PROJECT *"ISTEAC"*

Integration of solid waste management tools into specific settings of European and Asian Communities

Common Applied Research
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Project Documentation

related to

Activity 2b: Market research on composting technologies

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Index

1 Rationale

In the frame of its initial activities for the common applied research project ISTEAC and pursuant to the workplan concluded for it, the Institute for Waste Management and Contaminated Sites Treatment of Dresden University of Technology conducted a first general analysis on available technologies and general procedures for the composting of waste materials and their dispersion mainly within Germany. Part of this effort was the identification of relevant information sources and references that would allow for a broader and perhaps more thourough insight into the application of these technologies across Europe and to make examples of `good practice` known to the other partners joining this project. A clear perspective concerning the possible transfer and applicability of this knowledge under the special constraints of the Southeast Asian environment has been guiding the compliation of all these information.

The following document is providing the outcome of this initial effort.

2 Introduction

As population increases and urbanization continues to take place, the management of solid waste is becoming a major public health and environmental concern in urban areas.

Given the fact that composting always existed in the natural cycle it intuitively also makes sense to compost the organic fraction of the municipal solid waste stream. Composting is a natural process that simply recycles organic material back to the topsoil from where it is mined through typical agricultural practices. It provides several benefits: the process addresses more than half of a city’s waste stream; it reduces the need for waste deposits as one of the largest contributors to greenhouse gases; it enhances related recycling and incineration activities, and it can be relatively inexpensively organised and produce a beneficial product with a good marketing potential.

Therefore composting should be an important component within an integrated municipal waste management strategy. However, it can become part of a municipal waste management program only if adequate recognition is given to the need and costs associated with proper waste disposal because nothing is cheaper than not collecting solid waste.

In the developing countries where waste management in many cases and for various reasons has not been given sufficient attention in the past, problem realization is attaining momentum and endeavour is being made not only to develop the appropriate programmes but also to procure the knowledge and modern technology needed to cope with the ever growing discards from human activities and improve the overall waste management situation. Adequate knowledge of the state-of-the-art, the different technological options and impacts on and from their application are indispensable to get to the right solutions. The following chapters will therefore take a look at these subjects from the perspective of composting.

3 Composting

3.1 General requirements

The high organic content in the MSW stream of developing countries but also the climate in wet tropical countries is ideal for composting [1]. The raw materials which are most appropriate for composting include: vegetable and fruit waste; farm waste such as coconut husks and sugar cane waste; crop residues such as banana skins, corn stalks and husks; yard waste such as leaves, grass and trimmings; sawdust; bark; household kitchen waste; human excreta and animal manure. All of these organic materials are readily found in municipal solid waste generated in developing countries. Animal waste, such as carcasses and fish scraps, can be used as well but they are more likely to attract unwanted vermin and generate odours. Other organic matter such as wood, bones, green coconut shells, paper and leather decompose much slower and may hinder the composting process if used in excessive amounts.

However, the municipal waste stream also contains increasing quantities of glass, plastics, metals and hazardous materials which can contaminate the finished compost. These materials need to be separated from the organic fraction to prepare the feedstock for composting. That’s why a mechanical pre-treatment is usually preceding the stage of biological treatment and composting. Separating contaminants from the raw material at the compost site is however the more expensive option since it requires additional effort, space, and time, and it is likely that much of the contamination has already affected the organic fraction. Source separating the waste before collection is usually an environmentally and technically better way to improve the quality of the final compost.

Composting is an aerobic process that by definition requires oxygen. The consumption of oxygen is greatest during the early stages and gradually decreases as the process continues to maturity. Limiting the oxygen supply to the organic materials slows down the composting process, creating anaerobic conditions and potential odours. Different anaerobic reactions by microorganisms form intermediate decomposition compounds such as methane, hydrogen sulfide, and organic acids. Physically turning the compost or providing forced aeration maintains aerobic conditions and limits odours.

A C/N ratio ranging from 25/1 to 30/1 is described as the optimum for a fast composting process, but higher ratios up to 40/1 may be possible. Overleads of nitrogen in the input material must be avoided since almost the entire nitrogen fixed in the organic material is going to be released as ammonium thru micro-biological activities. High concentrations of ammonium at a pH>7 can cause the emission of ammonia. The optimum C/N ratio can be attained by combining various organic wastes. For example, leaves (high in carbon, low in nitrogen) can be blended with food waste (high in nitrogen) to balance the C/N ratio. In this way, emissions of ammonia can be minimized right from the beginning of the rotting.

