-separated and biodegradable material they are collected in the paper or starch bags, what is preferably, or in the plastic bags. The bulking materials are stored in a special separate construction.

[26] The information about VAPO composting plant is taken from the reference 81.
The wastes are going to the mixing-crushing unit where sewage sludge or household wastes are mixed with the corresponding bulking agents. A special machine is used for that purpose. It is comparatively expensive, but in a case of not very big plant, the loader (Allu-sållkross skopa) can be used instead of this machine. It is slower in operation but it is much cheaper. There is no automatic loading devices (like some pushers) since they are easily broken.

After that mixed waste goes to a collecting room from where it is taken by a loader to the composting tunnels. There are separate tunnels for sewage sludge and household waste. This is the main unit where the composting and hygienisation processes take place. Hygienisation is done at about $>60^\circ\text{C}$ during 1-2 weeks [81]. The difference between temperatures in the bottom of pile and in its tip is about $4^\circ\text{C}$ (for example, $60^\circ\text{C}$ – in the bottom and $64^\circ\text{C}$ – on the top) in the hygienisation step. This is very good (little difference in temperatures), since all material in a whole pile is for sure hygienized, and pathogenic bacteria and fungi are destroyed during the process.

The tunnels have good aeration and heating systems. For heating the material they use the heated and moisturized air from the tunnel besides. There are three methods to force the air in the tunnels. The first one is recirculation of its own hot air inside the tunnels; the second one is when heated and moisture air is forced under the floors of tunnels; and the third one is the warm fresh air (about $20^\circ\text{C}$), which is always maintained inside the plant. The machine room is situated right closed to the composting tunnels with huge fans, which serves for making under-pressure inside the plant, making very good aeration in composting tunnels and to move exhausted gases from the composting tunnels to the ammonia scrubber and bio-filter. Good aeration is done by the fans (about 1 m in diameter) which blow the air through the about 7 000 holes in the floor to the composting piles.

In this unit it takes 3 weeks for the household waste and 2 weeks for the sewage sludge to be able to take it to the maturation stage. About 45% of organic material is degenerated during this 3-week stage, that is 50% less volume of incoming waste is got.

Exhausted gases go to the bio-filter and ammonia scrubber. In the ammonia scrubber about 90% of ammonia is taken out and in the bio-filter 90% reduction of the rest contaminations and odorous components is achieved. According to Timo Valkeinen, there is almost no smell in the gases, which go from the bio-filter. Bio-filter consists of peat, compost and some other compounds. It should be changed once a year; old material goes to the composting stage to be composted. The bio-filter is not a very expensive thing in the plant to change regularly.

After the initial stage there are two ways of operating the waste could be in the plant.

If there is a lack of space for the composting plant, the option aerated maturation stage in tunnels is offered. Composting material from the composting tunnels goes to a 4-weeks maturation stage. Also some part of material is mixed with new bio-waste or sludge arriving at the plant; this is done to encourage the efficiency of the process. Here the aeration in tunnels is done from the top to the bottom, because the percent of dry substance is higher than in the initial composting tunnels and such aeration is done not to blow away part of composting material. For this an area of 3 500 m$^2$ of area is needed. After the maturation waste is taken by the loader to the sieving machine where metals, glass, different kinds of plastic and bulking agents are separated from the compost. The bulking material can be reused up to 20 times for new portions of waste in the composting plant.

The second option is when the composting material is taken from the composting tunnels after 3 weeks by loaders and is brought directly to the sieving machine where different kinds of contaminations are taken away. After this, clean composting material is taken to some open area where it is put in piles for windrow composting process. Compare to the first option, it takes 2,5-3 months more to get a mature compost. For this kind of plant it is necessary to have the area of 20 000 m$^2$ (for whole plant) if the amount of household waste is about 20 000 t/y.
During the process, all necessary measurements are taken continuously. There is a special control room inside the plant. Biological treatment in the tunnel reactors is a carefully controlled process, which advances systematically from one stage to the next. Process control automation optimizes conditions in each tunnel throughout the process by adjusting such parameters as the oxygen content, volume and temperature of the air that is blown in.

There is also supposed to have some wastewater treatment plant on the plant’s territory to take care of leachate from the composting process.

According to VAPO, it is possible to get 3 types of compost in the plant: the first one (of the best quality, mainly from the household waste) is used for farming; the second and the third (of different qualities, mainly from the sewage sludge because of the heavy-metal content) are used for the construction purposes and as soil enhancers. These materials have a high nutrient content and are ideal for a range of landscaping applications. The plant can also produce fuel from industrial sludges.

As I was told by Timo Valkeinen, the demands on compost quality and composting process in Finland are higher and stricter than in Sweden. So, in that case, there are no doubts that this plant could meet all Swedish requirements and regulations.

Also there is the possibility to get energy from VAPO composting process. If you have, for instance, 10 000 tons per year of organic waste, you get 2 500 tons per year of compost and also 350 kW energy, which can be used for the plant’s purposes as well as for the heating of the nearest areas (like district heating). The energy is taken from the exhausted warm gases from the outgoing pipes of the tunnel (55-65ºC) from the process with a “heat-convector”. This energy is created continuously because there are several tunnels in different stages.

Each VAPO Biotech composting plant is individually planned to meet the needs of the customer. The planning work takes into account such factors as the volume and quality of material to be composted and the way in which the final product will be utilized. Wastech composting plants also represent a flexible and reliable solution for the long-term. VAPO constantly monitors developments in relevant legislation and ensures that its plants are up-to-date. As requirements grow a Wastech plant can be easily expanded by increasing the number of tunnels.

VAPO offers comprehensive after-sales services, which are available to the customer:

- **Service contract** means that VAPO is responsible for the construction of the plant, owns the plant, and is responsible for its operation as well as for the marketing and delivering the final product;
- **Operating contract** means that the customer is responsible for constructing the plant and owns it, but VAPO takes responsibility for its operation [80].

**Investment and treatment costs for using the composting system**

There is no investment costs are necessary to built the plant. If you use the service from VAPO Biotech, it costs approximately 550 SEK/ton of waste during the 15 years on the contract basis when you use open composting for the maturation stage and approximately 650 SEK/ton of waste at the same circumstances but when you use aerated maturation stage in tunnels instead of windrow composting. And it takes about 6-7 month to build the composting plant with VAPO composting system [81].

**The main advantages of VAPO system are:**

- the tunnel composting technology allows treating the bio-waste and sludges in a controlled and environmentally compatible process;
- the good aeration barrier near the entrance for trucks and also under-pressure, which is created inside the plant, don’t allow the smell to get out of the plant;
- the availability of high efficient ammonium scrubber and bio-filter, which substantially reduce smell occurred during the process;
- there is possibility to maintain the necessary conditions (good aeration, oxygen content, moisture and temperature) during the process;
- process is not dependent on weather conditions, since it is inside the building where 20°C is always maintained;
- the time of composting process (in case of aerated maturation stage in tunnels) is substantially reduced;
- there is the possibility to treat large capacities of waste;
- the plant can operate without any stops (due to VAPO service);
- the plant downtime is minimized;
- all structural components are designed to withstand the difficult conditions found in the composting process, and the number of moving parts in the plant has been minimized;
- there is almost no start capital is needed to build the plant;
- the plant could be built on the distance in 300-500 m from the living area;
- factors such as noise, dust and workplace safety and hygiene are taken into consideration at the plant design stage;
- there is the possibility to get approval from SJV and quality certification form SP and RVF.

The main disadvantages of VAPO system are:
- the method is quite expensive in the operating.

Due to written above, this composting method is a quite good option for the biological treatment of organic waste.

6.2. Fermentation used in Swedish plants

Fermentation is also very common method of biotreatment of organic waste in Sweden. Biogas production in Sweden began from the 1960’s. In the 1970’s and 1980’s several small farm-sized plants were constructed for anaerobic digestion of manure. Since the mid of 1990’s several biogas plants have been constructed to digest food industry and slaughterhouse wastes, as well as the kitchen wastes from households and restaurants [41]. There are a lot of biogas plants in Sweden now, which use almost the similar technique for fermentation of organic waste. Below are the technical description of this biological treatment method and also some experiences of the plants providing the anaerobic digestion of biodegradable waste.

The plants in Sweden, which use fermentation\(^\text{27}\):
- Älmhults kommun (Älmhult)
- Borås kommun (Borås)
- Borlänge Energi (Borlänge)
- Falköpings kommun (Falköping)
- Kalmar Vatten och Renhållning AB (Kalmar)
- Kristianstad Renhållnings AB (Kristianstad)
- MERAB (Eslöv)
- NSR AB (Helsingborg)
- Nära (Klippan)
- Skellefteå kommun (Skellefteå)
- SRV återvinning AB (Huddinge)
- Svensk Biogas i Linköping (Linköping)
- TRAAB (Vänersborg)
- Uppsala kommun (Uppsala)

\(^\text{27}\)There could be some other fermentation plants, since I couldn’t contact all biological treatment companies in Sweden. Short information about these companies is in the Appendix 4.
At Västerås Renhållningsverk (the fermentation plant has been built in 2005) they are planning to treat 23 000 t/y of waste [47]:
- 14 000 tones of clean, source-separated organic waste, with a dry matter content of 30%, from households and institutional kitchens;
- 4 000 tones of grease trap removal sludge, with a dry matter content of 4%, from grease separators in institutional kitchens and restaurants;
- 5 000 tones of ensilaged ley crop from a contracted ley acreage of 300 hectares. The silage is expected to have a dry matter content of 35%.

They expect to get the following annual yields:
- Biogas from the new biogas plant is expected to contain 15 000 MWh energy, when upgraded to fuel quality corresponding to 1.5 million liters of petrol;
- Biogas from the sewage treatment plant, containing 8 000 MWh energy, will be upgraded to fuel quality. The total amount of produced vehicle fuel will correspond to 2.3 million liters of petrol;
- Digestion residuals that are expected to contain 150 tones of nitrogen, 30 tones of phosphorus and 100 tones of potassium.

The biogas-plant
In the plant, organic waste, ley crop and grease trap removal sludge will be treated by digestion in a closed process. An overview of the plant is shown in the Figure 6.27 and a flow chart is in the Figure 6.28.

The main characteristics of the plant are:
- A receiving hall where reception and quality control of incoming waste and separation of foreign material will take place. The hall is designed to enable a flexible handling of waste and silage including necessary storage capabilities;
- A receiving bunker for reception of all kind of liquid waste. The bunker can also be used for feeding of solid waste in case the walking floor is not in operation;
- A flexible and excessive pre-treatment of the waste. Three turbo mixers can be used independent from each other;
- A separation of the digestion residuals into one solid and one liquid phase without addition of any chemicals. The solid residue will mainly be used as a phosphorous fertilizer and the liquid part as a nitrogen fertilizer;
- A process that minimizes the need for addition of fresh water by circulation of process water (liquid digestate) for the dilution of the solid waste and the ley crop. Thereby the amount of liquid digestate to be transported to the farmers is minimized;
- A closed process with collection and treatment of all exhaust air in a scrubber and a bio filter in order to avoid any odour problems in the surroundings of the plant. The air is preheated before it enters the bio filter in order to ensure the intended function of the bio filter during winter conditions.

The wastes are delivered to the plant to two different reception facilities for solid and liquid waste. Solid wastes are separated from different contaminants and go to the turbinmixer where they are mixed with liquid waste, which comes from deep bunker (Figure 6.28).

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28 The information about Västerås Renhållningsverk is taken from the reference 47.
Then the mixed waste goes to a sand trap where the light and heavy fractions are separated from the waste. After wet crushing and suspension buffer tank, waste goes to the hygienisation unit, where the hygienisation of waste is done at 70°C during 1 hour. After this the waste goes to a digester, where the fermentation process takes place and where the biogas and digestate are produced.

The biogas from the biogas plant and biogas from the existing sewage treatment plant will be upgraded so it can be used as vehicle fuel for buses, refuse-collection vehicles and cars\textsuperscript{29}. The gas from the two production sites expected to be sufficient to supply at least 40 city buses, about 20 refuse-collection vehicles and 200 cars and other light transport vehicles. Biogas not sold as vehicle fuel will be used for production of electricity and heat in an existing gas-engine at the Gryta waste treatment plant. The produced heat will be led into the district heating system in Västerås.

The digestate goes to the centrifuges, where the solid and liquid digestate are separated from each other. The solid phase will be handled as “normal” farm manure and will be spread with conventional manure spreaders, i.e. the residuals must be dry enough to allow stacking. The liquid phase shall be pump-able and possible to spread with conventional slurry spreaders. Waiting for the spreading, digestion residuals will mainly be stored closed to the cultivated acreage. Liquid residuals will be stored in covered tanks in order to minimize the ammonia losses during storage. The basic principle for the design and placing of the stores shall be to minimize the transport distances in connection with spreading. The calculated quantities of solid digestion residuals, with dry matter content above 25%, is about to 6 500 tones per year. The liquid digestion residuals is estimated to be 15 000 tones per year. The dry matter content of the liquid phase will be approximately 2%.

**Quality control of the digestion residuals**

Digestion residuals from the material that is treated in the Växtkraft-plant are nowadays accepted as fertilizers in organic farming. One of the pre-conditions for a decision to build the plant was that the digestion residuals are accepted for use in conventional cereal production, according to the rules of Svenskt Sigill and Cerealia and in organic farming according to the rules of KRAV.

\textsuperscript{29} Schematic flow chart for upgrading of biogas to vehicle fuel is in the Appendix 10.
The quality control of the digestion residuals is expected to conform to the rules for certification of compost and digestion residuals that have been developed by the Swedish Environmental Protection Agency and the RVF. The quality control will be carried out in several stages, partly by inspections in connection with the collection and the reception at the plant and partly by analyses of the substrate and of the digestion residuals on delivery to the farm.

Spot checks will be carried out in connection with the collection of waste in order to ensure that the given directions are followed. If, at these spot checks, waste is found that does not belong in the container for organic waste, the household/business is informed. If subsequent spot checks show that the given directions are still not followed, the household/business in question will be suspended from the source-separation system. The biogas plant includes both a manual separation of wrongly sorted bags (organic waste is kept in brown paper bags - see Chapter 5, figure 5.2) by a manually operated crane, and a mechanical separation of one heavy and one light fraction.

The sludge from grease separators is checked both weight wise (the collected amount is registered at each collection site and the total registered amount must correspond to the amount delivered to the plant so as to ensure that no other substance occurs in the container), and also by chemical analyses.

Västerås Renhållningsverk invested about 76 million SEK for a whole plant including the biogas upgrading plant. Their treatment costs were 450 SEK/ton of waste during 2005.

The biogas plant in Kalmar is also divided into two different parts: organic waste treatment, which includes collection, hygienisation and digestion; and gas upgrading.

**Organic waste treatment**

The collection part of the Kalmar biogas plant consisted of two lines, one for solid and one for liquid waste. The solid manure and waste were emptied into a reception shute. The pulper, a kind of a mill, mixed and sliced the solid waste in to pieces of maximum 10 mm. Due to technical problems this line for solid waste is no longer in use. Substrates processed in the liquid line are mainly liquid manure, but also blood, milk waste and macerated slaughter products. To prevent contamination of microorganisms between different farms the vehicle, used at the biogas plant, is washed carefully both outside and inside the tank. The inside wash process also includes a disinfection step.

![Figure 6.29. Technological scheme of fermentation of organic waste used at Kalmar biogas plant](image-url)

83
Collection of liquid waste occurs in a tank and then the waste goes to the mixing tank, which also functions as a storage tank to maintain continuous flow (Figure 6.29). Their processing capacity for the plant is 40 000 ton/year, but in 2004 they fermented just 22 000 ton [82] 30.

For agricultural use of the end product a decrease of microorganisms is necessary and by heating a wide range of bacteria, parasites and virus are killed off. The hygienisation part consists of three tanks, 12 m³ each, used as a continuous process. The substrate has a detention time of 1 hour at a temperature of 70°C. The plant is equipped with several heat exchangers for recovering the energy.

The technique used in the digestion chamber is a continual one-step process with total mixing. The hygienised substrate is pumped into the chamber, which has a volume of 1 800 m³ and the detention time is 18-20 days (thermophilic process at 55°C). The end product, called biomanure, is stored in a reservoir before it is transported to the local farmers and used as a sanitized and odourless fertilizer.

Gas upgrading
From the digestion chambers the gas leaves automatically, by a low over pressure, to the gas storage tank. The tank is constructed as a floating clock and its purpose is to provide a buffer to enable time differences in the production and consumption. Normal content of produced gas in the digester is: methane 65-70%; carbon dioxide 30-35%; nitrogen <3%; hydrogen <3%. The gas is distributed to several sources: gas treatment (15%), internal heating (55%) and external steam production at the local hospital (30%). To convert raw gas to vehicle fuel several steps of treatment is necessary. First, the energy value must be increased, which is achieved by cleaning the raw gas to mainly methane. The method used is absorption in a water scrubber, which absorbs carbon dioxide but also hydrogen sulphide and particles. Second, to avoid corrosion in pipelines and motors, a device for drying is required. The final step is compression of the gas and the technique used is a RIX four-stage compressor. The equipment will clean the gas to 97-99% of methane and <2% carbon dioxide, and compressed it to approximately 250 bars. After treatment the biogas is transported in a high-pressure pipeline to the gas storage at the fuel station. The product, biogas, is nearly equivalent in properties with natural gas and the same technology for converting car motors is used.

Kalmar Vatten och Renhållning AB invested about 40 million SEK in 1998 to build the whole plant. Their treatment costs are 260-500 SEK/m³.

The biomanure from this plant is certificated by SPCR 120. The biogas plant has also permission from Swedish Board of Agriculture (SJV) and Länsstyrelsen i Kalmar län.

At the biogas plant in Linköping (built in 1995), various organic waste products are converted to biogas and bio fertiliser. Production is based on organic waste material, primarily from slaughterhouse remains and the food (mainly chicken) industry, together with manure from neighbouring farms. They don’t use household waste, since this waste is not standardised. The capacity of the plant is 54 000 t/y of waste.

The incoming material is mixed into homogeneous slurry in a reception tank after which it is hygienized by steam-heating to above 70°C for at least one hour in order to kill microorganisms (Figure 6.30). After cooling, the material is pumped into a digester to be broken down by different types of microorganisms in an anaerobic environment at about 38°C (a mesophilic process). They have 2 fermentation tanks (3 700 m³ each). The average detention time in the digester is one month [83] 31.

30 The information about Kalmar biogas plant is taken from the reference 82.
31 The information about Linköping biogas plant is taken from the reference 83.
After digestion unit they get biogas and digestate. The bio-fertilizer is cooled to about 20°C and stored at the plant a day or two before distribution to farms. Biogas consists of 70% of methane and 30% of carbon dioxide. When ready, a small portion of raw biogas is used in the production processes and the rest part of the gas is piped to the upgrading facility where it is purified in a pressurized water scrubber before it is supplied as a vehicle fuel. After filtering and drying, the gas meets the Swedish Standard for biogas for vehicles (SS 15 54 38). After the upgrading plant the biogas contains 97% of methane. Next to the biogas plant the sewage water treatment plant is located. The gas produced there in the sludge digestion process can also be upgraded and used as a vehicle fuel. The two plants are connected with a gas pipeline. The biogas plant is equipped with a liquid natural gas (LNG) tank. At peak biogas demand the LNG can be vaporized and mixed with the biogas in the pipeline, guaranteeing an uninterrupted gas supply.