Porosity, structure, texture, and particle size all influence the composting process. Porosity is a measure of the air spaces within the pile and affects airflow; structure refers to the rigidity of the particles and the ability to prevent settling and compaction; and texture describes the available surface area for microbial activity.

The optimum particle size is dependent upon the raw material, although a smaller particle size will increase the rate of aerobic decomposition since the available surface area is increased. Depending on the composition of the raw material, size reduction can be achieved by manual and mechanical methods such as screening, grinding, or chopping. Typical particle sizes should be approximately 1 cm for forced aeration composting and 5 cm for passive aeration and windrow composting [1]. Bulking agents can be added to the raw material if it lacks the structure to maintain adequate porosity within the compost pile. Such can be wood chips, recycled compost, peat moss, corncobs, crop residues, bark, leaves, shellfish shells, waste paper.

The porosity of the raw material affects the air flow within the windrow. Dense materials, such as manure, require smaller windrows to minimize anaerobic zones, whereas more porous and lighter materials, such as leaves, can be built into larger windrows. Also moisture content varies with the particle size and physical characteristics of the raw materials; the moisture content for composting should be at least 40 %, preferably between 50 and 60 % and the pH approximately 7. A low moisture content, usually below 40 percent, will slow the composting process whereas a high moisture content, usually above 65 %, will restrict air movement through the pore spaces and result in anaerobic conditions. Excess leachate may also be produced if the moisture content is too high. Moisture levels should be maintained so that materials are thoroughly wetted without being waterlogged.

A balance needs to be achieved between proper aeration and temperature requirements since small windrows tend to dissipate heat quickly and may not reach adequate temperatures to kill pathogens and weed seeds [1]. That’s why the entire quantity of the biodegradable waste shall be mixed in the course of the composting process and exposed to a temperature of:

- 55 °C as a minimum for at least two weeks; or
- 65 °C as a minimum for at least one week (60 °C in case of in-vessel composting).

[2]

Mature compost should meet the following parameters to ensure that it is stable:

- should have a C/N ratio of less than 22 to be safe for agricultural use
- should not re-heat over 20 °C upon standing
- should reduce volume of raw organic material by at least 60 percent

[1]

3.2 Technological solutions for compost production and their worldwide application

3.2.1 General approach

Given the various requirements to generate a good compost product from domestic waste various solutions using different process design and technical installations have been developed and are currently in use worldwide. Engineering sophisticated and highly efficient technical process schemes is becoming increasingly important before the background of ever growing legislative requirements and demands in the waste management sector.

Main objective of the mechanical pre-treatment which usually precedes composting is the creation of optimum conditions for the microorganisms. This includes:

- breaking up larger components to increase the surface area exposed to the microbiological activities;
- mixing the material of different composition, size and texture to obtain the optimum water content and structure for the decomposition processes.

Mechanical treatment and conditioning, either before or after the composting also includes the removal of disturbing components, especially metals. Depending on the composition of the input, the desired level of material separation and applied composting technology there can be one or several stages for screening, comminution, material separation and homogenization using combinations of technical appliances with various features and design.

Mechanical conditioning of the waste input, in principle, comprise the following steps:

- sorting of recyclables, pollutants and disturbing impurities

The various means of sorting differ according to the recovery targets set and costs. Manual sorting is a very reliable method of systematically separating substances/material of good quality from a batch of mixed waste. Sorting can be facilitated by such simple mechanical means as sieves and sorting conveyors. There is also a wide variety of technical equipment that is geared specifically to the properties of the targeted type of material. Such equipment includes everything from screening drums, to magnetic separators for use in recovering ferrous metals.

- comminution/disintegration

Whether or not waste comminution will be necessary or expedient depends very much on the characteristics of the waste material and on the nature of the downstream biological treatment process. Various types of mills and crushers with different comminuting effects and throughput rates are available on the market. Which type of comminutor is used depends on the type of waste involved and on the equipment's size reduction function within the overall concept of mechanical conditioning. Selection criteria include trouble-proneness and throughput rate.

- homogenization and moisture adjustment

Homogenization becomes especially necessary when waste inputs from different sources and of largely different size are to be used for composting together. Often a wheel loader or a mixing drum are used for homogenization. In many cases the necessary homogenization of the feedstock material for composting is achieved in the course of shredding and screening processes with rotating aggregates already.