The purified biogas is distributed to the bus depot and the public refueling station through underground pipelines. When demand increases, it may be feasible to distribute the biogas by gas trailers to other refueling stations. Fueling a vehicle with biogas is done at a pressure of about 200 bars. All city busses in Linköping run on biogas. They are refueled (slow-filling) during night stops at the depot, which has more than 60 parking spaces, making it the largest in Sweden for biogas busses. Cars are refueled at fast-fill dispensers, and are usually equipped with dual fuel systems – biogas and petrol. Biogas is the most environment-friendly fuel in existence. The combustion of biogas gives low emissions of nitrogen- and sulphur oxides, particles and uncombusted hydrocarbons.

The Linköping biogas plant has certification for biogas (SS 15 54 38) and for bio-fertilizer (SPCR 120). And also they are approved by SJV.

The biogas plant in TRAAB has also OptiBag sorting system for organic household waste. They use organic household waste and waste from food industry. The capacity of organic waste for optical sorting is 55 000 t/y and capacity the waste for fermentation is 22 000 t/y. In 2004 they have 11 600 tons waste for biotreatment [50]32.

There are two reception units at the plant, one is for source sorted organic waste, which is collected in ordinary plastic bags from the supermarkets, and the second one is for source-sorted waste, which is collected in bags of different colours (Figure 6.31).

From the collection unit for different kinds of waste, bags go to the optical sorting, where they are divided into three different flows: red bags go to the containers for incineration; green bags go to the fermentation; and bags of other colours go to the container to the landfill.

32 The information about TRAAB biogas plant is taken from the reference 50.
Bags from the collection unit for source-sorted organic waste go directly to the bag opener and crusher together with green bags, which come from the optical sorting unit. After that waste goes through the sieving machine, where plastic is separated from the organic waste and is directed to the collector for the incineration. And then metal contaminants are separated from the organic waste with special equipment. After that, the waste is ready to be fermented.

At first, it goes to the mixing and hygienisation unit where the hygienisation stage takes place during 1 hour at 70°C. There are 2 mixer-hygienizators (volume is 80 m³ each) at the TRAAB biogas plant. Then hygienised waste is pumped to the buffer tank from where it goes to the digestion unit. There are two digesters (volume is 1 200 m³ each) at the plant. The process is thermophilic at 55°C and lasts about a half of month.

During this stage, biogas and digestate are produced. Biogas (with content of 70% of methane) is used for the plant’s purposes and part of it goes outside (to produce heat or electricity). Digestate is collected in special tank. After that it goes to the dewatering and centrifugation and is divided into two fractions: solid bio-fertilizer (with about 20% of dry substances) and liquid substrate. The second one is treated in sewage treatment unit with getting of the clean liquid biomanure (with about 2-3% of dry substances).

TRAAB biogas plant invested about 63 million SEK in the TRAAB biogas plant: 20 million SEK for OptiBag sorting system and about 43 million SEK for the fermentation system.

TRAAB is satisfied with a method. They are approved by the Swedish Board of Agriculture (SJV) and they are doing their qualification year to get the certification SPCR 120 from RVF (till August 2006).
I have visited Uppsala biogas plant (Figure 6.32) and talked to Cecilia Ekval. This biogas plant was built in 1996 to treat the waste, to recover the energy and to recycle the nutrients. In 1990 households started to sort out their waste. In Uppsala municipality the inhabitants have an obligation to separate the waste. Organic waste they should put into the plastic bags, according to the regulations of the municipality.

Uppsala biogas plant treats liquid waste such as slaughterhouse waste (blood, glucose) and manure, solid waste such as organic waste from restaurants, kitchens and supermarkets, and small amount of food waste from households. From 2006 they are going to treat bigger amount of household waste (up to 8 000 t/y).

All wastes are weighted before they are taken to the plant for the biotreatment. This gives the possibility to see what kind of waste is delivered to the plant, in which amount, who is deliverer and who will pay for the delivering of waste. The amount of waste which was treated at the plant in 2004 was: industrial waste – 3 587 t/y (slaughterhouse waste – 3 014 t/y; organic waste from restaurants, kitchens and supermarkets – 564 t/y); household waste – 964 t/y. The capacity of this biogas plant is 50 000 t/y of waste.

After waiting the waste goes to the reception hall. There are two reception places for different kind of waste: one for liquid waste and another one for solid waste (Figure 6.33). The different kinds of trucks (from different companies) transport wastes to the biogas plant and biomanure from the plant. It is very comfortable since it allows keeping good sanitation conditions for biomanure and there is no re-injection of the final product.

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**Figure 6.32.** Uppsala Biogas plant [85]

**Figure 6.33.** Reception halls for liquid waste (a) and for solid waste (b) at Uppsala biogas plant (pictures made by Halyna Kosovska)

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33 The information about Uppsala biogas plant is taken from the reference 86, 87.
Liquid waste from the reception hall goes directly to the buffer tank by pipes (Figure 6.34). Solid waste has to be treated before the pumping to the buffer tank. This waste at first goes from the reception hall by conveyer to the two parallel pulpers where it is diluted (in the Uppsala biogas plant they use glucose instead of water for making solid waste more liquid) and then it goes to the two parallel sedimentation tanks where it is grinded to the size of 12 mm and where magnets from intestines of cows and vine corks are taken away. There is one container for glucose in this biogas plant. There is also one tank for manure storage at the plant (volume is 600 m$^3$), the waste from there also, together with the waste from sedimentation tank, goes to the buffer tank. The volume of the buffer tank is 500 m$^3$.

All wastes in the buffer tank are mixed (liquid material of 15% of dry substances) and then are directed to the hygienisation unit (Figure 6.35). There are 3 hygienisation tanks at the plant. All wastes are hygienised at least for 1 hour at 70ºC. There are two measurement devices in the middle and in the down of each hygienisation tank. When temperature falls below 70ºC, the hygienisation stage lasts one hour more. They use steam to heat up the material inside the hygienisation tanks. Steam is created from biogas, which they get from the fermentation process.

After hygienisation stage, material goes to the digestion chamber (volume is 2 800 m$^3$) where fermentation process takes place. At the Uppsala biogas plant they have thermophilic process, that is they digest material at 55ºC during about 17-20 days. There are two propellers inside the digestion chamber and the process lasts under continuous mixing.

They got two products after the fermentation of organic waste: liquid biomanure (with 3% of dry substances), and biogas (Figure 6.36). Biomanure is collected in the digested by-product tank (volume is 500 m$^3$) and then it is goes to the farmers where it is used as a fertilizer for the arable land. The same equipment is used for spreading the biomanure on the land as for the ordinary manure. Biogas (with 64% of CH$_4$ in it), which is taken from the digestion chamber and from the digested by-product tank, is collected in the special gas storage. After that biogas is cooled and dried with special equipment and then goes by pipes to the gas upgrading plant or to the local heating production. Excess gas is flared at the plant. Whole process, from taking the waste and to getting the finished products, takes about 20-30 days.
Their upgrading plant is situated at the sewage treatment plant territory. Gas from fermentation plant and from sewage treatment plant goes to the upgrading plant where it is upgraded to the vehicle fuel (Figure 6.37). At that plant incoming raw gas goes to the water scrubber tower where water is given from the top like a shower, it adsorbs CO\textsubscript{2} from the gas (since CO\textsubscript{2} is soluble in the water) and is collected from the down of the tower in the flash tank where CO\textsubscript{2} is separated from the water. CO\textsubscript{2} goes to the atmosphere and water is reused for the process again.

Upgraded gas with 98% of content of CH\textsubscript{4} is dried in the gas dryer and then goes to the special filling station and used as a vehicle fuel for busses and cars. They have 3 different rams for slow filling of busses (it takes several hours during the night to fill the busses). There are 46 busses in Uppsala, which run on biogas. And also there is one small filing station with fast filling for the cars. There are about 17 people in Uppsala which use cars running on biogas. The price for biogas is the same as for petrol and diesel.

They also have storage tank for the upgraded gas. This is for the case if there will be a lack of biogas which should be delivered to the filling station.

In Uppsala biogas plant they have invested about 110 million SEK in the biogas plant, upgrading plant and in the filling station. Also now (autumn 2005) they are investing money in the new system for opening plastic bags with source sorted organic household waste and separation plastic from the waste, since they are going to treat up to 8 000 t/y of organic household waste from 2006. Treatment costs are about 500 SEK per ton of waste (this is fee for the delivering of waste). Treatment costs on the contract basis are cheaper.

They have approval from SJV and quality certification from RVF and SP. At first they got the approval (now they have approval to treat category 2 materials) and then they were doing their qualification year (it lasted 3 years) after which they got the certification. They have a laboratory at the municipality where they analyse the samples they take at the plant; and also they send these samples to other laboratories. The samples are analysed on pathogens, nutrients, heavy metals, etc., according to the SPCR 120 (see Chapter 3.3.2).

So, fermentation of organic waste is a very good method of biological biotreatment, since there is not only the environmentally sound way of degradation of organic waste, but also the possibility to get solid fertilizer, liquid manure, which can be used for farmers’ purposes, and biogas. Biogas, created during the process, can be used for the plant heating purposes or for the district heating, and after the upgrading it can be sold as vehicle fuel. And it is also possible for the fermentation plant to get the approval from SJV and the quality certification from SP and RVF, and to follow Swedish laws concerning the organic waste treatment.

There some examples of suppliers of digestion systems:
Equipment for construction of digestion systems is, among others, supplied by:
- Malmberg Water AB, Åhus
- Läckeby Water AB, Läckeby
- Purac AB, Lund

Equipment for cleaning and handling of biogas is, for example, supplied by:
- Malmberg Water AB, Åhus
- Läckeby Water AB, Läckeby [21].
7. Biological treatment of organic food waste in Ukraine

During last years the amount of waste in Ukraine increases a lot. That is why the questions about solving of the problem with waste handling, especially organic waste handling, are raising dramatically now. In order to avoid ecological threats, it is necessary to organise the collecting of the waste in certain places or centres, its separation, and to construct new plants for biological treatment of organic food waste. It will allow improving ecological situation in Ukrainian cities, towns and villages and decreasing pollution of the environment.

At the moment, there are no plants in Ukraine, which provide biological treatment of organic waste in industrial scale; there are only several experimental equipments. Recently there was one fermentation plant for biotreatment of municipal solid waste in Ukraine, but it is closed now (already a half of year) because there was obsolete technology there. Also another one fermentation plant is being built now – this is a private plant, which is used for the biotreatment of waste, and since it is a private closed company, there is no available information for us (they don't want to make known their processing).

Ukraine needs some actions for developing new waste management system and implementing biological treatment methods for handling of organic waste.
8. Discussion

The main task of this diploma was to try to solve the problems of Södertörn area in Sweden (that is of the company SRV återvinning AB) and Yavoriv Region in Ukraine (see Chapter 1.6). To do this, the investigation of different methods of biological treatment and sorting of organic waste was done (see Chapters 6, 7 and 5 respectively). In this chapter these methods will be discussed for applying them for the Södertörn area and the Yavoriv Region and some suggestions for solving the problems in these regions will be proposed.

8.1. Suggestions for the Södertörn area in Sweden

The SRV company with its Sofielund plant provides biological treatment for the Södertörn area. For that it has open composting facilities and fermentation plant (it is not working now due to some breaks). As was mentioned in the Chapter 1.6.1, the main problems, which SRV would like to solve, are:

- reducing the smell and time of the composting process;
- increasing the capacity of the composting process and the quality of composted material;
- getting the approval from SJV and quality certification form SP and RVF, and following the EU Directives, Swedish laws, National and Regional goals.

To reach these aims, new composting method, which would be more advanced, or increasing the capacity of fermentation plant (actually building a new bigger fermentation plant) is needed for the company. Some options for that are discussed below.

Composting is a natural biological process. Simple compost piles (open composting) are entirely effective at reducing waste volume, but they are slow, odorous, attract vermin, are uneven in their treatment and may fail to control pathogens. In addition, the compost, obtained during the open composting, cannot be awarded the quality certification from RVF and approval from SJV because of a lot of problems with smell during the process and with proving the necessary parameters stated in the Animal By-product Regulations and SPCR 120 (see Chapter 6.1.1 for open composting and Chapter 3.3 for regulations). So, some other engineered composting systems should be proposed to achieve consistent, pathogen-free compost, within a reasonable timeframe on a large scale.

If we look at the Ag-Bag composting system, it looks better than open composting. This system helps to reduce the smell problems during the intensive composting stage provided inside the bags; but smell doesn’t disappear completely – there are still some smell problems due to passing of odorous air through the holes in the bags, which are made occasionally by birds, for example, by other ways, or through the special openings.

The time of the waste decomposition inside the bags is about 4-6 months (depends on the composition of incoming waste), and then open composting of the material is required for further maturation stage. So, sometimes process can take less time than open composting at the SRV (7 months) if intensive phase will be 4 months and maturation stage, for example, 2-3 months.

The capacity of the plant depends on area, which is available for the composting plant. For example, for a capacity of 14 000 tones waste per year, the 14 000:300=47 bags of CT8 300 ton are necessary (I took this kind of bag since it developed for medium-sized and large plants and have storing capacity of 300 tones of waste). Since composting takes no longer than 6 months, space for 47bags:2≥23.5 or for 24 bags is needed for one treatment. This corresponds to about 2.7m×75m×24bags≥4 860 m² or, taking with some reserve, 5 500 m². If intensive phase takes just 4 months (it is possible to compost the waste 3 times per year), then 47bags:3≥15.6 or 16 bags, which correspond to 2.7m×75m×16bags≥3 240 m² or about 4 000 m² space, are needed per one
treatment of composting. Some space for open composting is also required. It depends on the purposes for using the compost, since different time for the maturation stage is needed. SRV has 25 000 m² used for composting plant and they are not planning to extend this area. Taking into account calculations above, we can sum up that with this available space and, for example, 6 months intensive stage in the bags (as a worse case), and 10 000 m², as a maximum, needed for further maturation stage in windrows, SRV can treat (15 000m²:2.7m:75m)×2×300t≤44 444 or about 44 000 tones waste per year (note, that these calculations are approximate, since area for windrows are unknown and the figures for it are rough). As we see, it is possible to increase the capacity of plant on the available space using Ag-Bag composting system.

One Ag-Bag plastic bag (CT8 300 ton) costs 17 000 SEK (in 2005), including pipe, valve and connector. For 14 000 tones waste per year 47 bags are needed (according to the calculations above). So, all bags will cost 17 000SEK×47bags=799 000 SEK. In case of increased capacity – 30 000 tones waste per year (SRV has a permission to treat this amount of waste), the amount of money per year spent on bags will be: 17 000SEK×(30 000t:300t)=1 700 000 SEK (100 bags will be needed). In addition, the fan for each bag is required. It costs 18 000 SEK. So, to treat 14 000 tones waste 47 fans should be bought; it will cost 47fans×18 000SEK=846 000 SEK (or, I think, the price could be reduced, in case of using the one fan for several bags – when one bag is cut and thrown away, the fan for the next bag can be used and so on during several years). For 30 000 tones waste 100 fans are necessary, the price for them is 100fans×18 000SEK=1 800 000 SEK. The price for a loader is 1 350 000 SEK. Mixing machines costs 755 520 SEK (it is also possible not to use the mixing machine, as it is done in the Telge Återvinning AB in Södertälje, but the using of the mixing machine is recommended). Treatment costs for different capacity also differs: for 14 000 t/y costs are 162 SEK/ton; for 30 000 t/y costs are less than 143 SEK/ton. So, we can make some table of approximate calculations of using Ag-Bag composting system for the SRV återvinning AB (Table 8.1).

<table>
<thead>
<tr>
<th>Unit</th>
<th>14 000 t/y waste</th>
<th>30 000 t/y waste</th>
<th>14 000 t/y (according to Telge Återvinning AB)</th>
<th>30 000 t/y (according to Telge Återvinning AB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loader SEK</td>
<td>1 350 000</td>
<td>1 350 000</td>
<td>1 000 000</td>
<td>1 000 000</td>
</tr>
<tr>
<td>Bags SEK</td>
<td>47 - 799 000</td>
<td>100-1 700 000</td>
<td>470 000</td>
<td>1 000 000</td>
</tr>
<tr>
<td>Fans SEK</td>
<td>47- 846 000</td>
<td>100-1 800 000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(423 300)*</td>
<td>(900 000)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum SEK</td>
<td>2 995 000</td>
<td>4 850 000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(2 571 700)*</td>
<td>(3 950 000)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing machine SEK</td>
<td>755 520</td>
<td>755 520</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sum SEK</td>
<td>3 750 520</td>
<td>5 605 520</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(3 327 220)*</td>
<td>(4 705 520)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine for heating the waste SEK</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sieving machine SEK</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sum SEK</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Treatment cost SEK/ton</td>
<td>162</td>
<td>143</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* The prices in the brackets are in case of using the one fan for two bags at the first year of implementing the system (a half of year for one bag and another half year for another bag). The first two columns with figures mean the prices for units suggested by the “company-producer” of technique and the second two columns with figures mean the prices for which the “company-user” buys the technique.
The differences between prices in case of bags and loaders in different columns mean that it is possible to bargain with the company, which produces this kind of technique, to reduce the price for buying the system.

It is difficult to say anything about increasing quality of compost when using the Ag-Bag composting system. It could be so, in comparison to the compost obtained from the open composting, when using infrared system for heating the waste (to reach the hygienisation of waste), which is also suggested to use together with Ag-Bag system. And also composted material should be well-source-sorted and well-sieved to get rid of different contaminants, which are left after the composting process.

As was mentioned in the Chapter 6.1.2, it is very difficult to get the quality certification for the compost, obtained after composting in Ag-Bag system, from RVF because of difficulties in proving the hygienisation stage during the process, proper conditions for composting material inside the bags, proper mixing the organic waste and structure materials, prove that size of materials is not more than 12 mm, etc. The same problems occur for biotreatment plants with getting the approval on plants’ technical applications from SJV to be able to use the compost for farming purposes.

So, that is why, I think, the Ag-Bag composting system is not the best option for the SRV to use for biological treatment of organic waste, since there are still a lot of problems with using this system. However this system could be good for composting of the residue after the fermentation. In that case it is not necessary to reach high temperatures for hygienisation of material during the process, since it was already done in the previous fermentation stage, and the odour problems also will be reduced when using residue and garden waste for composting.

**RotoCom (bagging) composting system** is somehow alike to Ag-Bag system. There are odour problems due to the same causes as in the Ag-Bag system and it is almost impossible to reach the necessary temperature for hygienisation of the material. And this system doesn’t offer any mixing machine (system could be improved by implementing mixing and/or heating machine). The good thing, in comparison to Ag-Bag system, is the availability of oxygen and temperature measuring system. With help of this device it is possible to provide continuous monitoring of parameters.

According to APIESSE – Italian company producing this system – composting process with RotoCom system takes about 4-6 weeks inside the bags and about 1 month in windrow composting (I think, it is so because of quite warm climate in the Italy). For Borlänge Energy composting plant it takes about 1 year to get mature compost (at first in the box composting, then in the RotoCom composting, and finally in the windrow composting). I think, composting process with this system can take less than 1 year (since I have the figure just from the one RotoCom composting plant existing in Sweden), but maybe not less than 6-7 month, since it is dependent on the weather and it is quite difficult to get mature compost for 2-3 months. So, the processing time is not very good for the SRV, since it is almost the same as they have for open composting.

According to the capacity of waste, which can be treated with this composting system, we can make the following calculations. One bag can contain about 240 tons of waste. For 14 000 tones waste per year 14 000t:240≥58.3 or 59 bags are necessary. If supposed that intensive stage inside the bags takes about 6 months, then a space of 3m×60m×(59bags:2)≥5 310 m² or about, with some reserve, 6 000 m² for composting process inside the RotoCom bags is needed. In case of increased capacity, for 30 000 tones waste per year 30 000t:240≥125bags are needed. The space required for them is: 3m×60m×(125bags:2)≥11 250 m² or about 12 000 m². Also some additional space for open composting is needed. It takes less space than for composting in bags, since during the intensive stage inside the bags the quantity of material is reduced, but still 75-85% of primary waste is left. It means, that approximately 6 000m²×0.85≥5 100 m² (in case of 14 000 t/y) or 12 000m²×0.85≥10 200m² (in case of 30 000 t/y) are needed for maturation stage in windrows.
According to these calculations, the available space at the SRV is sufficient for RotoCom composting system (12 000 m² + 10 200 m² = 22 200 m² it is less than 25 000 m²).

If using the example of Borlänge Energy composting plant, box composting can be needed before composting in bags in order to provide the hygienisation of material (since it is impossible to reach 65° or 70°C inside the plastic bags of the RotoCom system) and to minimize the odour during the process (since there could be under-pressure and bio-filters or scrubbers to prevent odour spreading). The box composting also takes some place. In that case, 25 000 m² may not be enough to build RotoCom composting system together with the box composting at the SRV.

The approximate price for RotoCom composting system for SRV can be estimated as following: one bag costs about 10 000 SEK, in case of 59 bags (14 000 t/y waste) 59 bags × 10 000 SEK = 590 000 SEK is needed and in case of 125 bags (30 000 t/y waste) 125 bags × 10 000 SEK = 1 250 000 SEK is needed; one fan costs about 13 000 SEK, and each bag requires one fan, then 59 fans will cost 59 fans × 13 000 SEK = 767 000 SEK and 125 fans will cost 125 fans × 13 000 SEK = 1 625 000 SEK (or, I think like in the version of Ag-Bag system, the price could be reduced, in case of using the one fan for several bags – when one bag is cut and thrown away use the fan for the next bag and so on during several years; perforated pipes from the bags can also be used more for the following cycles). Price for the RotoCom machine is 1 200 000 SEK. Treatment cost is about 75-125 SEK per ton depending on many factors: filling and emptying the bags – is about 10-15 SEK per ton of material; using of the RotoCom machine – is about 24 SEK per ton of waste (if amount of waste is 10 000 tons per year); using bags – is about 40-75 SEK per ton of material. All these figures are tabulated below (Table 8.2).

### Table 8.2. Approximate calculations for the SRV for using RotoCom composting system

<table>
<thead>
<tr>
<th>Unit</th>
<th>14 000 t/y waste</th>
<th>30 000 t/y waste</th>
<th>14 000 t/y waste (according to Borlänge Energy)</th>
<th>30 000 t/y waste (according to Borlänge Energy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RotoCom Loader</td>
<td>SEK 1 200 000</td>
<td>1 200 000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bags</td>
<td>SEK 590 000</td>
<td>1 250 000</td>
<td>413 000</td>
<td>875 000</td>
</tr>
<tr>
<td>Fans</td>
<td>SEK 767 000</td>
<td>1 625 000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(383 500)*</td>
<td>(812 500)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>SEK 2 557 000</td>
<td>4 075 000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(2 173 500)*</td>
<td>(3 262 500)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sieving machine</td>
<td>SEK -</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sum</td>
<td>SEK -</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Treatment cost</td>
<td>SEK/ton ≤ 125</td>
<td>≤ 125</td>
<td>650 (including box composting)</td>
<td>650 (including box composting)</td>
</tr>
</tbody>
</table>

* The prices in the brackets are in case of using the one fan for two bags at the first year of implementing the system (a half of year for one bag and another half year for another bag).

The first two columns with figures mean the prices for units suggested by the “company-producer” of technique and the second two columns with figures mean the prices for which the “company-user” buys the technique.

So, as we can see, the RotoCom (bagging) composting system is cheaper than Ag-Bag composting system. The differences between prices for bags in different columns mean that it is possible to bargain with the company, which produces this kind of technique, to reduce the price for buying the system.

As for the Ag-Bag composting system, it is also quite difficult to get the quality certification and approval for RotoCom composting system because of the similar problems in proving the
hygienisation stage (normally there’s no insulation and it is very difficult to reach hygienisation temperature in all material), the necessary conditions inside the bags, proper mixing the organic waste and structure materials, size of materials of no more than 12 mm, etc.

So, I think, the RotoCom (bagging) composting system also is not the best option for the SRV to use it for the biotreatment of organic waste because of not very sophisticated control of the process. As for the Ag-Bag composting system, it could also be a good option, when using this system for composting the residue after the fermentation. In that case it is good to take into account that this method is cheaper in comparison with the Ag-Bag system.

If we come to the **BIODEGMA composting system**, we can see that this system is more reliable than Ag-Bag or RotoCom (bagging) composting system, as for me. There are no such problems like breaking of bags or changing bags for each treatment with this method.

Semi-permeable (Gore-tex) membranes reduce the odour problems during the intensive phase inside the modules (but odour problems are arising during the moving composting material from intensive stage to the maturation stage). These membranes also prevent escaping fungus spores to the atmosphere and getting rain water inside the modules. So, there are almost no environmental influencing factors on composting material. The temperature (when it is so cold) also can be regulated by heating pre-composting material with a space heater.

Time for composting using the BIODEGMA facility is: 3-4 weeks inside the closed modules for intensive phase; 4 weeks in open curing modules; and about 5-7 weeks in windrows for further maturation stage. Totally, whole process takes about 3-4 months. It is almost half the time than the duration of open composting at the SRV.

The modular system allows treatment capacity of waste between 5 000 – 40 000 tones per year. So, it is possible to treat, for example, 30 000 tones organic waste per year as is permitted for the SRV.

As was estimated by the BIODEGMA company, 8 modules will be needed for the SRV to treat 14 500 tones waste per year (7 500 tones food waste and 7 000 tones garden waste). For 22 000 tones per year (15 000 tones of food waste and 7 000 tones garden waste, since amount of garden waste may not increase and food waste can increase due to implementing new sorting system for households) 11 modules are necessary. The price for that is: for 8 modules plus civil works – 11 979 993 SEK; for 11 modules plus civil works – 16 181 047 SEK. In case of using the aerated open curing modules (in addition to open composting) more money will be required: 17 024 470 SEK in case of 14 500 t/y; and 22 982 778 SEK for 22 000 t/y (Table 8.3).

Treatment costs mainly depend on amount of energy and fuel, which will be used during the process, and on labour demand for running the process. It is understandable, that the systems with a greater level of automation will reduces labour costs, but have a risk of increasing power and maintenance costs. It is usually, that processing of very large annual quantities of material with highly automated loading/unloading and turning equipment becomes cost efficient. So, with increasing of site capacity, treatment costs per tone are decreasing.

The space, which will be needed for a whole plant, is the following: for a capacity of 14 500 t/y – 1 586 m² for intensive stage, 3 000+2 000=5 000 m² for curing/maturation stage and 1 071 m³ for storage of compost are necessary; for 22 000 t/y – 2 378 m² for intensive stage, 3 500+2 500=6 000 m² for curing/maturation stage and 1 625 m³ for storage of compost are needed. The space, which is available at the SRV, is enough for using BIODEGMA facility for treatment of 22 000 tones waste per year and even more.

It is possible to reach 70ºC during the intensive stage inside the modules. Also there is a computer system, which registers all measurements of temperature (temperature is measured in the center and
in the surface of the piles inside the modules) and air supply. So, there is a possibility to control the temperature and air during the process and a possibility to prove the maintenance of hygienisation stage during the required time and at the required temperature.

**Table 8.3. Approximate calculations for the SRV for using BIODEGMA composting system**

<table>
<thead>
<tr>
<th>Unit</th>
<th>14 500 t/y waste</th>
<th>22 000 t/y waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules</td>
<td>SEK 8 mod. – 7 550 000</td>
<td>11 mod. – 10 100 000</td>
</tr>
<tr>
<td>Civil works</td>
<td>4 429 993</td>
<td>6 081 047</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>11 979 993</strong></td>
<td><strong>16 181 047</strong></td>
</tr>
<tr>
<td>Modules with aerated open curing modules</td>
<td>SEK 8+8 mod. – 8 648 000</td>
<td>11+11 mod. – 11 515 000</td>
</tr>
<tr>
<td>Civil works</td>
<td>8 376 470</td>
<td>11 467 778</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>17 024 470</strong></td>
<td><strong>22 982 778</strong></td>
</tr>
<tr>
<td>Loader</td>
<td>SEK -</td>
<td>-</td>
</tr>
<tr>
<td>Mixing machine</td>
<td>SEK -</td>
<td>-</td>
</tr>
<tr>
<td>Sieving machine</td>
<td>SEK -</td>
<td>-</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>SEK -</strong></td>
<td><strong>-</strong></td>
</tr>
<tr>
<td>Treatment cost</td>
<td>SEK/ton (350-500)*</td>
<td>(350-500)*</td>
</tr>
</tbody>
</table>

* Figures are taken from composting plants in Sweden, which use BIODEGMA composting system

According to the certification, there are no plants in Sweden yet, which would have quality certification from RVF and approval from SJV. On the other hand, only composting plants, which use BIODEGMA technique for the biological treatment of the organic waste, are doing their qualification year and, probably, they will be able to get the certificate.

So, as for me, BIODEGMA composting system is quite a good option for the SRV to use for the biotreatment of waste. All Swedish composting plants, which use BIODEGMA system, are satisfied with the method, they almost don’t have any problems with odour during the process, and also they provide the composting process in enclosed reactor, which helps them to control the process. They can maintain the necessary temperature, moisture and aeration, which should be kept during the composting process to get the product of a good quality. From the other side, the system is not cheap and also has some odour problems during the transportation of the waste from the closed modules to open maturation stage. Anyway, BIODEGMA composting system can solve the SRV’s problems and it is real possibility to obtain approval and certification. This system can be used for the organic waste without previous fermentation and also in combination with the anaerobic digestion.

**Rotocom rotary composting system** is another way to treat the organic waste in a biological way. This system seems to be a quite good choice, since it is a method, which can treat animal by-products and it is possible to reach 70°C to ensure the hygienisation of the material. The smell during the process can be reduced a lot because of using bio-filters and chemical scrubbers and because the vessels can be located inside the building, which also helps to reduce odour problems. It takes about 6 weeks to get mature compost: 7-10 days in the Rotocom vessel and about 1 month in windrow composting. So, the time of the composting process can be reduced substantially using the Rotocom rotary system.

The process is continuous and can treat a wide range of waste amount. One Rotocom machine (RC159) can treat 5 000 tones waste per year. So, to treat 14 000 t/y 14 000t : 5 000t ≥ 2.8 or 3 such machines are needed. It will cost for SRV approximately 600 000Euro × 3 machines = 1 800 000 Euro or about 1 800 000 Euro × 9.3 = 16 740 000 SEK. In case of increased capacity to 30 000 t/y, 30 000t:
5 000 t = 6 RC159 machines are needed. It will cost about \((600 000 \text{Euro} \times 9.3) \times 6 \text{machines} = 33 \, 480 \, 000 \, \text{SEK}\). These prices are just for the vessels. Also loaders, mixer and in-feed conveyor, scrubbers and bio-filters as well as some civil works will be needed. The treatment costs depend on consumption of electricity and lubrication, amount of treated waste, etc. and they can vary. Table 8.4 shows these calculated figures. As we can see, even from those not completed estimations, this system is expensive, actually the most expensive composting system described in this Thesis Work.

According to the space required for this Rotocom rotary system, \(3\, \text{m} \times 22.5\, \text{m} \times 3 \geq 202.5 \, \text{m}^2\) or \(250 \, \text{m}^2\) are needed for place for 3 vessels (capacity 14 000 t/y); and \(3\, \text{m} \times 22.5\, \text{m} \times 6 \geq 405 \, \text{m}^2\) or \(450 \, \text{m}^2\) are needed for place for 6 vessels (capacity 30 000 t/y). As we see, this system doesn’t require a lot of space.

**Table 8.4. Approximate calculations for the SRV for using Rotocom rotary composting system**

<table>
<thead>
<tr>
<th>Unit</th>
<th>14 500 t/y waste</th>
<th>30 000 t/y waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessels</td>
<td>SEK</td>
<td>SEK</td>
</tr>
<tr>
<td>3 ves. – 16 740 000</td>
<td>6 ves. – 33 480 000</td>
<td></td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>SEK</strong></td>
<td><strong>33 480 000</strong></td>
</tr>
<tr>
<td>Loader</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Mixer and in-feed conveyor</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Civil works</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Bio-filters and scrubbers</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Sieving machine</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>SEK</strong></td>
<td>-</td>
</tr>
<tr>
<td>Treatment cost</td>
<td>SEK/ton</td>
<td>-</td>
</tr>
</tbody>
</table>

I think, it would be possible to get approval for this kind of composting since this system can be operated to meet Animal By-product Regulations (see Chapter 3.3.1), and the plant is able to get the quality certificate as well. However, it is difficult to confirm that, since there is no composting plant in Sweden with Rotocom rotary composting system and it is difficult to see the practical side of using this method.

In spite of the advantages of Rotocom rotary composting system and opportunity to get approval and the certificate, I think, this method is too expensive to implement it for the biotreatment at the SRV. Similar processing conditions and final product with similar quality can be achieved with using other methods (maybe not only composting but fermentation as well) which are much cheaper.

**VAPO composting system** is another quite good option for the SRV to implement. This is tunnel composting system, which is located inside the building. Due to this, under-pressure inside the building and bio-filters and scrubbers the odour problems are very much reduced. Also process is continuously controlled and necessary conditions (good aeration, oxygen content, moisture and temperature) are maintained during the process. The process is not dependent on weather conditions, since it is inside the building where 20ºC is always maintained.

Needed time for whole process is: 3 weeks in the intensive phase in the tunnels (note, that it is possible to reach more than 60ºC during 1-2 weeks for the hygienisation of the waste at this stage of the process); 4 weeks in the aerated maturation stage in tunnels or 2.3-3 months in the windrows (after these stages the compost is ready). In case of the aerated maturation stage in tunnels 3 500 m² are needed for the construction of the whole plant. In case of maturation stage in the open composting (without maturation in tunnels) 20 000 m² are needed for whole plant if amount of household waste is about 20 000 tones per year. The available space at the SRV is quite sufficient.
for the whole amount of incoming waste in the future for VAPO composting plant (according to Timo Valkeinen).

No investment costs are necessary to build the plant if using the service offered from VAPO Biotech. It costs approximately 550 SEK/ton of waste during the 15 years on the contract basis when using open composting for the maturation stage and approximately 650 SEK/ton of waste at the same circumstances, but when using aerated maturation stage in tunnels instead of windrow composting (see Table 8.5).

**Table 8.5. Approximate calculations for the SRV for using VAPO composting system**

<table>
<thead>
<tr>
<th>Unit</th>
<th>14 500 t/y waste</th>
<th>30 000 t/y waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loader</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Mixing machine</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Sieving machine</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Bio-filters and scrubbers</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Civil works</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Sum</td>
<td>SEK</td>
<td>-</td>
</tr>
<tr>
<td>Treatment cost:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Open composting</td>
<td>SEK/ton</td>
<td>550</td>
</tr>
<tr>
<td>- Aerated maturation stage</td>
<td>SEK/ton</td>
<td>650</td>
</tr>
</tbody>
</table>

*Cursive* means that prices for the units are in case of Operating contract; in case of Service contract all prices are included in the treatment costs.

Seems, that this system can get the quality certificate and approval, but since there are still no plants in Sweden with VAPO composting system, so it is difficult to say for sure. VAPO composting plants are very popular in Finland and met Finish requirements. As was said in the *Chapter 6.1.6*, the demands on compost quality and composting process in Finland are higher and stricter than in Sweden. So, such plants in Sweden should also meet all Swedish requirements and regulations.

I would recommend to use this methods at the SRV for biological treatment of organic waste (it is also possible to treat sewage sludge using it). This method is quite expensive in the operating, but, from the other side, no big investment capital is needed to build the plant, and it is always possible to use a cheap loader. Also the good thing is that this method allows avoiding smell problems (almost), substantially reduce time for composting process (in case of aerated maturation stage in tunnels), treat large capacities of waste; control the process and maintain necessary parameters during it. And also there is the quite real possibility to get the approval from SJV and quality certification form SP and RVF and to follow the EU Directives, Swedish laws, National and Regional goals. So, VAPO composting system can solve the SRV’s problems and it is real possibility to obtain approval and certification. This system can be used for the organic waste without previous fermentation and also in combination with the anaerobic digestion.

**Fermentation** is another method of biological treatment, which is good for biodegradation of organic waste, especially of homogenized waste from food industries, restaurants, supermarkets, and slaughterhouse waste and manure. Organic household waste can also be treated by fermentation, but garden waste is difficult to transform in the anaerobic digestion plant.

Fermentation plants are very a good option for treatment of the waste since, as a result of this method, biogas, liquid manure and solid fertilizer could be obtained. Due to the complicate process and technique, enclosed system and ensuring hygienisation stage it is easy (much easier than for composting plants) to prove that all requirements of Animal By-product Regulations and SPCR 120 for approval and certification respectively are achieved. Ten fermentation plants in Sweden are already approved by SJV and 6 biogas plants already have the quality certification for their digestate from RVF.
Since a whole process occurs inside the closed reactors, there are almost no odour problems during the process (except of reception area). Fermentation plants can treat 50 000 tones waste per year (sometimes even 60 000 tones per year), it depends on size of the plant. Fermentation process takes from a half of month (thermophilic process at 55°C) to about one month (mesophilic process at 38°C).

The quality of liquid or solid fertilizer is very good since incoming waste is quite clean (almost without different plastic or metal contaminants, etc.), and pre-treatment of waste is done at the plant before the waste goes to the hygienisation stage (for example, magnets from cow’s intestines or corks from vine bottles are removed, as it is done at the Uppsala biogas plant – see Chapter 6.2). Note, that it is very important to clean and disinfect all tank vehicles entering and leaving the biogas plant, in order to avoid re-injection of the final product. One way to maintain good sanitation is to have separate tanks in the vehicles for the transport of raw substrate and residues.