For the biological treatment or composting process the options take a broad range of processes that differ primarily by reason of

- the employed aeration and turning techniques
- the duration of the rotting
- the degree of containment, including collection and treatment of emissions.

The choice of which process to use depends on the objectives of waste treatment and various local boundary conditions, e.g., the waste incidence and composition, climatic conditions, and emission control requirements.

With regard to the first two criteria, one can roughly distinguish between open forms and enclosed systems for composting with either passive or active aeration. Open forms of composting though being more time-intensive and sensitive to externalities are generally more attractive since they are much more inexpensive than using enclosed systems. This aspect and the fact that open composting is well suited to the climatic conditions in Southeast Asia make this a preferable option for countries such as Vietnam and The Philippines.

The most widely applied composting technologies are briefly described hereafter.

3.2.2 Windrow Composting

Windrow composting is a simple and versatile method where organic matter is built into long, narrow piles and physically turned either on a regular basis or when required based on temperature and oxygen requirements. The size, shape, and spacing of the windrows depend on various factors, such can be the composition of the input material, available space and equipment used for turning. Regular turning of the windrows helps oxygenate the pile; breaks up particles to increase surface area; improves the porosity to prevent settling and compaction; and allows trapped heat, water vapour, and gases to escape. Turning schedules differ in dependence from the rate of decomposition, moisture content, porosity of the material, and the desired composting time. However, turning the compost can be labour intensive or require expensive equipment. Most common is the use of special turning machines (compost turner) fitted to or independently of the shape of the windrow or turning without specialised equipment, for example with the help of wheel loaders. Bucket or wheel loaders are normally used to build high windrows whereas turning machines create low and wide windrows.

Windrows are typically used for large volumes which can require a lot of space. In addition, windrows can have odour problems and leachate concerns if exposed to rainfall.

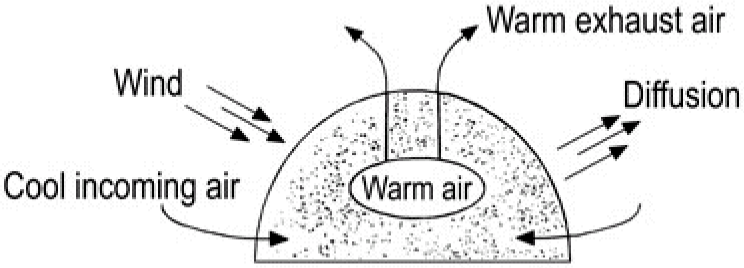
Covering the windrows with a water-proof layer or semipermeable foil (e.g. GoreTex®) became thus a proven strategy in areas facing extreme climatic conditions.

Source: Internet [7]

3.2.2.1 Passively Aerated Static Windrow or Pile

This method is very similar to windrow composting except that turning is not required for aeration. Air is supplied to the organic material through perforated pipes embedded in the pile. Even more simple are stationary rotting heaps with passive aeration. Here the waste is dumped in loose piles on a separate surface. In either case the organic material is thoroughly mixed before being place on top of a porous base to ensure proper air distribution and prevent uneven composting. Both windrow and heaps are passively aerated in exploitation of the waste's self-generated heat of biodegradation. Ventilating elements (e.g., drain pipes) inside allow the air to take on heat, ascend, and draw fresh air in behind it (chimney effect). The warm gases rising out of the heap or windrow causes air to flow through the pipes and the rotting waste. The rotting time amounts to between 4 and 12 months, and the specific space requirement ranges between about 0.5 and 1 $m^2/Mg*a$.

Passive composting or piling is simple and low cost but is very slow and may result in objectionable odours.



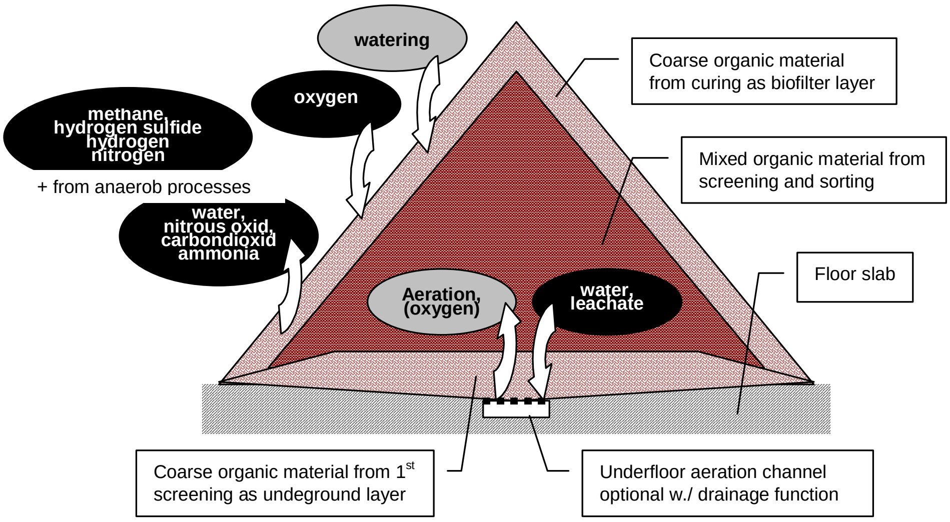
3.2.2.2 Aerated Windrow or Pile

The aerated static pile method combines techniques from passive aerated windrows with more advanced technology. This method also builds the material into a pile on top of a porous base and then covers it with a layer of peat or compost. Air is introduced to the stacked pile via perforated pipes and blowers. Bulking agents and amendments are used to create good structure and maintain porosity. Pile heights can vary from 1.5 to 2.5 meters depending on the aeration system used. This method requires no labour to turn compost but is weather sensitive, and can have unreliable pathogen reduction due to imperfect mixing. Good initial mixing of the organic is therefore required to prevent air channeling and anaerobic areas in the pile.

Source: Internet [7]

To avoid such negative effects right from the beginning, shorten the whole rotting process and obtain better control over it, windrows are usually turned either in regular intervals or in dependence from the control measurements. In addition, special constructive arrangements and technical installations can support the operations in large scale applications and facilitate emission control and process management thru necessary supplies with oxygen and water. The aeration system is usually operated by a programmed timer or a temperature sensor which can adjust the airflow rates to produce the desired temperature profile. Timers tend to be a simple way to regulate the airflow, but they do not maintain optimum process temperatures. Temperature sensors are better for controlling the composting system; however this method requires greater airflow rates, larger blowers, higher costs and an overall more sophisticated control system.

Recommended structure of a triangular compost windrow in response to the in-/outflow processes during the rotting phase



3.2.3 In-Vessel Composting

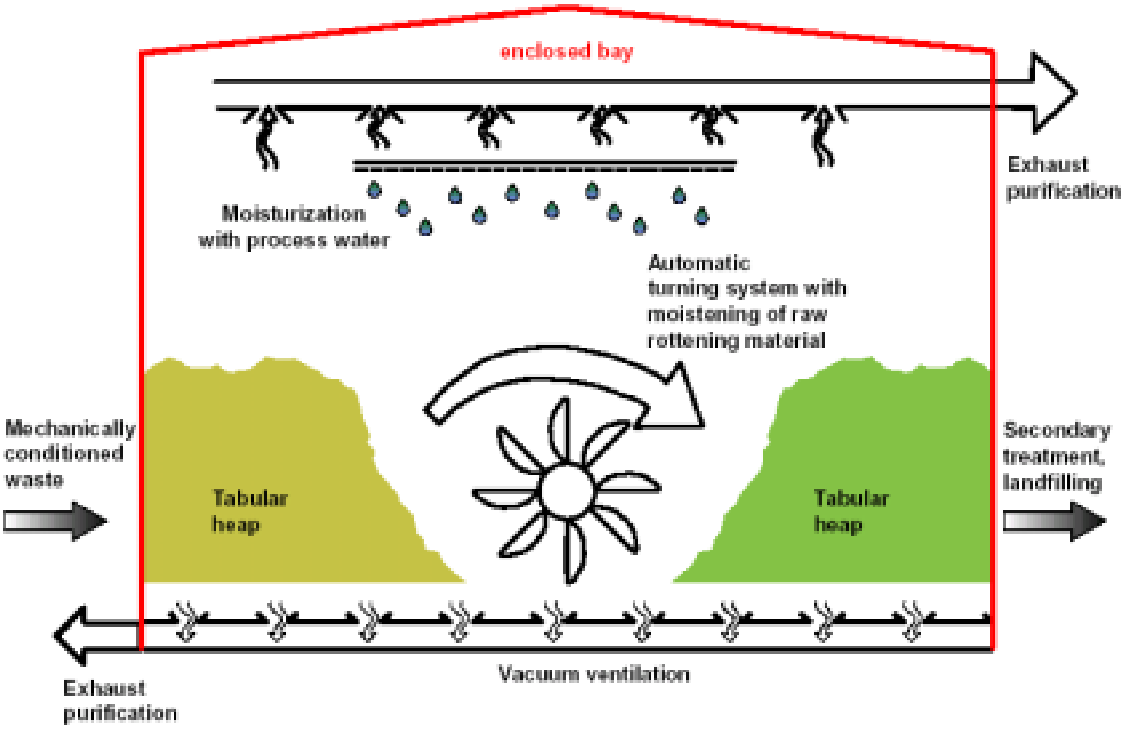
In-vessel composting means the composting of biodegradable waste in a closed reactor with minimised thermal exchange with the atmosphere and relies on various methods of aeration and mechanical turning to control the process. These mechanical systems are designed to minimize odours and process time by controlling airflow, temperature, and oxygen concentration. These systems can be divided into two major categories: plug flow and dynamic. A plug flow system operates on the first-in, first-out principle, whereas a dynamic system mixes the material mechanically throughout the process. Box composting and silos are representative of plug flow systems, while rectangular agitated beds and rotating drums which are characteristic of dynamic systems. The initial investment can be high and handling volumes are typically lower than in windrow composting systems.