Building of fermentation plant is more expensive than establishing of composting plant. It costs from 40 million SEK to 110 million SEK (including biogas upgrading plant, filling station; sometimes optical sorting system or recycling centers). And also during the process some unforeseen breaks can occur what can be the reason of stops in the process for some time, and it will require more money for repairing. On the other hand, biogas, created during the process, can be used for the plant heating purposes or for the district heating, and after the upgrading it can be sold as vehicle fuel. So, a fermentation plant can also have a profit from the production of biogas. Treatment costs at the fermentation plants are about 450-500 SEK/ton of waste (Table 8.6).

| Table 8.6. Approximate calculations for the SRV for using fermentation plant |
|---------------------------------|-----------------|-----------------|
| Unit                           | 14 500 t/y waste | 30 000 t/y waste |
| Investment costs SEK           | 40-110 million* | 40-110 million* |
| Treatment cost SEK/ton          | 450-500*        | 450-500*        |

* Figures are taken from fermentation plants in Sweden

I think that it is quite advantageous to have a fermentation process at the SRV for biological treatment of organic waste because not only organic household and restaurant waste and green waste can be treated, but also other kind of organic waste mentioned above. Also there is a possibility to get not only solid fertilizer, but liquid manure, which can be used for farmers’ purposes, as well as biogas. It is also possible to get approval and certification, and follow Swedish laws. The fermentation plant either can be used by itself or together with the composting plant.

According to the sorting methods, it is necessary to have preferably the source sorting of the household waste, since industrial waste (from restaurants, supermarkets, slaughterhouse waste) almost doesn’t need to be sorted.

There are several good options for the SRV to use for sorting the waste. Plastic bags made of special biodegradable plastic, in which SRV treats waste now and which come from Sollentuna municipality, are a good choice when composting the organic waste. Here are some problems with knots, which are not broken down during the process and have to be separated from the ready compost. It is not necessary to use crusher-opener for this king of bags. It is not very good to use such kind of bags for the fermentation the waste, since plastic is not allowed to be fermented together with waste and it is not biodegraded totally during the process.

If using ordinary plastic bags from supermarkets, some machine for opening and crushing the bags is needed, and also the compost should be sieved in order to separate the plastic remains after the composting process. In case of fermentation, before the organic household waste get to the hygienisation stage and digestion chamber, remains of crushed plastic bags should be separated (it is not allowed for plastic to be fermented together with the waste). For that some special kind of
machine is needed, which would crush the bags and at the same time separate plastic from the waste (as it is being done at the Uppsala biogas plant during the autumn 2005-winter 2006).

In case of paper bags, it is better to compost crushed paper bags, since they can be almost decomposed together with the waste. And these bags can be just crushed before the fermentation process, without separation of them. Some biotreatment plants in Sweden started to use bio-bags – starch bags. I think, such kind of bags is the best choice for the SRV to use for organic waste, since they are made of natural organic material, which is easily biodegradable. However, probably here are could also be some problems with the bags, for example, due to not often and regular collection of waste bags could start to decompose at the households’ collecting points.

For collecting the bags different kinds of bins can be used. It could be just bins of different colors for different fractions. It could also be bins for four different fractions in each bin. And also the bins with holes for aeration can be chosen. I think, the last one is a quite good choice, since it allows to have aeration inside the bins and to reduce the smell occurring during the time, when bags with waste are inside the bins. Waste should be collected once a week from multi-family houses and every second week from single-family houses, in summer times the collection can be provided more often (for example, once a week).

I think, these sorting methods are quite cheap comparing to optical sorting. A 140 l bin with holes, which is used for single-family houses, costs 400 SEK and a 240 l bin with holes, used in multi-family houses, costs 500 SEK.

Optical (OptiBag) sorting is also a good option for the source sorted waste. The good things of this method are that ordinary bins can be used for collecting the bags, since different kinds of waste are put in the plastic bags of different colors; and it is quite easy to out sort different waste – it is done automatically and very fast by using optical machine. The difficulties are that this system require to have some special colors of bags for food waste at least (the machine can recognize just several shades of colors); it is necessary to have a machine for separating the crushed plastic from the waste (in case of fermentation); the system is quite expensive (20-30 million SEK) and if some breaks are happen during the operation it will take some time and money to repair it. I think, it is better to invest money in good treatment method than in optical sorting, since anyway waste should be treated in a good way and well sorted waste in “bags for biotreatment” is not guaranteed neither in optical sorting nor in sorting in bags and bins, if people don’t sort waste at source in the proper way.

Vacuum sorting system is also a good method for sorting the waste (see Chapter 5.1.3), but it is better to use it on density populated areas (the Södertörn area is not such area) and this system is not cheap.

Anyway, in spite of the method, which will be chosen for sorting the waste, it is very important to provide necessary education of households in how to source separate waste and what kind of waste is allowed to be put inside the bags that go to the biological treatment, because the quality of compost or digestate depends a lot on the quality of source sorting the waste.

So, we can make some conclusions of the discussion above. Taking into account a lot of different things, – such as that the equipment should ensure that all material is sufficiently hygienized and treated; should ensure odour reduction and provide sufficient treatment capacity of waste; ensure that all existence rules and even new ones, which are coming with stricter requirements, are met – and analysis of the methods above, I would suggest for the SRV the following:

- Establish source sorting of the household waste with using paper or starch bags (the second one is better, since it made of natural material which is easily biodegradable) and bins with holes for collecting these bags; provide collecting the waste from bins every second week; take some steps (measures) to educate people in how to do correct source sorting.
- Provide composting and fermentation for separate streams of organic waste:
  composting – for the organic household waste, food waste from supermarkets and restaurants and green waste using VAPO (it is more expensive, but more reliable than BIODEGMA and there is the possibility to get energy from the process) or BIODEGMA (which is cheaper than VAPO and is a quite good system) composting systems;
  and fermentation, using the small Sofielund fermentation plant, – for treatment of slaughterhouse waste and food waste from industries.

This suggestion could be good in case of:
- treatment of small quantities of slaughterhouse waste and food waste from industries, coming for the treatment – since these wastes can be only fermented and the capacity of small Sofielund fermentation plant could be enough for treatment;
- in case when this slaughterhouse and industrial food waste is very clean – separate treatment will ensure keeping them clean since their mixing with other waste will be avoided;
- treatment of quite big amount of other organic waste, such as household and green waste, waste from restaurants and big supermarkets – since it can be treated in the composting plant and suggested plants can be built for large treatment capacity.

- Or combine fermentation and composting methods for the treatment of organic waste:
  fermentation (as a first stage of treatment) – build a new fermentation plant with capacity for 50,000 tonnes waste per year (it is quite good to have this plant together with biogas upgrading plant) for treatment all streams of food waste;
  composting (as a second stage of treatment) – use BIODEGMA composting system (in case of availability of enough money, since this system is much better that Ag-Bag or RotoCom), or use Ag-Bag (more expensive than RotoCom bagging system) or RotoCom bagging (it is cheaper and almost with the same characteristics as Ag-Bag system) composting systems – for treatment of the solid material, obtained after fermentation, and for treatment of green waste (in that case it is not necessary to reach high temperatures during the process since hygienisation of material was provided in the fermentation stage).

This suggestion could be good in case of:
- treatment of large quantities of industrial organic waste, coming for treatment – since these waste are supposed to be fermented and it can be done at the fermentation plant of big capacity;
- treatment of a very good quality source sorted organic household waste put in the paper or starch bags – since waste, which goes to biogas plant, should be very clean and it can be fermented without additional equipment for separation of different contaminants, which are not allowed to be in the anaerobic digestion plant;
- using some equipment for separation glass, metal, plastic or other contaminants from the organic waste before it reaches the hygienisation unit – usage of large amount of waste is supposed to have some quantities of contaminations in the waste and they should be taken away;
- treatment of not large amount of garden waste – since garden waste should be composted and, if its amount is not big, composting could be done at small composting facility.

I think, the SRV should have both fermentation and composting methods for treatment of organic waste, since it will allow them to treat both food household waste and garden waste, as well as food waste from restaurants, big supermarkets, food industry, slaughterhouse waste and manure.

From a Systems Analysis point of view, fermentation and incineration of waste are more preferable methods in relation to composting, since it is possible to get energy during these processes and, contrary to them, composting requires input energy for its running. This Thesis Work doesn’t distinguish the choosing of the best methods for the SRV for treatment of organic waste from this point of view. It could be an additional investigation for further study.
8.2. Suggestions for the Yavoriv Region in Ukraine

As was written in the Chapter 1.6.2, the main problems for Yavoriv Region are:
- a lot of quarries, which are left after mining activity of the “Sulphur” plant, and which should be eliminated;
- a lot of spontaneous dumping sites, which are the sources of spreading different deceases, contamination of soil, ground water and air pollution, odour problems from the organic fraction, etc., and the decision should be taken to turn the flow of waste away form them.

Both these main problems can be solved by developing biological treatment of organic waste in Ukraine. Composting or fermentation plants can treat organic fraction of waste what will reduce the flow of waste to the landfills. Also obtained compost from the composting process can be used to fill up the quarries and in recultivation of these areas, for example, as soil for growing trees. In that case compost can include heavy metals and other compounds, which are not allowed to be put in farmer lands.

To reach these aims, new legislations should be established in Ukraine concerning the biological treatment of waste, source sorting the waste, etc. Ukraine needs to develop its own system of waste management engaging corresponding institutes, state and municipal structures, which are responsible for the waste and public organisations, taking into account experience of the leading countries in waste management, such as Sweden. To make people conscious and aware and to prompt the source sorting of household waste, economical stimulation (incentives, penalties), juridical (legal) measures (actions), agitation and propaganda among inhabitants should be carried out in Ukraine.

I think, at the beginning, it is good for Ukraine to start from implementing open composting plants, since there is a need for compost in Ukraine now and it is not a very expensive method of treating the waste. On the early stage, it is possible to provide open composting of food waste from restaurants and supermarkets (this waste is more or less sorted and homogenized), or mixed household waste together with garden waste, since compost will not be used for farming purposes and can include some contaminants. And then, when new rules will be taken and some work in education people in source sorting will be made, more advanced composting plants and fermentation plants can be built for treatment the separately collected compostable household waste.

Progress in environmental management is driven by several factors. Most important is public understanding of environmental problems and an economical situation allowing actions for a better environmental management. Some of the most important factors for improving waste management system in any country in the world are listed below:

- **Economy.** Any waste management system should be not very expensive with good payback due to income. Recycling of material or energy can in most cases be done with profit.
- **Public awareness** of negative impact from waste on humans and the environment is a most important factor to improve waste management. Simply understanding the reason to manage different types of waste in different ways will make a tremendous difference.
- **Organisation and co-operation.** Responsibilities in waste management have to be well defined between different actors on the waste market and authorities. Dialogue and co-operation between authorities and waste management organisations with opposite opinions will drive progress forward.

To implement waste management ideas in Ukraine there has to be authorities responsible for environment on all levels, state – regionally – and locally. The responsibilities for these organisations on all levels have to be well defined. To really get some progress it is important for
the authorities to have a counterpart to discuss possible improvements in waste management and to have an easily accessible representative of an entire line of waste trade.

Simplified it is recommended to have the following organizations:
- One authority responsible for environment working with environmental information and control of waste management on a local, regional and state level. In Sweden this is divided in several authorities working on different levels. On a national level “The Swedish Environmental Protection Agency” represents them.
- An association of trade representing local councils responsible for waste management on a local level and companies working with waste management in any way. In Sweden this is represented by “RVF - the Swedish Association of Waste Management” organizing most companies working with waste management.
- An association of trade representing all companies working with processes having a significant environmental impact in some way. One organization like this does not exist in Sweden, but there are several trade associations representing different types of industries.

Having several representatives with different aspects of waste management will create a dialogue between different opinions to improve environmental management. It is also very practical for authorities to have a single or at least very few counterparts to inform regarding new laws and other important information instead of multiple minor actors on the waste market.

And also it should be taken in account, that main attention in any program of household waste handling has to be focused on work with population. Only active position of population is a guarantee of successful activity in source separation of waste. This work takes a lot of time and a lot of money, but it is profitable in a long run. In Sweden public awareness and acceptance for costs related to actions for a better environment are very high compared to most countries in the world. That is why, it is quite easy to implement environmental control and laws in this country.
9. Conclusions

This thesis work describes two regions – one is the Södertörn Area in Sweden (and the SRV company since it is responsible for biotreatment of the waste in this region) and the second one is the Yavoriv Region in Ukraine – their environmental characteristic and their needs in implementing new biological treatment methods for organic food waste. In order to suggest the most suitable biotreatment method for these two regions a lot of studies have been done.

Different rules and regulations for organic waste handling in Sweden and Ukraine were overviewed. The main Swedish means of control, – such as Regulation on Animal By-products (EC No 1774/2002), National and Regional Goals, Requirements for Certification (SPCR 120) and for Approval, – and Ukrainian “Law about Waste” were described. So, the legislation and regulation system concerning the waste handling in Sweden is developed very well, there are a lot of stimulations for the companies to continuously improve systems and techniques for treatment of organic waste. Legislation system in Ukraine concerning organic waste is developed quite badly and a lot of work should be done to develop it in waste management sphere.

Different sorting methods for organic food waste, which are used in Sweden – such as source sorting with plastic and paper bags, optical sorting and vacuum sorting systems – were studied, and their main advantages and disadvantages were examined. Sorting system in Sweden is developed quite well; variety of a lot of different methods of sorting the waste is making the source separation a favorable option for households; and high awareness of people in sorting the waste allows to get quite clean fraction of organic food waste for treating them at the biological treatment plant. It was investigated that there is no sorting of organic waste in Ukraine, and a lot of efforts, such as new regulations, educational programs for households, etc., should be done to implement and then develop this system in Ukraine.

Different biological methods for treatment of organic waste were studied from theoretical and practical sides. Composting methods, – such as Open composting, Ag-Bag, BIODEGMA, VAPO, RotoCom (bagging) and Rotocom rotary composting systems, – and fermentation, which are used in Sweden for biotreatment of the organic waste, were overviewed from two points of view (from “company-producer” the technique and from “plant-user” the technique) and their advantages, disadvantages, as well as investment and treatment costs were examined. It was found that there are a lot of different biological treatment methods in Sweden for treatment of organic waste such as food household waste and garden waste, food waste from restaurants, big supermarkets and food industry, slaughterhouse waste and manure. So, biological treatment of organic waste in Sweden is developed very well. Biotreatment is a quite good option, which reduces the amount of waste to landfill, reduces bad impact on the environment, and allows getting the cleanest vehicle fuel as well as digestate or compost, which could be used as fertilizer or soil improver. Sweden can be an example in organizing biological treatment for other countries, particularly for Ukraine. It was investigated that for the moment there is no biological treatment of organic waste in Ukraine and a lot of efforts should be done to implement and develop this system there.

Different biotreatment methods, which are described in the thesis, are discussed for applying them for the Södertörn area in Sweden and the Yavoriv Region in Ukraine, taking into account different technological and economic aspects of the methods.

It was suggested for the SRV to establish:
- source sorting of the household waste with using paper or starch bags and bins with holes;
- provide composting and fermentation for separate streams of organic waste (composting with using VAPO or BIODEGMA systems and fermentation) in case of treatment of
small quantities of very clean industrial waste and of quite big amount of household and green waste, or of quite big amount of other organic waste, such as household and green waste, waste from restaurants and big supermarkets;

- or provide a combination of fermentation and composting methods for the treatment of organic waste (the first stage – fermentation and the second stage – composting with BIODEGMA, Ag-Bag or RotoCom composting systems) in case of treatment of large quantities of industrial organic waste or of a very good quality source sorted organic household waste and of not large amount of garden waste, as well as in case of using some equipment for separation different contaminants from organic waste.

For Ukraine it was suggested to start biological treatment the waste from open composting system (since the compost is needed for the Yavoriv Region to fill in a lot of quarries) and then to begin developing of waste management system with new rules, sorting the waste, more advanced composting and fermentation methods.

**Recommendations for further studies**

This Thesis Work makes a wide and, as much as was possible, deep overview of different biological treatment methods (composting and fermentation) to be able to suggest the best solution in biological treatment of organic waste for the SRV and the Södertörn area and for the Yavoriv Region. Due to the difficulties, which were in gathering of the information, it was not quite possible to get all necessary information in order to do a very deep analysis of the methods.

In order to make more concrete suggestions, I would recommend to make deeper study of methods, which are already suggested in this work, – such as visit plants, which use the method (since it was impossible for me to visit all plants and make my own conclusions about different biotreatment methods); look more carefully on advantages and disadvantages of the methods; make more accurate costs calculations for the SRV for using the concrete method or methods.

Also it would be good to distinguish the choice of composting and fermentation from Systems Analysis point of view. In that case, the result of choosing the best method for the SRV could be different from my own suggestions.

Because of a lot of difficulties in collecting the information from Ukraine, it is also possible that some aspects are not taken into account. To be able to make the right suggestions for Ukraine, some deeper studies about what is done already in Ukraine according to organic waste and its treatment and what could be done to develop the waste management system there should be made.
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_A lot of practical information about using different composting and fermentation methods are taken from contacting people from the Swedish composting and fermentation plants (direct interview, phone calls, e-mails). These persons and their contact information are listed in the Appendix 4._

_Conact information of different companies, which produce composting systems, are listed below:_

**Componordic System AB (Ag-Bag composting system)**

Barbro Beck-Friis  
Agronomist, Ph.D. sales Manager

Box 139 (Hantverkargatan 11)  
S-761 22 Norrtälje, Sweden  
Phone: +46 176 128 50  
Cellphone: +46 70 379 00 18  
Fax: +46 176 128 55  
E-mail: barro.beck-friis@componordicsystem.se  
[www.componordicsystem.se](http://www.componordicsystem.se)

**BIODEGMA GmbH (BIODEGMA composting system)**

Ralf Müller  
Managing Director

Martin-Luther-Str. 26  
71636 Ludwigsburg  
Phone: +49-7141-6 88 88-11  
Fax: +49-7141-6 88 88-25  
Mobile: +49-171-694 7336  
E-mail: rm@biodegma.de  
[www.biodegma.de](http://www.biodegma.de)
ClaesTech AB *(RotoCom bagging composting system)*

Claes Anderson

Box 107 (Beatebergs Gård)
76223 Rimbo, Sweden
Phone:+4617567010
Fax:+4617567014
Mobile:+46708945600
E-mail: claes.anderson@swipnet.se

ANDAR Holdings Ltd *(Rotocom rotary composting system)*

Dr. Steve Kroening, PhD

PO Box 435
Timaru, New Zealand
Tel: +64 3 688 2044
Fax: +64 3 688 2640
Web: www.andar.co.nz
www.rotocom.com

Vapo Oy Biotech *(VAPO composting system)*

Timo Valkeinen
Area Export Manager

Wedavägen 1A, 4tr.
152 42 Södertälje, Sweden
Tel: +46 8 550 877 70
Fax: +46 8 550 877 74
Mobile phone: +46 70 2760 788
E-mail: timo.valkeinen@vapo.fi
www.vapo.fi

OptiBag Systems AB *(Optical sorting system)*

Stefan Holmertz
Managing Director

Phone: +46 142 18509
E-mail: sh@optibag.se
Appendices

Appendix 1. Description of Category 1, 2 and 3 Materials

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(m) producer: any person whose activity produces animal by-products;

(n) TSEs: all transmissible spongiform encephalopathies, except those occurring in humans;

(o) specified risk material: material referred to in Annex V to Regulation (EC) No 999/2001 of the European Parliament and of the Council of 22 May 2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies (1);

2. The specific definitions set out in Annex I shall also apply.

Article 3

General obligations

1. Animal by-products, and products derived therefrom, shall be collected, transported, stored, handled, processed, disposed of, placed on the market, exported, carried in transit and used in accordance with this Regulation.