In-vessel systems using perforated barrels, drums, or specially manufactured containers are simple to use, easy to turn, require minimal labour, are not weather sensitive, and can be used in urban and public areas.

Source: Internet [7]

In rotting bays the advantages of a closed system are combined with windrow composting. In fully automated rotting bays, the organic materials are piled into tabular heaps, force-ventilated, and automatically turned by a turning unit. During the turning process, the material is watered as necessary. The exhaust from the heap is collected and treated in a so-called closed system. In the course of rotting, the waste therefore "wanders" from the input end to the output end of the bay. From there, it is forwarded to curing in order to become a mature compost or get re-composted.

Source: Self made photo; Bay composting w/. turning system Wendelin



Source: GTZ [4]

The specific space requirement for intensive processes amounts to about 0.2–0.3 m²/Mg*a. Closed systems make it possible to collect gaseous emissions, odors and particulates. The active aeration, watering and mixing functions enable control and optimization of the rotting process, thus considerably accelerating the main biodegradation phase. The rotting period for this kind of process lasts only 2 to 5 weeks, plus 7 to 26 weeks of secondary rotting [4].

3.2.4 Vermicomposting

Vermicomposting, also known as vermiculture, is a simple technology using the natural digestion process of red-worms and earthworms to break down organic material. From the moment it hatches, a worm can consume daily its body weight in organic matter. The waste is continuously turned and mixed as the worms burrow through the medium. Vermicomposting is applied largely on a small-scale level only.

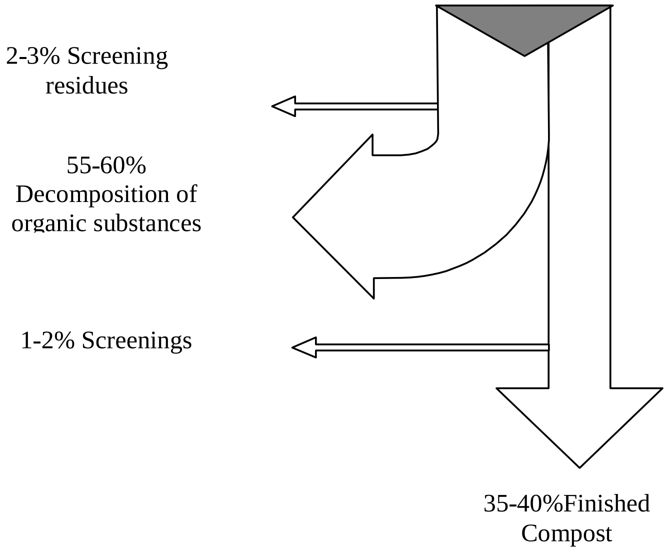
3.3 Effectiveness of composting

Each of aforementioned methods aim at the aerobic decomposition of biodegradable waste under controlled conditions and its reconstitution into humus by the action of micro- and macroorganisms, involving bonding of as much as possible nitrogen onto carbon molecules, fixing proteins and carbohydrates in forms readily available to plants in order to produce compost. The arrangements are made to ensure a thermophilic temperature range, a high level of biological activity under favourable conditions with regard to humidity and nutrients as well as an optimum structure and air perfusion over a period of several weeks.