2. However, Member States may regulate under national law the importation and placing on the market of products not referred to in Annexes VII and VIII, pending the adoption of a decision in accordance with the procedure referred to in Article 33(2). They shall immediately inform the Commission of the use that they make of this possibility.

3. Member States shall, either individually or cooperatively, ensure that adequate arrangements are in place, and that a sufficient infrastructure exists, to ensure compliance with the requirement of paragraph 1.

CHAPTER II
CATEGORISATION, COLLECTION, TRANSPORTATION, DISPOSAL, PROCESSING, USE AND INTERMEDIATE STORAGE OF ANIMAL BY-PRODUCTS

Article 4

Category 1 material

1. Category 1 material shall comprise animal by-products of the following description, or any material containing such by-products:

(a) all body parts, including hides and skins, of the following animals:

(b) animals suspected of being infected by a TSE in accordance with Regulation (EC) No 999/2001 or in which the presence of a TSE has been officially confirmed;

(ii) animals killed in the context of TSE eradication measures;

(iii) animals other than farmed animals and wild animals, including in particular pet animals, zoo animals and circus animals.

(iv) experimental animals as defined by Article 2 of Council Directive 86/609/EC of 24 November 1986 on the approximation of laws regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes (2), and

(v) wild animals, when suspected of being infected with diseases communicable to humans or animals;

(b) specified risk material, and

(ii) where, at the time of disposal, specified risk material has not been removed entire bodies of dead animals containing specified risk material;

(c) products derived from animals to which substances prohibited under Directive 96/22/EC have been administered and products of animal origin containing residues of environmental contaminants and other substances listed in Group B(3) of Annex I to Council Directive 96/23/EC of 29 April 1996 on measures to monitor certain substances and residues thereof in live animals and animal products and repealing Directives 85/358/EEC and 86/409/EEC and Decision 89/187/EEC and 91/664/EEC (3). If such residues exceed the permitted level laid down by Community legislation or, in the absence thereof, by national legislation:

(d) all animal material collected when treating waste water from Category 1 processing plants and other premises in which specified risk material is removed, including screenings, materials from desanding, grease and oil mixtures, sludge and materials removed from drains from those premises, unless such material contains no specified risk material or parts of such material;

(e) catering waste from means of transport operating internationally; and

(f) mixtures of Category 1 material with either Category 2 material or Category 3 material or both, including any material destined for processing in a Category 1 processing plant.

2. Category 1 material shall be collected, transported and identified without undue delay in accordance with Article 7 and, except as otherwise provided in Articles 23 and 24, shall be:


(a) directly disposed of as waste by incineration in an incineration plant approved in accordance with Article 12;

(b) processed in a processing plant approved under Article 13 using any of processing methods 1 to 5 or, where the competent authority so requires, processing method 1, in which case the resulting material shall be permanently marked, where technically possible with small, in accordance with Annex VI, Chapter 1, and finally disposed of as waste by incineration or by co-incineration in an incineration or co-incineration plant approved in accordance with Article 12;

(c) with the exclusion of material referred to in paragraph 1(a) and (ii), processed in a processing plant approved in accordance with Article 13 using processing method 1, in which case the resulting material shall be permanently marked, where technically possible with small, in accordance with Annex VI, Chapter 1, and finally disposed of as waste by burial in a landfill approved under Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (f);

(d) in the case of catering waste referred to in paragraph 1(a), disposed of as waste by burial in a landfill approved under Directive 1999/31/EC or

(e) in the light of developments in scientific knowledge, disposed of by other means that are approved in accordance with the procedure referred to in Article 33(2), after consultation of the appropriate scientific committee. These means may either supplement or replace those provided for in subparagraphs (a) to (d).

3. Intermediate handling or storage of Category 1 material shall take place only in Category 1 intermediate plants approved in accordance with Article 10.

4. Category 1 material shall not be imported or exported except in accordance with this Regulation or with rules laid down under the procedure referred to in Article 33(2). However, the import or export of specified risk material shall take place only in accordance with Article 5(1) of Regulation (EC) No 999/2001.

**Article 5**

**Category 2 material**

1. Category 2 material shall comprise animal by-products of the following description, or any material containing such by-products:

(a) manure and digestive tract content;

(b) all animal materials collected when treating waste water from slaughterhouses other than slaughterhouses covered

by Article 4(1)(d) or from Category 2 processing plants, including screenings, materials from desalting grease and oil mixtures, sludge and materials removed from drains from those premises;

(c) products of animal origin containing residues of veterinary drugs and contaminants listed in Group B(1) and (2) of Annex I to Directive 96/23/EC, if such residues exceed the permitted level laid down by Community legislation;

(d) products of animal origin, other than Category 1 material, that are imported from non-member countries and, in the course of the inspections provided for in Community legislation, fail to comply with the veterinary requirements for their importation into the Community, unless they are returned or their importation is accepted under restrictions laid down under Community legislation;

(e) animals and parts of animals, other than those referred to in Article 4, that die other than by being slaughtered for human consumption, including animals killed to eradicate an epizootic disease;

(f) mixtures of Category 2 material with Category 3 material, including any material destined for processing in a Category 2 processing plant;

(g) animal by-products other than Category 1 material or Category 3 material.

2. Category 2 material shall be collected, transported and identified without undue delay in accordance with Article 7 and, except as otherwise provided in Articles 23 and 24, shall be:

(a) directly disposed of as waste by incineration in an incineration plant approved in accordance with Article 12;

(b) processed in a processing plant approved in accordance with Article 13 using any of processing methods 1 to 5 or, where the competent authority so requires, processing method 1, in which case the resulting material shall be permanently marked, where technically possible with small, in accordance with Annex VI, Chapter 1, and:

(i) disposed of as waste either by incineration or by co-incineration in an incineration or co-incineration plant approved in accordance with Article 12, or

(ii) in the case of rendered fats, further processed into fat derivatives for use in organic fertilizers or soil improvers or for other technical uses, other than in cosmetics, pharmaceuticals and medical devices, in a Category 2 oleochemical plant approved in accordance with Article 14;

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(e) processed in a processing plant approved in accordance with Article 13 using processing method I, in which case the resulting material shall be permanently marked, where technically possible with small, in accordance with Annex VI, Chapter 1, and:

(i) in the case of resulting proteinaceous material, used as an organic fertilizer or soil improver in compliance with requirements, if any, laid down in accordance with the procedure referred to in Article 33(2) after consultation of the appropriate scientific committee,

(ii) transformed in a biogas plant or in a composting plant approved in accordance with Article 15, or

(iii) disposed of as waste by burial in a landfill approved under Directive 1999/31/EC;

(d) in the case of material of fish origin, ensiled or composted in compliance with rules adopted in accordance with the procedure referred to in Article 33(2);

(e) in the case of manure, digestive tract content separated from the digestive tract, milk and colostrum, if the competent authority does not consider them to present a risk of spreading any serious transmissible disease;

(f) used without processing as raw material in a biogas plant or in a composting plant approved in accordance with Article 15 or treated in a technical plant approved for this purpose in accordance with Article 18,

(g) applied to land in accordance with this Regulation, or

(h) transformed in a biogas plant or composted in accordance with rules laid down under the procedure referred to in Article 33(2),

(i) in the case of entire bodies or parts of wild animals not suspected of being infected with diseases communicable to humans or animals, used to produce game trophies in a technical plant approved for this purpose in accordance with Article 18;

(j) disposed of by other means or used in other ways, in accordance with rules laid down under the procedure referred to in Article 33(2), after consultation of the appropriate scientific committee. These means or ways may either supplement or replace those provided for in subparagraphs (a) to (i).

3. Intermediate handling or storage of Category 2 material, other than manure, shall take place only in Category 2 intermediate plants approved in accordance with Article 10.

4. Category 2 material shall not be placed on the market or exported except in accordance with this Regulation or with rules laid down under the procedure referred to in Article 33(2).

Article 6

Category 3 material

1. Category 3 material shall comprise animal by-products of the following description, or any material containing such by-products:

(a) parts of slaughtered animals, which are fit for human consumption in accordance with Community legislation, but are not intended for human consumption for commercial reasons;

(b) parts of slaughtered animals, which are rejected as unfit for human consumption but are not affected by any signs of diseases communicable to humans or animals and derive from carcasses that are fit for human consumption in accordance with Community legislation;

(c) hides and skins, hooves and horns, pig bristles and feathers originating from animals that are slaughtered in a slaughterhouse, after undergoing ante-mortem inspection, and were fit, as a result of such inspection, for slaughter for human consumption in accordance with Community legislation;

(d) blood obtained from animals other than ruminants that are slaughtered in a slaughterhouse, after undergoing ante-mortem inspection, and were fit, as a result of such inspection, for slaughter for human consumption in accordance with Community legislation;

(e) animal by-products derived from the production of products intended for human consumption, including degreased bones and glands;

(f) former foodstuffs of animal origin, or former foodstuffs containing products of animal origin, other than entering waste, which are no longer intended for human consumption for commercial reasons or due to problems of manufacturing or packaging defects or other defects which do not present any risk to humans or animals;

(g) raw milk originating from animals that do not show clinical signs of any disease communicable through that product to humans or animals;

(h) fish or other sea animals, except sea mammals, caught in the open sea for the purposes of fishmeal production;

(i) fresh by-products from fish from plants manufacturing fish products for human consumption;

(j) shells, hatchery by-products and cracked egg by-products originating from animals which did not show clinical signs of any disease communicable through that product to humans or animals.
(k) blood, hides and skins, hooves, feathers, wool, horns, hair and fur originating from animals that did not show clinical signs of any disease communicable through that product to humans or animals; and

(l) catering waste other than as referred to in Article 4(1)(e).

2. Category 3 material shall be collected, transported and identified without undue delay in accordance with Article 7 and, except as otherwise provided in Articles 23 and 24, shall be:

(a) directly disposed of as waste by incineration in an incineration plant approved in accordance with Article 12;

(b) processed in a processing plant approved in accordance with Article 13 using any of processing methods 1 to 3; in which case the resulting material shall be permanently marked, where technically possible with small quantities of copper, in accordance with Annex VI, Chapter I, and disposed of as waste either by incineration or by co-incineration in an incineration or co-incineration plant approved in accordance with Article 12 or in a landfill approved under Directive 1999/31/EC;

(c) processed in a processing plant approved in accordance with Article 17;

(d) transformed in a technical plant approved in accordance with Article 18;

(e) used as raw material in a petfood plant approved in accordance with Article 18;

(f) transformed in a biogas plant or in a composting plant approved in accordance with Article 15;

(g) in the case of catering waste referred to in paragraph 1(l), transformed in a biogas plant or composted in accordance with rules laid down under the procedure referred to in Article 33(2) or, pending the adoption of such rules, in accordance with national law;

(h) in the case of material of fish origin, ensiled or composted in accordance with rules laid down under the procedure referred to in Article 33(2) or

(i) disposed of by other means, or used in other ways, in accordance with rules laid down under the procedure referred to in Article 33(2), after consultation of the appropriate scientific committee. These means or ways may either supplement or replace those provided for in subparagraphs (a) to (h).

3. Intermediate handling or storage of Category 3 material shall take place only in Category 3 intermediate plants approved in accordance with Article 10.
Appendix 2. Specific requirements for biogas and composting plants

ANNEX VI

SPECIFIC REQUIREMENTS FOR THE PROCESSING OF CATEGORY 1 AND 2 MATERIAL AND FOR BIOGAS AND COMPOSTING PLANTS

CHAPTER 1

Specific requirements for the processing of Category 1 and Category 2 material

The following requirements apply in addition to the general requirements laid down in Annex V.

A. Partition

1. The layout of Category 1 and Category 2 processing plants must ensure the total separation of Category 1 material from Category 2 material from reception of the raw material until dispatch of the resulting processed product.

2. However, the competent authority may authorise the temporary use of a Category 2 processing plant for the processing of Category 1 material when a widespread outbreak of an epidemic disease or other extraordinary and unavoidable circumstances leads to a lack of capacity at a Category 1 processing plant.

The competent authority must re-authorise the Category 2 processing plant in accordance with Article 13 before it processes Category 2 material again.

B. Processing standards

3. The critical control points that determine the extent of the heat treatments applied in processing must be identified for each processing method as specified in Annex V, Chapter III. The critical control points may include:

(a) raw material particle size;

(b) temperature achieved in the heat treatment process;

(c) pressure applied to the raw materials and

(d) duration of the heat treatment process or feed rate to a continuous system.

Minimum process standards must be specified for each applicable critical control point.

4. Records must be maintained for at least two years to show that the minimum process values for each critical control point are applied.

5. Accurately calibrated gauges/recorders must be used to monitor continuously the processing conditions. Records must be kept to show the date of calibration of gauges/recorders.

6. Material that may not have received the specified heat treatment (e.g. material discharged at start-up, or leakage from coolers) must be recycled through the heat treatment or collected and represented.

7. Animal by-products must be processed in accordance with the following processing standards.

(a) Processing method 1 must be applied to:

(i) Category 2 material, other than manure and digestive tract content, destined for biogas or composting plants or intended to be used as organic fertilizers or soil improvers, and

(ii) Category 1 and Category 2 material destined for landfills.
(b) Any of processing methods 1 to 5 must be applied to:

(i) Category 2 material from which the resulting product is destined for incineration or co-incineration;

(ii) Category 2 material from which the rendered fat is destined for a Category 2 oleochemical plant; and

(iii) Category 1 or Category 2 material destined for incineration or co-incineration.

However, the competent authority may require processing method 1 to be applied to Category 1 material destined for incineration or co-incineration.

C. Protocol products

8. Processed products derived from Category 1 or 2 materials, with the exception of liquid products destined for biogas or composting plants, must be permanently marked, where technically possible with small, using a system approved by the competent authority. Detailed rules for such marking may be laid down under the procedure referred to in Article 3(2).

9. Samples of processed products destined for biogas or composting plants or landfills, taken directly after heat treatment must be free from heat-resistant pathogenic bacteria spores (C. perfringens absent in 1 g of the products).

CHAPTER II
Specific requirements for the approval of biogas and composting plants

A. Biogas

1. Biogas plants must be equipped with:

(a) a pasteurisation/homogenisation unit which cannot be bypassed, with:

(i) installations for monitoring temperature against time;

(ii) recording devices to record the results of these measurements continuously; and

(iii) an adequate safety system to prevent insufficient heating; and

(b) adequate facilities for cleaning and disinfecting vehicles and containers on leaving the biogas plant.

However, a pasteurisation/homogenisation unit is not mandatory for biogas plants that transform only animal by-products that have undergone processing method 1.

2. Composting plants must be equipped with:

(a) a closed composting reactor, which cannot be bypassed, with:

(i) installations for monitoring temperature against time;

(ii) recording devices to record the results of these measurements continuously; and

(iii) an adequate safety system to prevent insufficient heating; and

(b) adequate facilities for cleaning and disinfecting vehicles and containers transporting untreated animal by-products.
3. Each biogas plant and composting plant must have its own laboratory or make use of an external laboratory. The laboratory must be equipped to carry out the necessary analyses and approved by the competent authority.

B. Hygiene requirements

4. Only the following animal by-products may be transformed in a biogas or composting plant:

(a) Category 2 material, when using processing method 1 in a Category 2 processing plant;

(b) manure and digestive tract contents;

(c) Category 3 material.

5. Animal by-products referred to in paragraph 4 must be transformed as soon as possible after arrival. They must be stored properly until treated.

6. Containers, receptacles and vehicles used for transporting untreated material must be cleaned in a designated area. This area must be situated or designed to prevent risk of contamination of treated products.

7. Preventive measures against birds, rodents, insects or other vermin must be taken systematically. A documented pest control programme must be used for that purpose.

8. Cleaning procedures must be documented and established for all parts of the premises. Suitable equipment and cleaning agents must be provided for cleaning.

9. Hygiene control must include regular inspections of the environment and equipment. Inspection schedules and results must be documented.

10. Installations and equipment must be kept in a good state of repair and measuring equipment must be calibrated at regular intervals.

11. Digestion residues must be handled and stored at the plant in such a way as to preclude recontamination.

C. Processing standards

12. Category 3 material used as raw material in a biogas plant equipped with a pasteurisation/hygienisation unit must be subjected to the following minimum requirements:

(a) maximum particle size before entering the unit: 12 mm;

(b) minimum temperature in all material in the unit: 70 °C and

(c) minimum time in the unit without interruption: 60 minutes.

13. Category 3 material used as raw material in a composting plant must be subjected to the following minimum requirements:

(a) maximum particle size before entering the composting reactor: 12 mm;

(b) minimum temperature in all material in the reactor: 70 °C and

(c) minimum time in the reactor at 70 °C (all material): 60 minutes.

14. However, pending the adoption of rules in accordance with Article 6(2)(g), the competent authority may, when assessing waste as the only animal by-product used as raw material in a biogas or composting plant, authorise the use of processing standards other than those laid down in paragraphs 12 and 13 provided that they guarantee an equivalent effect regarding the reduction of pathogens.
D. Digestion residue and amputations

15. Samples of the digestion residues or components taken during or on withdrawal from storage at the bovine or composting plant must comply with the following standards:

*Salmonella* absence: 25 g; n = 5, c = 0, m = 0, M = 0

Enterobacteriaceae: n = 5, c = 2, m = 10, M = 300 in 1 g

where:

n = number of samples to be examined;

m = threshold value for the number of bacteria; the result is considered satisfactory if the number of bacteria in all samples does not exceed m;

M = maximum value for the number of bacteria; the result is considered unsatisfactory if the number of bacteria in one or more samples is M or more;

c = number of samples the bacteriological count of which may be between m and M; the sample will be considered acceptable if the bacteriological counts of the other samples is m or less.

CHAPTER III

Treatment standards for the further processing of rendered fats

The following processes may be used to produce fat derivatives from rendered fats derived from Category 2 material:

1. transsterification or hydrolysis at least 200 °C, under corresponding appropriate pressure, for 20 minutes (glycerol, fatty acids and esters);

2. saponification with NaOH 1.5% (glycerol and soap);

(a) in a batch process at 95 °C for three hours; or

(b) in a continuous process at 140 °C 2 bars (2,000 hPa) for eight minutes, or under equivalent conditions laid down in accordance with the procedure referred to in Article 34(2).
Appendix 3. 15th National Quality Objective – A Good Built Environment

The outcome within a generation for this environmental quality objective should include the following:

- The built environment provides aesthetic experiences and well-being and offers a wide range of housing, workplaces, services and culture that give everybody the opportunity to live a full and stimulating life, while reducing everyday transport needs.
- The cultural, historical and architectural heritage in the form of buildings and built environments, including places and landscapes with special assets, are protected and enhanced.
- A sustainable urban structure is developed, both in connection with the location of new buildings, structures and industries and with the use, management and conversion of existing buildings.
- The living and leisure environment, and wherever possible the work environment, meets society's requirements in terms of design, freedom from noise and access to sunlight, clean water and clean air.
- Areas of unspoiled nature and green spaces close to built-up areas, which are easily accessible, are protected in order to meet the need of play, recreation, local farming and a healthy local climate.
- Biological diversity is preserved and enhanced.
- Transports and transport facilities are located and designed in such a way as to limit interference with the urban or natural environment and so as not to pose health or security risks or be otherwise detrimental to the environment.
- Environmentally sound, good-quality public transport systems are available, and there are plenty of facilities for safe pedestrian and cycle traffic.
- People are not exposed to harmful air pollutants, noise nuisances, harmful radon levels or other unacceptable risks to health or safety.
- Land and water areas are free of toxic and dangerous substances and other pollutants.
- The use of energy, water and other natural resources is efficient, resource saving and environmentally sound; the preferred energy sources are renewable.
- Natural gas is only used where it is not possible to use substitutes in specific applications.
- Deposits of gravel that are valuable for the drinking water supply and the natural and cultural landscape are preserved.
- The quantity and dangerousness of waste are decreasing.
- Waste and residues are separated by categories and recycled on a cooperative basis by urban areas and the surrounding rural areas.

Interim target 1, 2010

By 2010 land use and community planning will be based on programmes and strategies for:

- achieving a varied supply of housing, workplaces, services and cultural activities, in order to reduce car use and improve the scope for environmentally sound and resource-efficient transport;
- preserving and enhancing cultural and aesthetic assets;
- preserving and enhancing green spaces and water bodies in urban and suburban areas and ensuring that the proportion of hard surfaces does not increase;
- promoting more efficient energy use, use of renewable energy resources and development of production plants for district heating, solar energy, bio fuels and wind power.

Interim target 2, 2010

By 2010 built environments of cultural heritage value will be identified and a programme will be in place for the protection of their cultural assets. In addition, long-term protection will be provided for at least 25% of valuable built environments.
Interim target 3, 2010
By 2010 the number of people who are exposed to traffic noise in excess of the guide values approved by Parliament for noise in dwellings will have been reduced by 5% compared with 1998.

Interim target 4, 2010
By 2010 extraction of natural gravel in the country will not exceed 12 million tonnes per year and reused materials will represent at least 15% of the aggregates used.

Interim target 5, 2005
The quantity of waste disposed of to landfill, excluding mining waste, will be reduced by at least 50% by 2005 compared with 1994, at the same time as the total quantity of waste generated does not increase.

Interim target 6, 2008
All landfill sites will conform to uniform standards by 2008 and will meet stringent environmental requirements in accordance with Council Directive 1999/31/EC on the landfill of waste.

Interim target 7, 2010
The environmental impact of energy use in residential and commercial buildings will decrease and will be lower in 2010 than in 1995. This will be achieved, inter alia, by improving energy efficiency and eventually reducing total energy use.

Interim target 8, 2010/2015/2020
By 2020 buildings and their characteristics will not have adverse impacts on health. It must therefore be ensured that
- all buildings in which people frequently spend time or spend extended periods of time have ventilation of documented efficiency by 2015,
- radon levels in all schools and pre-schools are below 200 Bq/m³ air by 2010 and that
- radon levels in all dwellings are below 200 Bq/m³ air by 2020.

Interim target 9, 2010
By 2010 at least 35% of food waste from households, restaurants, caterers and retail premises will be recovered by means of biological treatment. This target relates to food waste separated at source for both home composting and centralized treatment.

Interim target 10, 2010
By 2010 food waste and comparable wastes from food processing plants etc. will be recovered by means of biological treatment. This target relates to waste that is not mixed with other wastes and that is of such a quality as to be suitable, following treatment, for recycling into crop production.
### Appendix 4. Table of composting and fermentation plants in Sweden with short description

<table>
<thead>
<tr>
<th>Number</th>
<th>Companies and contact persons</th>
<th>Methods they use for biotreatment</th>
<th>Short technical description, duration of process</th>
<th>Cost expenses</th>
<th>Kinds of wastes</th>
<th>Amount and composition of waste</th>
<th>Sorting methods</th>
<th>Certifications and approval</th>
<th>Experiences</th>
</tr>
</thead>
</table>
| 1      | (Fågelmyra biogasanläggning) Borlänge Energi (Borlänge)  
Christian Olhans  
christian.olhans@borlange-energi.se  
0243-731 54 | Composting | Box composting and RotoCom composting systems (4-5 weeks in the box composting and 14-16 weeks in the RotoCom facility, then – open composting). Whole duration of the process is about 1 year. | Investment costs – approx. SEK 60 million in all plant; 1,5 million SEK in RotoCom system. **Price for one bag** is about **7 000 SEK** (they charge bags after each time of using). **Treatment costs**: they take **SEK 650/ton** for treatment of sorted OHHW. | Sorted waste from HH, food industry, supermarkets; garden waste for composting. They have about 12 000 t/y waste: 2 000 t/y of green waste and 10 000 t/y of organic waste. | Source sorting (paper bags and bio-bags, plastic bins with holes). Collecting the waste – once a 2 weeks. Bags are opened and crushed before the treatment. |  | They are satisfied with the method. They have already it for 7-8 months. They think that this method is cheaper that Ag-Bag composting. It is difficult to reach and maintain 65°C or 70°C in RotoCom system. They have smell problems. |  |
| 2      | Kuskatorpet AB Komposteringsanläggningen (Halmstad)  
Per Nilsson | Fermentation | - | - | - | - | - | - | - | They don’t have any certification but work to get it |  |
<p>|        |                                |                            |                                              |               |                |                                |                |                             | <em>I didn’t get the information</em> |
|        |                                |                            |                                              |               |                |                                |                |                             | <em>I couldn’t contact the person</em> |</p>
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<tr>
<th>Number</th>
<th>Companies and contact persons</th>
<th>Methods they use for biotreatment the waste</th>
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<th>Certifications and approval</th>
<th>Experiences</th>
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</thead>
</table>
| 1      | Borås kommun Gatukontoret (Borås)  
Tisse Jarlsvik  
tisse.jarlsvik@boras.se  
033-35 74 96 | Fermentation | Biogas is produced from the content of black bags (after crushing and screening). |  | Municipal (HH, restaurants, shops, etc.), industrial waste, sludge, contaminated soils and ashes; garden waste (for composting). | 300 000 t waste/year in total (100 000 t waste/year to landfill; 65 000 t waste to biological treatment). *Composition*: food remains; fruit, vegetable peelings; meat, fish offal; bread; coffee grounds; teabags; waste from flowers, kitchen roll. | Source sorting (black plastic bags for organic waste, white bags – for other waste), optical sorting of municipal waste, mechanical sorting. | Approved - Regulation 1774/2002 | By sorting, recycling and biotreatment, the people of Borås have reduced the quantity of landfill waste from approximately 100 000 tons/year to 30 000 tons/year. This corresponds to the weight of a queue of cars 280 km long. |
| 2      | Borås Renhållningsverk (Borås)  
Tisse Jarlsvik  
tisse.jarlsvik@boras.se  
033-35 74 96 | Composting | After the fermentation, the waste goes to compost hall (20 weeks for compost to become ready). They use Ag-Bag composting system. | They invested 100 mil SEK (investment costs) in environmentally compliant waste handling (recycling centres, depots, sorting and biotreatment plants, etc.). |  |  |  |  |  |
| 3      | MERAB (Eslöv)  
Björn Liwing  
0413-684 45 | Composting | Open (windrow) composting. |  | Source sorted OHHW, from food industry and big supermarkets. |  |  |  | They don’t have any certifications and approval. |
<p>| 4      | Fermentation | Ordinary fermentation. |  |  |  |  |  |  | They have odour problems during the process. |</p>
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<tr>
<td>5</td>
<td><strong>Vafab Miljö (Sala, Fagersta, Västerås)</strong>&lt;br&gt;Torbjörn Ånger&lt;br&gt;021-39 35 41</td>
<td>Composting</td>
<td>Closed (in-vessel) composting – BIODEGMA; Gore-tex membrane (solve odour problems); 4 weeks of treatment in closed modules. Then open composting.</td>
<td>Treatment costs – SEK 350/t (they had subsidies from government in 1999 – 50% of investment).</td>
<td>Source separated OHHW, from food industry, supermarkets, restaurants; garden waste (for composting).</td>
<td>6 000 t/y organic waste; 2 000 t/y garden waste.</td>
<td>Source sorting (paper bags, plastic bins on wheels). Collection – once a 2 weeks.</td>
<td>They don’t have any certification, since don’t use compost for agriculture purposes.</td>
<td>They think this method is the best, since Gore-tex membranes solve odour problems (better than bio-filters), and also water is turned back to composting material during the process; good aeration of the process.</td>
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<td>6</td>
<td><strong>Renova (Göteborg)</strong>&lt;br&gt;Jesper Grandin&lt;br&gt;<a href="mailto:Jesper.Grandin@renova.se">Jesper.Grandin@renova.se</a></td>
<td>Fermentation</td>
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<td>7</td>
<td>Nordvästra Skånes Renhållnings AB (or NSR AB) (Helsingborg)</td>
<td>Composting</td>
<td>Dry fraction is composted in a membrane composting facility with forced aeration – <strong>BIODEGMA</strong> concept.</td>
<td>They don’t want to say the <strong>investment costs</strong>.</td>
<td>Source sorted waste from households and industries.</td>
<td>Source sorting the waste, using paper bags which are put in two bins with 4 different fractions in each bin. The waste is collected every 2 weeks.</td>
<td>They don’t have certification for compost.</td>
<td>They are satisfied with the method. The only problem is the odour when moving material from closed to open modules; and the risk of drying out the material.</td>
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<td>Jessica Cedervall</td>
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<td><a href="mailto:jessica.cedervall@nsr.se">jessica.cedervall@nsr.se</a></td>
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<td>042-10 79 70</td>
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<td></td>
<td>Karin Eken Södergård</td>
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<td>042-10 78 60</td>
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<td><a href="mailto:Karin.Eken-Sodergaard@nsr.se">Karin.Eken-Sodergaard@nsr.se</a></td>
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<td></td>
<td>Ludvika kommun Tekniska kontoret (Ludvika)</td>
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<tr>
<td>8</td>
<td>Ludvika kommun Tekniska kontoret (Ludvika)</td>
<td>Composting</td>
<td>Open (windrow) composting, duration of the process – 1-1.5 years.</td>
<td>Mixed HHW, sometimes sorted OHHW from some municipalities.</td>
<td>10 000 t/y; (they are allowed to treat – 30 000 t/y).</td>
<td>They don’t have any certification and approval.</td>
<td>Mixed HHW smells less than sorted HHW.</td>
<td>Quality certification. Approve d – Regulation 1774/2002</td>
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<td>9</td>
<td><strong>Affärsverken AB (Karlskrona)</strong>&lt;br&gt;Kajsa Carlsson&lt;br&gt;<a href="mailto:Kajsa.Carlsson@affv.se">Kajsa.Carlsson@affv.se</a>&lt;br&gt;0455-783 94</td>
<td>Composting</td>
<td>Membrane composting facility – <strong>BIODEGMA</strong> concept (Gore-tex membrane, which stops drops and particles). Food waste is mixed with 25-30% wood chips. Duration of composting: 3-4 weeks in closed modules (intensive phase), 4 weeks in open box, 5-7 weeks for maturation in open composting (turning the pile once a week), if space is – 10 weeks more for maturation.&lt;br&gt;&lt;br&gt;Their <strong>investment costs</strong> were: ca <strong>5 million SEK</strong> to install BIODEGMA process, and <strong>5-6 million SEK</strong> for land, concrete works and for the reception area.</td>
<td>Their investment costs were: ca <strong>5 million SEK</strong> to install BIODEGMA process, and <strong>5-6 million SEK</strong> for land, concrete works and for the reception area.</td>
<td><strong>Source sorted HHW</strong>, from restaurants and schools; green waste.</td>
<td><strong>3 500 t/y food waste</strong> (they are allowed to have 9 750 t/y). The composition of the waste is the similar to other composting plants.</td>
<td>Source sorting the wastes in brown paper bags (for HHW – they are collected once a 2 weeks, in summer times – more often; for restaurants – once every week).Paper bags are put into the 130 l plastic bins with small holes for the ventilation. Bags are ripped open in a scoop with 4 screws to cut waste. Shredded green waste is mixed with food waste.</td>
<td>They don’t have any certification and approval.</td>
<td>They don’t have any certification and approval.</td>
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<tr>
<td>10</td>
<td><strong>LSR (Landskrona)</strong>&lt;br&gt;Mats Hafström&lt;br&gt;0418-45 01 07</td>
<td>Composting</td>
<td><strong>Open (windrow)</strong> composting.</td>
<td>Garden waste.</td>
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<td>11</td>
<td>Nårab (Klippan)</td>
<td>Composting</td>
<td>Open (windrow) composting.</td>
<td>Source sorting.</td>
<td>Sorted organic waste; garden waste.</td>
<td>No sorting (it’s not needed for the process).</td>
<td>They don’t have any certification and approval.</td>
<td>The method is cheap (cheap construction, low investment costs), no necessity to sort the waste.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dan Waldemarsson 0435-296 50</td>
<td>Fermentation</td>
<td>They get 4 000 t/y of ready product after the fermentation.</td>
<td>Mixed OHHW.</td>
<td>10 000 t waste per year.</td>
<td>Mechanical sorting the waste at the plant.</td>
<td>They don’t have any certification and approval.</td>
<td>They have problems with smell, that’s why they are thinking about composting with plastic bags.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Västblekinge Miljö AB (Mörrum)</td>
<td>Composting</td>
<td>Open (windrow) composting.</td>
<td>Source sorting.</td>
<td>Mixed HHW.</td>
<td>8 000 t/y of sorted OHHW; 5 000 t/y of slaughterhouse waste.</td>
<td>They don’t have any certification and approval.</td>
<td>They have no plans for the certification and approval.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Matilda 0454-593 65</td>
<td>Fermentation</td>
<td></td>
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<td>Source sorting the waste.</td>
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<td>I didn’t get the answer</td>
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<td>13</td>
<td>Gräfsäsen (Östersund)</td>
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<td>Kenneth Ivansson 063-14 34 90</td>
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<td></td>
<td>Source-sorted OHHW; slaughterhouses waste.</td>
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<td>I didn’t get the answer</td>
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<td>14</td>
<td>Skellefteå kommun Gatukontoret (Skellefteå)</td>
<td>Fermentation</td>
<td>They have fermentation plant with gas upgrading unit. The plant is going to start on June 2006.</td>
<td>Source sorting the waste.</td>
<td>8 000 t/y of sorted OHHW; 5 000 t/y of slaughterhouse waste.</td>
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<td>I didn’t get the answer</td>
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<td></td>
<td>Roland Hägglund <a href="mailto:roland.hagglund@skelleftea.se">roland.hagglund@skelleftea.se</a> 0910-73 64 80</td>
<td>Fermentation</td>
<td></td>
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<td>Source sorting the waste.</td>
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<td>I didn’t get the answer</td>
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<td>15</td>
<td><strong>Tekniska Förvaltningen (Luleå)</strong></td>
<td>Composting</td>
<td>Closed (in-vessel) composting – <strong>BIODEGMA</strong></td>
<td><strong>Investment costs</strong> – approx. <strong>SEK 3.9 million/year</strong>. <strong>Treatment costs</strong> – <strong>SEK 500/ton</strong>.</td>
<td>Sorted OHHW and industrial waste, are put in separate bins.</td>
<td>3 500 metric wet ton waste yearly (plant can handle 12 000 t/y). They have 8 000 t/y all waste.</td>
<td>Source sorting (paper bags; now they are changing to starch bags; 140 l containers with holes). Collection the waste – every 2 weeks. Bags are opened and crushed.</td>
<td>They don’t have any certification and approval (except of ISO).</td>
<td>They are satisfied with the method, since they don’t have any problem with bad smell. They have a contract with BIODEGMA for 15 years. They have already this technology for 1 year. They say that this is a little expensive but it is possible to bargain with the BIODEGMA company.</td>
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<td>16</td>
<td><strong>Sysav (Malmö)</strong></td>
<td>Composting</td>
<td>Open (windrow) composting.</td>
<td>Garden waste; they collect HH and industrial waste but for other plants.</td>
<td>They don’t have any certification and approval.</td>
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<td>17</td>
<td><strong>Örebro kommun (Örebro)</strong></td>
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<td>(BIODEGMA)</td>
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<td>I couldn’t contact the person</td>
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<td>15</td>
<td>Uppsala kommun Tekniska kontoret (Uppsala)</td>
<td>Composting</td>
<td>Open (windrow) composting.</td>
<td>Source sorted OHHW, green waste.</td>
<td>8 000 t/y of OHHW; 4 000 t/y of green waste.</td>
<td>Source sorting the waste in plastic bags, then they have brown bins for waste for composting and green bins for waste to incineration.</td>
<td>They don’t have any approval and certification.</td>
<td>They have problems with smell. They want to change this composting to BIODEGMA or Ag-Bag.</td>
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<td>18</td>
<td>Cecilia Ekvall <a href="mailto:cecilia.ekvall@uppsala.se">cecilia.ekvall@uppsala.se</a> 018-727 42 27 (13)</td>
<td>Fermentation</td>
<td>They have 2 sedimentation and 2 pulper tanks for grinding and diluting of solid waste. They have hygienisation stage for 1 hour at 70°C. They have thermophilic fermentation at 55°C; retention time is 17 days. Duration of whole process is about 20-30 days. They have upgrading plant for biogas and filling station for busses and 1 small filling station for cars.</td>
<td>They have already invested 110 million SEK in biogas plant, upgrading plant and filling station. Now they are investing money in new system for opening plastic bags with OHHW and separation plastic from the waste, since they are going to treat HHW as well from 2006. Their treatment cost is 500 SEK/t – fee for delivering the waste.</td>
<td>They treat liquid waste (manure, blood and glucose from slaughterhouses), and solid waste (organic waste from restaurants, kitchens and supermarkets; from households and from industries).</td>
<td>The amount of waste is (2004): industrial waste – 3 587 t/y (slaughterhouse waste – 3 014 t/y; organic waste from restaurants, kitchens and supermarkets – 564 t/y); HHW – 964 t/y. From 2006 they are going to treat up to 8 000 t/y of OHHW.</td>
<td>For HHW – source sorting in plastic bags; for the rest of waste – waste is sorted at the place where it is formed; or these wastes don’t have to be sorted.</td>
<td>They have approval from SP and certification from RVF. At first they got approval and then they were doing their qualification year (it lasted 3 years) and then they got certification. Now they have approval to treat the Category 2 materials.</td>
<td>Since they use also solid waste for fermentation, these wastes should be treated and diluted before the pumping to the buffer tank, where wastes are mixed. From 2006 they are going to ferment OHHW. Magnets (from the intestines of cows) and corks (restaurants waste) should be taken away.</td>
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<td>19</td>
<td>Älmhults kommun (Älmhult)</td>
<td>Fermentation</td>
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<td>Jöran Johansson 0476-550 00</td>
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<td>20</td>
<td>Telge återvinning (Södertälje)</td>
<td>Composting</td>
<td>Ag-Bag composting system (fermentation and composting take place). Duration of the process: 1-4 weeks – fermentation in bags; 16-20 weeks – composting in bags. Then open composting.</td>
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<td>Annette Ovland <a href="mailto:annette.ovland@telgeatervinning.se">annette.ovland@telgeatervinning.se</a> 08-553 222 13</td>
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<td>They invested about 1 million SEK in the loader machine. 1 plastic bag costs about 10 000 SEK (they change bag after using it one time). They paid 30 million SEK for building OptiBag sorting facility.</td>
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<td>They use source sorted OHHW, waste from food industry, restaurants and supermarkets; garden waste.</td>
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<td>They have about 10 000 – 15 000 t/y of organic waste and about 3 500 – 5 000 t/y of green waste.</td>
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<td>The households sort their waste at home (put food waste into green plastic bags), then at the company they have OptiBag sorting system (sort out organic and non-organic waste).</td>
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<td>They don’t have any certification for the product and approval. But they are working to get it.</td>
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<td>They say that this system is cheap, easy in operating; they can make their own mix of organic and green waste (it possible to regulate it manually). But they have difficulties with the hygienisation unit (impossible to prove it), and also bags become broken often.</td>
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<td>21</td>
<td>Kils biogas-läggning Kils Avfallshantering AB (Kil)</td>
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<td></td>
<td>Teo Nordin</td>
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<td>I couldn’t contact the person</td>
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<td>22</td>
<td>Mossvägen Falköpings kommun (Falköping)</td>
<td>Fermentation</td>
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<td>5 000 kg/day (are allowed for 14 000 kg/day)</td>
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<td>Contact person doesn’t know anything about certification.</td>
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<tr>
<td></td>
<td>Tage Åkesson <a href="mailto:Tage.Akesson@falkoping.se">Tage.Akesson@falkoping.se</a> 0705-16 24 12</td>
<td>Composting</td>
<td>Open (windrow) composting.</td>
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<td>Garden waste; residue from fermentation.</td>
<td>30-50 kg/day</td>
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<td>23</td>
<td>Kalmar Biogasanläggning Kalmar Vatten och Renhållning AB (Kalmar)</td>
<td>Fermentation</td>
<td>Fermentation plant consists of hygienisation stage (70°C, 1h) and digesting (thermophilic) stage (55°C, 20 days).</td>
<td>They invested 40 million SEK to build the plant in 1998. Their treatment costs are 260-500 SEK/m³.</td>
<td>Slaughterhouse waste, manure from cows.</td>
<td>40 000 t/y (capacity of plant); 22 000 t/y – amount of waste they treat (2004).</td>
<td></td>
<td>They have certification SPCR 120 for biomanure and have the permit from SJV and Länsstyrelsen i Kalmar län. Also they have EMAS and ISO 14 000 for whole company.</td>
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<td></td>
<td>Linda Pettersson 0480-45 12 08 <a href="mailto:linda.pettersson@kvra.b.kalmar.se">linda.pettersson@kvra.b.kalmar.se</a></td>
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<td>Quality certification, Approved - Regulation 1774/2002</td>
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<td>24</td>
<td>Kristianstad Renhållnings AB (Kristianstad)</td>
<td>Fermentation</td>
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<td></td>
<td>Ola Odesson</td>
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<td>I couldn’t contact the person</td>
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<p>| Quality certification, Approved - Regulation 1774/2002 |</p>
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<tr>
<td>25</td>
<td><strong>Svensk Biogas i Linköping (Linköping)</strong>&lt;br&gt; Peter Unden 013-20 80 60</td>
<td>Fermentation</td>
<td>Hygienisation stage – 70°C, 1h; 2 fermentation tanks – 38°C, 30 days.</td>
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<td>Slaughterhouse waste (milk, yogurt); waste from chicken industry.</td>
<td>54 000 t/y (the capacity of plant).</td>
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<td>They have certification for their products: for biogas (SS 15 54 38) and for bio-fertiliser (SPCR 120).</td>
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<td>26</td>
<td><strong>Alingsås kommun (Alingsås)</strong>&lt;br&gt; Charlotte Löfgren <a href="mailto:charlotte.lofgren@alingsas.se">charlotte.lofgren@alingsas.se</a> 0322-61 63 08</td>
<td>Composting</td>
<td>Open (windrow) composting.</td>
<td></td>
<td>OHHW, park and garden waste, horse manure.</td>
<td>2 000 t/y – OHHW; 10 000 t/y – park and garden waste; horse manure and similar waste. <em>Composition:</em> all sorts of scraps of food; coffee grounds and filters; ashes (not from tobacco); bones (from chicken, meat, fish); flowers and soils; garden waste in bags; kitchen paper and napkins.</td>
<td>Source sorting (corn-starch bags are put in a bin); manual sorting at the company.</td>
<td>They don’t have any certification and approval.</td>
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<td>27</td>
<td>Västerås Renhållningsverk (Västerås)</td>
<td>Fermentation</td>
<td><strong>Investment costs – 76 million SEK</strong> (all included); <strong>Treatment costs – 450 SEK/ton</strong> of waste.</td>
<td></td>
<td>Separated OHHW (fruit and vegetable peel, meet bones, fish remains; bread-scrap; coffee grounds, coffee and tea filters, wilted flowers, pot plants, earth from repotting; kitchen-roll paper, popcorn; sweets, chocolate); industrial waste, waste from restaurants, crops.</td>
<td>23 000 t/y; 14 000 t of clean, source-separated organic waste (HH, institutional kitchens); 4 000 t of grease trap removal sludge (institutional kitchens, restaurants); 5 000 t of ensilaged ley crop.</td>
<td>Source-sorting (paper-bag model). Bags are collected in brown plastic bins with holes for aeration. Collection the waste is done every second week. Bags are opened and crushed before the treatment.</td>
<td>They have approval from KRAV, Svenskt Sigill, and Cerealia.</td>
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<td>Per-Erik Persson</td>
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<td><a href="mailto:Per-Erik.Persson@vafabmiljo.se">Per-Erik.Persson@vafabmiljo.se</a></td>
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<td></td>
<td>Composting</td>
<td>Open (windrow) composting.</td>
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<td>Garden waste.</td>
<td>15 000 t/y.</td>
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<td>Sörab (Vallentuna) Tonny Hendered</td>
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<td>I couldn’t contact the person</td>
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<td>29</td>
<td>Norrlandsjörd &amp; Miljö AB (Luleå) Kurt Johansson <a href="mailto:kurt@norrlandsjord.se">kurt@norrlandsjord.se</a> 0920-25 00 00 08-251 773</td>
<td>Composting</td>
<td>Closed (in-vessel) composting — BIODEGMA concept: reception hall; 5 closed modules for 4 weeks treatment; 5 open modules for the next 4 weeks treatment; open asphalt surface for after treatment (approximately 6-12 weeks).</td>
<td>-</td>
<td>OHHW, waste from restaurants, supermarkets; garden waste.</td>
<td>20 000 t/y.</td>
<td>Source sorting (plastic bags).</td>
<td>They follow the regulations from RVF (SPCR 120), but they are not certificated. They also don’t have approval.</td>
<td>They say this is a simple technique with good results and not so expensive equipment compared with other techniques. But they have a lot of work with wheel loader to move the waste during the treatment time. And also they have to sieve the waste with drum sieving machine at least two times during the treatment to take away not organic waste.</td>
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<td>ÖGRAB Kattarp (Broby) Christer Johansson</td>
<td>Composting</td>
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<td>I couldn’t contact the person</td>
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<td>31</td>
<td>TRAAB Heljestorp (Vänersborg) Jörgen Fredriksson <a href="mailto:jf@traab.se">jf@traab.se</a> 0703-97 40 92</td>
<td>Fermentation</td>
<td>They have thermophilic process, 2 biodigesters (120 m³), 2 blenders, 2 hygienisation tanks (80 m³ – 70°C during 1 hour). In the end of the process they have solid biomanure – 20% TS; liquid biomanure – 2-3% TS; biogas – 70% CH₄.</td>
<td>Investment cost – 63 million SEK (20 million SEK for OptiBag sorting system and about 43 million SEK for building the biogas plant) in 1999.</td>
<td>Capacity for optical sorting – 50 000 ton; capacity for fermentation – 22 000 ton. They fermented 11 600 t waste/y (in 2004).</td>
<td>Source sorting the waste – OptiBag sorting method (green bags for organic material; red bags for combustible waste; and other – for landfill).</td>
<td>They are approved by Swedish Board of Agriculture (SJV) and they do their qualification year for certification SPCR 120 (RVF) (till August 2006).</td>
<td>They are satisfied with equipment, but they are always in development…</td>
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<td>32</td>
<td>Älvsbyn kommun (Älvsbyn) Roger Broström</td>
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<td>-----------------------------------------------</td>
<td>--------------</td>
<td>----------------</td>
<td>---------------------------------</td>
<td>----------------</td>
<td>-----------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>33</td>
<td>SRV återvinning AB (Huddinge)</td>
<td>Composting</td>
<td>Open (windrow composting; duration of the process – approximately 7 months.)</td>
<td></td>
<td>OHHW, food waste from big supermarkets and restaurants; garden and park waste.</td>
<td>7 242 t/y food waste; 6 945 t/y park/garden waste (have capacity – 15 000 t/y both for food and garden/park waste).</td>
<td>Source-sorting the waste (special kind of plastic bags for food waste, which are easy to compost).</td>
<td>No certification and approval.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fermentation</td>
<td>Hygienisation unit – 70°C, 1h; digestion unit.</td>
<td></td>
<td>Food (liquid) waste from large kitchen and restaurants.</td>
<td>Plant capacity 4 000 t/y food waste (have permission for capacity – 50 000 t/y).</td>
<td>Source-sorting the waste (without using plastic bags).</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>34</td>
<td>Sollentuna kommun Renhållningen</td>
<td>Sorting the waste – collection contractor, which handles collection and transport of the waste.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>I didn’t get the answer</td>
</tr>
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</table>
Appendix 5. Investment and treatment costs for Ag-Bag composting system