Due to the aerobic disintegration of the biodegradable substances and decomposition of large parts into carbondioxid and water a significant reduction in mass and volume of the input material takes place. The aerobic decomposition generates 0.6-0.8 g water and 25.1 kJ thermal energy per gram of organic matter. This amount of energy is enough to vaporise 10.2 g of water, i.e. 13 to 17 times more water than the process generated. The water content of the input therefore decreases considerably. The organic content, measured by ignition loss, can be reduced by more than a half, i.e. the value of 60-65 % ignition loss in the collected domestic waste goes down to 25-30 % after the rotting process [3]. The corresponding mass reduction of the input normally ranges from 40 to 60 %, the reduction by volume ranges between 50 and 70 %.

Seen in combination with the mechanical pre-treatment and separation processes the following overall mass balance can be drawn for the composting of biowaste.

Mass Balance of Bio-waste Composting Process



A separate collection of biodegradable waste to generate the feedstock for composting significantly improves the overall handling of the process, result in a higher safety from damages on the equipment and operational break downs as well as with regard to the quality of the final compost product while at the same time reducing the technical input for pre-treatment. Investigations all over the world showed that composting of source separated biodegradable material ensures the quality and composition of the end product to be more consistent and environmentally benign. What is of particular importance is that carrier substances of hazardous material and heavy metals such as electronic components, composites or batteries can be largely excluded in this way from reaching the composting site or contaminating the organic fraction in the course of collecting, transporting or during the processing of the waste. It is however impossible to remove harmful organic substances and most of the heavy metals from the input by technical means during the mechanical conditioning and treatment.

Batteries may deserve a particular mention in this respect due to the fact that

- the amounts to be found in the MSW from Asian countries are likely to be higher than that in western European countries where separate collection systems are widely introduced and people are generally connected to electric supply networks,
- the proposed treatment scheme does not allow to separate them from the input stream by the means of technical equipment and
- their content on mercury and cadmium can critically contribute to heavy metal concentrations in the compost product.

Heavy metals are present as soluble or non-soluble anorganic salts or organically fixed. Opposite to disturbing materials which retain an inert character, they are included into the transformation process and can be directly incorporated into biomass or become part of the end product in metabolised form. In support of this assessment the following table shall be presented. It shows indicative heavy metal concentrations in different MSW composts and demonstrates that source separated municipal wastes produce a higher quality end product compared to non-source separated municipal solid waste.

Table 1: Concentration of heavy metals in different composts

Heavy metal	Source separated MSW compost Europe and North America	Source separated MSW compost Java Indonesia	Non-source separated SWM compost Netherlands	**Proposed Standards for Developing countries**
Arsenic	0	5	0	**10**
Cadmium	1.2	9.0	7.3	**3**
Chromium	27	20.0	164.0	**50**
Copper	15	54.0	608.0	**80**
Lead	86	99.0	835.0	**150**
Mercury	0.9	0.9	2.9	**1**
Nickel	17.0	50.0	173.0	**50**
Zinc	287.0	236.0	1567.0	**300**