Kalkyl Ag Bag CT8 160 ton & Blandarvagn

<table>
<thead>
<tr>
<th>Förutsättningar: H.h.sopor eller rötslam v.h 67% blandas med strukturmaterial v.h 35% - (2/3- 1/3) v.h 55%</th>
<th>% per år</th>
<th>CT8</th>
<th>Fläkt</th>
<th>Blandarvagn 24 m³ (stand.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pris (ex. moms)</td>
<td></td>
<td>Kr</td>
<td>Kr</td>
<td>Kr</td>
</tr>
<tr>
<td>1. Avskrivning</td>
<td>5 år</td>
<td>20,0%</td>
<td>1.350 000</td>
<td>18 000</td>
</tr>
<tr>
<td>2. Ränta 1.350 000 : 2 x 6% = medelränta</td>
<td>6,0%</td>
<td>40 500</td>
<td>540</td>
<td>22 665,60</td>
</tr>
<tr>
<td>3. Underhåll</td>
<td>2,0%</td>
<td>27 000</td>
<td>360</td>
<td>15 110,40</td>
</tr>
<tr>
<td><strong>Summa 1, 2, 3</strong></td>
<td>28,0%</td>
<td>337 500</td>
<td>4 500</td>
<td>188 870</td>
</tr>
</tbody>
</table>

Bag inkl. rör, ventiler och anslutningar 15 000 kr.

**Ventiler, slangar och anslutningar kan återanvändas vilket gör 22 kr/ton**

<table>
<thead>
<tr>
<th></th>
<th>7000 ton/år</th>
<th>14 000 ton/år</th>
<th>21 000 ton/år</th>
<th>28 000 ton/år</th>
<th>35 000 ton/år</th>
<th>42 000 ton/år</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT8</td>
<td>Kr/ton</td>
<td>48</td>
<td>24</td>
<td>16</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Drivmedel</td>
<td>Kr/ton</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fläkt</td>
<td>Kr/ton</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bag (160 t)</td>
<td>Kr/ton</td>
<td>94</td>
<td>94</td>
<td>94</td>
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<td>94</td>
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<tr>
<td><strong>Summa</strong></td>
<td>Kr/ton</td>
<td>144</td>
<td>120</td>
<td>112</td>
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<td>106</td>
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<tr>
<td>Strukturmaterial</td>
<td>Kr/ton</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Blandarvagn</td>
<td>Kr/ton</td>
<td>27</td>
<td>14</td>
<td>9</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Betong</td>
<td>Kr/ton</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Asfalt</td>
<td>Kr/ton</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Grus</td>
<td>Kr/ton</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Lastmask. 550 kr/tim</td>
<td>Kr/ton</td>
<td>20</td>
<td>20</td>
<td>20</td>
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<td>20</td>
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<td>Hygienisering</td>
<td>Kr/ton</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Summa</strong></td>
<td>Kr/ton</td>
<td>236</td>
<td>199</td>
<td>186</td>
<td>180</td>
<td>177</td>
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</tbody>
</table>
**Kalkyl Ag Bag CT8 300 ton & Blandarvagn**

Förutsättningar: H.h.sopor eller rötslam v.h 67% blandas med strukturmaterial v.h 35% - (2/3- 1/3) v.h 55%

<table>
<thead>
<tr>
<th></th>
<th>% per år</th>
<th>CT8</th>
<th>Fläkt</th>
<th>Blandarvagn 24 m³ (stand.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Kr</td>
<td>Kr</td>
<td>Kr</td>
</tr>
<tr>
<td>Pris (ex. moms)</td>
<td>1.350 000</td>
<td>18 000</td>
<td>755 520</td>
<td></td>
</tr>
<tr>
<td>1. Avskrivning</td>
<td>20,0%</td>
<td>270 000</td>
<td>3 600</td>
<td>151 104</td>
</tr>
<tr>
<td>2. Ränta 1.350 000 : 2 x 6% = medelränta</td>
<td>6,0%</td>
<td>40 500</td>
<td>540</td>
<td>22 665,60</td>
</tr>
<tr>
<td>3. Underhåll</td>
<td>2,0%</td>
<td>27 000</td>
<td>360</td>
<td>15 110,40</td>
</tr>
<tr>
<td>Summa 1, 2, 3</td>
<td>28,0%</td>
<td>337 500</td>
<td>4 500</td>
<td>188 870</td>
</tr>
</tbody>
</table>

Bag inkl. rör, ventiler och anslutningar 17 000 kr.

**Ventiler, slangar och anslutningar kan återanvändas vilket gör 10 kr/ton**

<table>
<thead>
<tr>
<th></th>
<th>7000 ton/år</th>
<th>14 000 ton/år</th>
<th>21 000 ton/år</th>
<th>28 000 ton/år</th>
<th>35 000 ton/år</th>
<th>42 000 ton/år</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT8</td>
<td>Kr/ton</td>
<td>48</td>
<td>24</td>
<td>16</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Drivmedel</td>
<td>Kr/ton</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fläkt</td>
<td>Kr/ton</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bag (300 t)</td>
<td>Kr/ton</td>
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<td>57</td>
<td>57</td>
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<tr>
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<td>83</td>
<td>75</td>
<td>71</td>
<td>69</td>
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<td>Strukturmaterial</td>
<td>Kr/ton</td>
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<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Blandarvagn</td>
<td>Kr/ton</td>
<td>27</td>
<td>14</td>
<td>9</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Betong</td>
<td>Kr/ton</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
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<tr>
<td>Asfalt</td>
<td>Kr/ton</td>
<td>13</td>
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<td>13</td>
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<td>13</td>
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<tr>
<td>Grus</td>
<td>Kr/ton</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
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<tr>
<td>Lastmask. 550 kr/tim</td>
<td>Kr/ton</td>
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<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Hygienisering</td>
<td>Kr/ton</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Summa</td>
<td>Kr/ton</td>
<td>199</td>
<td>162</td>
<td>149</td>
<td>143</td>
<td>140</td>
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</tbody>
</table>
# Appendix 6. Investment and treatment costs for BIODEGMA composting system

## SRV Composting Plant

### Budgetary Costs

### 8 Modules

<table>
<thead>
<tr>
<th>Technique for 8 Modules</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil works</td>
<td>7,350,000 SEK</td>
</tr>
<tr>
<td>Concrete slab 1,306 m²</td>
<td>1,540 SEK</td>
</tr>
<tr>
<td>Asphalt driving area 272 m²</td>
<td>275 SEK</td>
</tr>
<tr>
<td>Concrete walls 2,090 m²</td>
<td>2,090 SEK</td>
</tr>
<tr>
<td>Ventilation station 163 m²</td>
<td>1,045 SEK</td>
</tr>
<tr>
<td>Aeration channels 640 m²</td>
<td>385 SEK</td>
</tr>
<tr>
<td>Ground work 2,000 m²</td>
<td>132 SEK</td>
</tr>
<tr>
<td>Drainage 150,000 SEK</td>
<td></td>
</tr>
<tr>
<td>Unforeseen</td>
<td>395,927 SEK</td>
</tr>
<tr>
<td>Total Civil Works</td>
<td>4,429,993 SEK</td>
</tr>
</tbody>
</table>

### 11 Modules

<table>
<thead>
<tr>
<th>Technique for 11 Modules</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil works</td>
<td>10,100,000 SEK</td>
</tr>
<tr>
<td>Concrete slab 1,795 m²</td>
<td>1,540 SEK</td>
</tr>
<tr>
<td>Asphalt driving area 408 m²</td>
<td>275 SEK</td>
</tr>
<tr>
<td>Concrete walls 2,090 m²</td>
<td>2,090 SEK</td>
</tr>
<tr>
<td>Ventilation station 245 m²</td>
<td>1,045 SEK</td>
</tr>
<tr>
<td>Aeration channels 880 m²</td>
<td>385 SEK</td>
</tr>
<tr>
<td>Ground work 3,000 m²</td>
<td>132 SEK</td>
</tr>
<tr>
<td>Drainage 200,000 SEK</td>
<td></td>
</tr>
<tr>
<td>Unforeseen</td>
<td>542,822 SEK</td>
</tr>
<tr>
<td>Total</td>
<td>6,081,047 SEK</td>
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</tbody>
</table>

---

*BIODEGMA GmbH, Ludwigsburg*  
2005-11-24
SRV Composting Plant

Budgetary Costs

8 Closed modules + 8 open curing modules

<table>
<thead>
<tr>
<th>Technique</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil works</td>
<td>8,648,000 SEK</td>
<td></td>
</tr>
<tr>
<td>Concrete slab</td>
<td>2,611 m²</td>
<td>1,540 SEK</td>
</tr>
<tr>
<td>Asphalt driving area</td>
<td>544 m²</td>
<td>275 SEK</td>
</tr>
<tr>
<td>Concrete walls</td>
<td>986 m²</td>
<td>2,090 SEK</td>
</tr>
<tr>
<td>Ventilation station</td>
<td>326 m²</td>
<td>1,045 SEK</td>
</tr>
<tr>
<td>Aeration channels</td>
<td>1,280 m²</td>
<td>385 SEK</td>
</tr>
<tr>
<td>Ground work</td>
<td>2,000 m²</td>
<td>132 SEK</td>
</tr>
<tr>
<td>Drainage</td>
<td></td>
<td>300,000 SEK</td>
</tr>
<tr>
<td>Unforseen</td>
<td></td>
<td>747,897 SEK</td>
</tr>
<tr>
<td>Total Civil Works</td>
<td></td>
<td>8,376,470 SEK</td>
</tr>
</tbody>
</table>

11 Closed modules + 11 open curing modules

<table>
<thead>
<tr>
<th>Technique</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil works</td>
<td>11,515,000 SEK</td>
<td></td>
</tr>
<tr>
<td>Concrete slab</td>
<td>3,590 m²</td>
<td>1,540 SEK</td>
</tr>
<tr>
<td>Asphalt driving area</td>
<td>748 m²</td>
<td>275 SEK</td>
</tr>
<tr>
<td>Concrete walls</td>
<td>1,324 m²</td>
<td>2,090 SEK</td>
</tr>
<tr>
<td>Ventilation station</td>
<td>449 m²</td>
<td>1,045 SEK</td>
</tr>
<tr>
<td>Aeration channels</td>
<td>1,760 m²</td>
<td>385 SEK</td>
</tr>
<tr>
<td>Ground work</td>
<td>3,000 m²</td>
<td>132 SEK</td>
</tr>
<tr>
<td>Drainage</td>
<td></td>
<td>400,000 SEK</td>
</tr>
<tr>
<td>Unforseen</td>
<td></td>
<td>1,023,825 SEK</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>11,467,778 SEK</td>
</tr>
</tbody>
</table>
SRV Composting Plant

**Capacity** 14,500 Mg/a

<table>
<thead>
<tr>
<th>Input Tonnage (Mg/a)</th>
<th>Density (Mg/m³)</th>
<th>Volume (m³/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen Waste</td>
<td>7,500</td>
<td>0.70</td>
</tr>
<tr>
<td>Green Waste</td>
<td>7,000</td>
<td>0.30</td>
</tr>
<tr>
<td>Total</td>
<td>14,500</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Calculation of the modules:
- Length 3m
- Width 6.5m
- Height of the walls 2m
- Volume 250 m³
- Weight 106 Mg
- Retention time 3 weeks
- Capacity per module 4.34 Mg/ha
- Capacity per module 1,772 Mg/a
- Required number of modules 8.0

Space demand intensive stage:
- Modules 2×2.2m × 2.4m
- Space needed: 1,304 m²
- Driving areas 28m × 10m
- 380 m²

Mass balance:
- Input into modules 14,500 Mg/a
- Retention time 3 weeks
- Mass loss 22% 3,190 Mg/a
- Output to curing/maturation 11,310 Mg/a

Input Maturation:
- Retention time 12 weeks
- Mass loss 20% 2,900 Mg/a
- Total mass loss 41% 6,300 Mg/a
- Screen overflow 5% 750 Mg/a
- Contaminants 5% 750 Mg/a
- Matured compost product 48% 6,960 Mg/a

Energy demand:

<table>
<thead>
<tr>
<th>Number of fans</th>
<th>Electric load (kW)</th>
<th>Total load (kW)</th>
<th>Operating Time (h/a)</th>
<th>Consumption (kWh/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration</td>
<td>8</td>
<td>2</td>
<td>16</td>
<td>61.32</td>
</tr>
</tbody>
</table>

Fuel consumption:

<table>
<thead>
<tr>
<th>Number of machines</th>
<th>Consumption (l/h)</th>
<th>Operating Time (h/a)</th>
<th>Total Consumption (l/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel loader</td>
<td>2</td>
<td>11</td>
<td>2,288</td>
</tr>
<tr>
<td>Fe treatment</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Trench</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Screen</td>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

Labour Demand:
- 2 wheel loader driver (drives wheel loader, maintenance of all machines)
- 1 operation manager (Drives wheel loader, organization, marketing)

BIODEGMA GmbH 14,500 tpa 2005-11-24
SRV Composting Plant

<table>
<thead>
<tr>
<th>Capacity</th>
<th>22,000 Mg/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Tonnage (Mg/a)</td>
<td>Density (Mg/m³)</td>
</tr>
<tr>
<td>Kitchen Waste</td>
<td>15,000</td>
</tr>
<tr>
<td>Green Waste</td>
<td>7,000</td>
</tr>
<tr>
<td>Total</td>
<td>22,000</td>
</tr>
</tbody>
</table>

**Calculation of the modules**
- Length: 21m
- Width: 6.5m
- Height of the walls: 2m
- Volume: 210 m³
- Weight: 125 Mg
- Retention Time: 3 weeks
- Mass loss: 22%
- Capacity per module: 442.4 m³/a
- Capacity per module: 2.045 Mg/a
- Required number of modules: 10.5 → 11

**Space demand Intensiv stage**
- Modules: 240.8m x 24m
- Driving area: 42m x 10m
- 1968 m²
- 420 m²

**Mass balance**
- Input into modules: 22,000 Mg/a
- Retention time: 3 weeks
- Mass loss: 22%
- Output to curing/maturation: 17,360 Mg/a
- Retention time: 12 weeks
- Mass loss: 20%
- Total mass loss: 4.2%
- Screen overflow: 5%
- Contaminants: 5%
- Matured compost product: 48%
- Storage compost (5 months): 16,266 m³/a

**Space demand Curing/Maturation**
- Volume/a: 25,600 m³
- Throughput/a: 4
- Required storage capacity in maturation: 7,160 m²
- Average volume of windows: 220 m³
- Height: 2m
- Required space: 3,900 m²

**Energy demand**
- Number of fans: 11
- Aeration: 1.6 kW
- Total load: 17.6 kW
- Operating Time: 6.72 h/a
- Consumption: 107.923 kWh/a

**Fuel consumption**
- Number of machines: 2.5
- Consumption: 11 l/h
- Operating Time: 22 h/a
- Consumption: 62.320 l/h/a

**Labour Demand**
- 3 wheel loader driver (driver wheel loader, maintenance of all machines)
- 1 operation manager (driver wheel loader, organization, marketing)

BIODEGMA GmbH 22,000 tpa 2005-11-24
SRV Composting Plant

Budgetary Costs

6 Modules + windrow composting

<table>
<thead>
<tr>
<th>Technique for 6 Modules</th>
<th>5,980,000 SEK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Civil works</strong></td>
<td></td>
</tr>
<tr>
<td>Concrete slab</td>
<td>579 m²</td>
</tr>
<tr>
<td>Asphalt driving area</td>
<td>408 m²</td>
</tr>
<tr>
<td>Concrete walls</td>
<td>380 m²</td>
</tr>
<tr>
<td>Ventilation station</td>
<td>122 m²</td>
</tr>
<tr>
<td>Aeration channels</td>
<td>480 m²</td>
</tr>
<tr>
<td>Ground work</td>
<td>1,600 m²</td>
</tr>
<tr>
<td>Drainage</td>
<td></td>
</tr>
<tr>
<td>Unforseen</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>

6 Modules 6 aerated open curing modules + windrow composting

<table>
<thead>
<tr>
<th>Technique for 6 Modules</th>
<th>6,745,000 SEK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Civil works</strong></td>
<td></td>
</tr>
<tr>
<td>Concrete slab</td>
<td>1,958 m²</td>
</tr>
<tr>
<td>Asphalt driving area</td>
<td>408 m²</td>
</tr>
<tr>
<td>Concrete walls</td>
<td>760 m²</td>
</tr>
<tr>
<td>Ventilation station</td>
<td>245 m²</td>
</tr>
<tr>
<td>Aeration channels</td>
<td>960 m²</td>
</tr>
<tr>
<td>Ground work</td>
<td>3,200 m²</td>
</tr>
<tr>
<td>Drainage</td>
<td></td>
</tr>
<tr>
<td>Unforseen</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>
## SRV Composting Plant

### Capacity

<table>
<thead>
<tr>
<th>Input Tonnage (Mg/a)</th>
<th>Density (Mg/m³)</th>
<th>Volume (m³/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen Waste</td>
<td>9,000</td>
<td>0.70</td>
</tr>
<tr>
<td>Green Waste</td>
<td>3,000</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12,000</strong></td>
<td><strong>0.53</strong></td>
</tr>
</tbody>
</table>

### Calculation of the modules

- Length: 27m
- Width: 6.5m
- Height of the walls: 3m
- Volume: 270 m³
- Weight: 15.1 Mg
- Retention time: 3 weeks
- Capacity per module: 4.147 m³/a
- Capacity per module: 2.185 Mg/a
- Required number of modules: 5.4 -> 6

### Space demand Intensive stage

- Modules: 6 m x 1.4 m
- Driving areas: 3.6 m x 1.0 m

### Mass balance

- Input into modules: 12,000 Mg/a
- Retention time: 3 weeks
- Mass loss: 22%
- Output to curing/maturation: 9,360 Mg/a
- Input Maturation: 9,360 Mg/a
- Retention time: 12 weeks
- Mass loss: 20%
- Storage compost (6 months)

### Energy demand

<table>
<thead>
<tr>
<th>Number of fans</th>
<th>Electro-load (kW)</th>
<th>Total load (kW)</th>
<th>OperatingTime (h/a)</th>
<th>Consumption (kWh/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1.6</td>
<td>9.6</td>
<td>6130</td>
<td>55,867</td>
</tr>
</tbody>
</table>

### Fuel consumption

<table>
<thead>
<tr>
<th>Number of machines</th>
<th>Consumption (l/h)</th>
<th>OperatingTime (h/a)</th>
<th>Total Consumption (l/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel loader</td>
<td>1</td>
<td>1</td>
<td>2,288</td>
</tr>
<tr>
<td>Pre treatment</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Turner</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Screen</td>
<td>1</td>
<td>10</td>
<td>600</td>
</tr>
</tbody>
</table>

**BICDEGMA Gmbh**

Winrow maturation

2005-02-09
Appendix 7. The technological scheme of RotoCom (bagging) composting system

FLOW CHART OF THE PROCESSING STEPS FOR COMPOSTING THE ORGANIC MATERIAL
WITH APIESSE (RotoCom) SYSTEM

1. Selection of the organic material
   - A solid and porous mixing is advisable

2. Grinding and mixing

3. Hopper loading

4. Bag filling

5. Bag sealing

6. Connection to the blower and starting of timed aeration

7. Compaction as desired

8. Splitting to allow air out

9. Daily inner temperature control (ideal range: 55°-65°C)

10. Third week – retiming of forced air supply

11. Analysis of BOD = biological oxygen demand

12. Control of the oxygen demand

13. After about 50 days stop air supply and bag opening

14. Preparation of a pile and periodic turning for some weeks

15. Mature compost

16. Recycle of the perforated pipes

17. Mixing and riddling
FLOW CHART OF THE PROCESSING STEPS FOR BIO-STABILIZATION AND COMPOSTING OF URBAN SOLID WASTE WITH *APIESSE* (RotoCom) SYSTEM

1. **URBAN SOLID WASTE**
   - GRINDING AND RIDDLING
   - HOPPER LOADING
   - BAG FILLING AT LOW COMPACTION
   - BAG SEALING AND LATERAL SPLITTING TO ALLOW AIR OUT
   - CONNECTION TO THE BLOWER AND STARTING TIMED AERATION
   - DAILY INNER TEMPERATURE CONTROL (IDEAL RANGE =55°C-65°C)
   - THIRD WEEK: LOWERING OF THE FORCED VENTILATION
   - MOVING THE MATERIAL TO ANOTHER DESTINATION

2. **FOOD WASTE**
   - GRINDING AND RIDDLING
   - HOPPER LOADING
   - BAG FILLING AT LOW COMPACTION
   - BAG SEALING AND LATERAL SPLITTING TO ALLOW AIR OUT
   - CONNECTION TO THE BLOWER AND STARTING TIMED AERATION
   - DAILY INNER TEMPERATURE CONTROL (IDEAL RANGE =55°C-65°C)
   - THIRD WEEK: LOWERING OF THE FORCED VENTILATION
   - MOVING THE MATERIAL TO ANOTHER DESTINATION

3. **POST-SELECTED URBAN ORGANIC WASTE**
   - GRINDING AND RIDDLING
   - HOPPER LOADING
   - BAG FILLING AT LOW COMPACTION
   - BAG SEALING AND LATERAL SPLITTING TO ALLOW AIR OUT
   - CONNECTION TO THE BLOWER AND STARTING TIMED AERATION
   - DAILY INNER TEMPERATURE CONTROL (IDEAL RANGE =55°C-65°C)
   - THIRD WEEK: LOWERING OF THE FORCED VENTILATION
   - MOVING THE MATERIAL TO ANOTHER DESTINATION

**THIRD WEEK BIO-STABILIZATION**

- THIRD WEEK: LOWERING OF THE FORCED VENTILATION
- AFTER ABOUT 50 DAYS END OF THE AIR SUPPLY AND BAG OPENING
- RECYCLE OF THE PERFORATED PIPES
- PREPARATION OF A PILE AND PERIODIC TURNING
- MIXING AND RIDDLING; RECYCLING BRUSHWOODS

**LOW QUALITY COMPOST**

**MATURER COMPOST**
Appendix 8. Investment and treatment costs for RotoCom (bagging) composting system

Economics depends on many factors: amount of waste you treat; type of waste; moisture content in the waste; existing site you have; place with concrete or no, etc...

If talking only about machinery and equipment and handling closely related to Rotocom, then we will the following prices.

Assumption
Amount waste per year: 10 000 ton

Rotocom Machine: 1 200 000 SEK
Depreciation 7 years: 14%
Interest: 0,5x5=2,5%
Maintenance: 2,5%
Annual cost: ca 20%
Annual cost in SEK: 240 000 SEK
Cost per ton: 240 000/10 000=24 SEK/ton

Bag
Volume is ca 400 m³ (60 m length)
Cost: 9 000-10 000 SEK
Cost per m³: 18-25 SEK per m³ of material you put into the bag (if bulk-density of your mix is around 550-700 kg/m³)
Cost per ton: between 40-75 SEK/ton depending on type of the material for composting

Aeration
Cost of one fan: is ca 12 000-13 000 SEK (you need one fan per bag).
This is only timer-regulated aeration. You could also have temperature or oxygen regulation. Normally the retention time in the bag is 30-60 days for source-separated household waste (SSO), 21-30 days for sewage sludge (BIO). The retention time decides how many fans you will need.

Handling
Filling time for one bag is about 4 hours (it means 4 hours with a loader)
Emptying time is about 1-2 hours
Estimation of filling and emptying: 10-15 SEK per ton of the material.

ROUGH ESTIMATION OF COST PER TON: 75 – 125 SEK per ton of waste.

According to the cost estimations made by APIESSE s.r.l. in Italy, investment and treatment costs from RotoCom composting system are:
- the machine brand costs 90.000 Euro;
- a bag of Ø240 cm x 60 m costs about 300-500 Euro;
- fan costs 790 Euro (each one is with a power consumption of 1400 W and each one (one per bag) works at 50% of the composting time);
- it costs 16,5 Euro/meter for the operator to bag compost;
- it costs 12 Euro/ton of compost.
Appendix 9. Total process solution using Rotocom rotary composting system

The Rotocom system is specifically designed as a modular system, allowing installation of any number of rotary vessels with integrated shredding, mixing, screening systems and odour control systems from Andar.

Sludge Mixer: The Rotocom unit is unique in the pre-mixing stage. However the sludge mixer is recommended when combining separate waste streams such as household waste and bulking agent. The mixer helps ‘break open’ heavy sludges to aid the composting process and provide an immediate volume reduction. Due to the nature of the rotating drum, all other compostable material is mixed within the vessel during the process.

Shredders: They are required when green waste is composted to optimize particle size. Coarsely shredded green waste is an ideal bulking agent for a heavy sludge as this aids the aeration and mixing within the Rotocom.

Automated In-feed Systems: Recommended for feeding any blend of green waste, sawdust, biosolids, sludge and recycled material into the Rotocom. Automated bucket, auger or conveyor systems are available depending on the material composition.

Out-feed Conveyors: Recommended to automate the Rotocom system allowing large volumes of compost to be handled with low operator involvement.

Bio-filter: Required to process offensive odours. All process air is extracted from the vessels and processed through enclosed bio-filters where the volatile compounds are absorbed into the filter media and degraded. Depending on site-specific details, it is possible to use static maturation windrows as the bio-filter.

Scrubbers: Water and chemical scrubbers are recommended where space limitations or local conditions do not allow the use of bio-filters for removal of offensive odours. The scrubber produces a neutral aqueous effluent if chosen.

Screening: Recommended to remove oversized materials after the composting process. The use of two-stage screening allows fine compost to be separated and sold while the coarser material is recycled for moisture control and bulking agent.

Key process features
The Rotocom system incorporates mixing, shredding, in-feed, the rotary vessel(s) and a screening system, providing: continuous stable operation; corrosion resistance from stainless steel manufacture; self cleaning internal features; robust design due to automatic welding of the vessel shell; low mechanical stresses due to static internal features; mixing of material through the vessel; integrated temperature and humidity control systems; continuous air flow throughout the biomass to ensure aerobic activity; controlled flow of biomass through the system; the ability to handle a discontinuous feed rate regime; easy operation by one multi-task operator.
Appendix 10. Schematic flow chart for the upgrading of biogas to vehicle fuel in Västerås

The main characteristics of the upgrading plant are:

- Use of simple and proven water scrubber technique for the purifying of the biogas
- Surplus heat from the purification will be used in the biogas plant
- Expected to have high availability
- Advanced measurement and surveillance system for controlling the process and the gas quality
- Used process water is treated before it is led to recipient
- The outgoing air-gas mixture is treated in a chemical scrubber and in a bio filter in order to avoid odour problems
- The loss of methane in the process is guaranteed to be less than 2% and is expected to be less than 1%. Further reduction of the methane is presumed to occur in the bio filter

The main characteristics of the biogas system are:

- Fast filling of buses and refuse collection vehicles. Filling time less than five minutes
- Very high availability due to
  - double high pressure compressors with 100% redundancy
  - few critical components in the fuelling system
  - liquid natural gas as reserve in case of break down of gas production
  - big high pressure storage
  - possibility to fill up 40 buses without use of high pressure compressors
- A public filling station for cars and other small vehicles