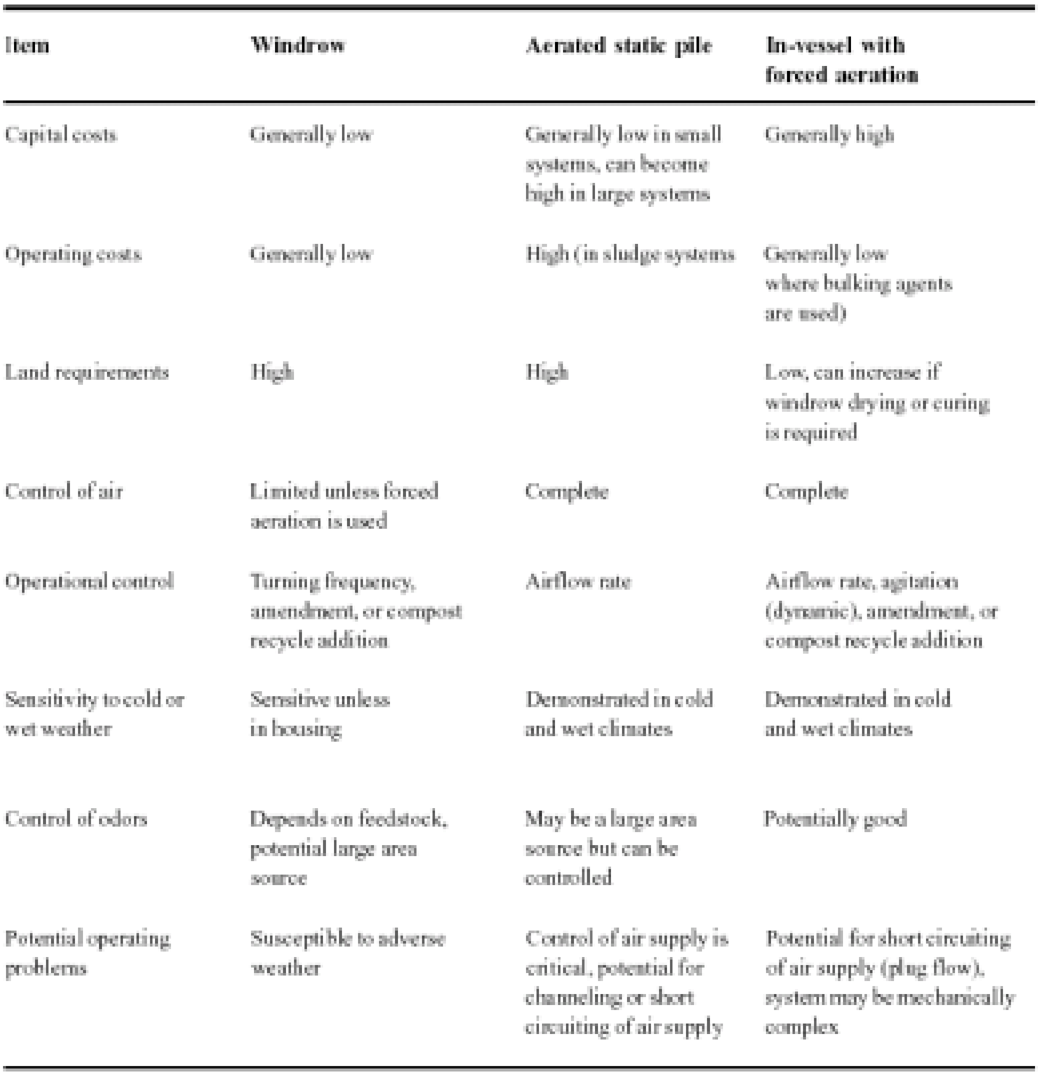
(World Bank, 1997a)

Introducing a separate collection of biowaste in developing countries can be feasible and successfully realised with a proper preparation and appropriate measures for the early information of all parties involved. Thereby it has to be clear that the separate collection of biowaste in countries with tropical climate and yet less developed infrastructure always poses a particular challenge with regard to collection organisation and logistics.

3.4 Selecting the appropriate process

The following table provides an overview on the comparative advantages and disadvantages of the different composting technologies based on various criteria. It clearly indicates that under the general conditions and constraints which can be assumed for countries in Southeast Asian windrow composting in combination with certain constructive measures to minimise unfavourable influences by the weather represents one preferable option.

Table 2: Comparative overview on main composting technologies



Item	Windrow	Aerated static pile	In-vessel with forced aeration
Capital costs	Generally low	Generally low in small systems, can become high in large systems	Generally high
Operating costs	Generally low	High (in sludge systems	Generally low where bulking agents are used)
Land requirements	High	High	Low, can increase if windrow drying or curing is required
Control of air	Limited unless forced aeration is used	Complete	Complete
Operational control	Turning frequency, amendment, or compost recycle addition	Airflow rate	Airflow rate, agitation (dynamic), amendment, or compost recycle addition
Sensitivity to cold or wet weather	Sensitive unless in housing	Demonstrated in cold and wet climates	Demonstrated in cold and wet climates
Control of odors	Depends on feedstock, potential large area source	May be a large area source but can be controlled	Potentially good
Potential operating problems	Susceptible to adverse weather	Control of air supply is critical, potential for channeling or short circuiting of air supply	Potential for short circuiting of air supply (plug flow), system may be mechanically complex

Source: [1]

Which composting system is the most appropriate nevertheless has to be decided based on its technological feasibility, economic costs, and social and environmental impacts within the given environment. Composting is site specific.

3.5 Impacts of Composting

3.5.1 Environmental impact of composting

Even though organic decomposition is a natural process, all forms of waste treatment involve some amount of emissions due to the composition and properties of collected domestic waste and mechanical work undertaken. The nature and the extent of those emissions are heavily dependent on both the chosen process and the local boundary conditions. Notwithstanding there are health and safety issues for workers and neighbouring residents that need to be addressed. Establishing compost standards and taking precautions in the facility design and operations should assist in the mitigation of any negative health and safety impacts

The most important kinds of emissions and suggestions on how to limit them are dealt with hereafter:

- Liquid effluent

Liquid effluent, i.e., wastewater in form of leachate and press water, is produced in the course of the treatment. Leachate is created when water percolates through the waste and biological and chemical constituents from the waste is brought into solution. Composting of organic enriched, wet domestic waste is likely to produce leachate, potentially high in BOD and phenols, which should not be discharged into water bodies nor allowed to infiltrate into the soil to avoid water contamination. The receiving point in the area in which mechanical conditioning takes place should preferably be paved. Collecting and re-circulating the leachate into active compost piles will mitigate any environmental impacts while at the same time enhance the compost process (the composting process is usually a net-water user). Otherwise the leachate must be treated and disposed of.

- Odours and germs

Odorous emissions are unavoidable for extensive treatment processes. As soon as compost heaps no longer receive an adequate supply of oxygen, the odour nuisance worsens. For a simple heap-rotting process, odour and gas emissions can be reduced by covering the heaps with screened, pretreated waste. Especially during the handling of waste, germs contained within can escape to the surrounding environment. For the personnel involved in operations at the receiving point and sorting, exposure to the germs can amount to a health hazard, but the pathogens would have no effect at any substantial distance. Concerned personnel should be given personal protection equipment, i.e. respiratory mask, protection gloves. A well operated composting facilities should produce minimal objectionable odours, however.

- Noise

The operation of comminuting, screening, handling and ventilating equipment can involve substantial noise annoyance, especially for the operating personnel and for people living nearby. Appropriate measures for the protection of personnel (i.e. personal protection equipment where necessary) and noise reduction must hence be undertaken.

From an overall perspective, the impacts related to composting can be summarised in following points:

Benefits

- Increases overall waste diversion from final disposal, especially since as much as 80% of the waste stream in low- and middle- income countries is compostable.
- Enhances recycling and incineration operations by removing organic matter from the waste stream.
- Produces a valuable soil amendment—integral to sustainable agriculture.
- Promotes environmentally sound practices, such as the reduction of methane generation at landfills.
- Enhances the effectiveness of fertilizer application.
- Can reduce waste transportation requirements.
- Addresses significant health effects resulting from organic waste, such as reducing sources for excessive reproduction of insects and animals that may carry infections.
- Provides an excellent opportunity to improve a city’s overall waste collection.
- Accommodates seasonal waste fluctuations, such as leaves and crop residue.
- Can integrate existing informal sectors involved in the collection, separation and recycling of wastes.

Constraints on Composting

- Inadequate attention to the biological process requirements.
- Over-emphasis placed on mechanized processes.
- Poor feedstock which yields poor quality finished compost, for example heavy metal contamination.
- Lack of vision and poor marketing for the final compost product.
  (The issue of compost marketing is not so much finding a use for the finished compost but rather finding cost-effective applications. The history of many failed composting projects can be attributed to poor marketing strategies and inadequate attention to long-term financing.)
- Difficulties in securing finances and overall accounting practices which neglect that the economics of composting also rely on externalities.
  (Composting rarely generates profits on its own. However, when viewed as a component of an integrated solid waste management program, composting can provide economic benefits on a much larger scale. The costs of composting includes raw materials, production, marketing, and hidden environmental costs; whereas the benefits involve the market value of the compost, savings from avoided waste disposal costs, as well as various positive environmental impacts.)
- Sensible preoccupation by municipal authorities to first concentrate on providing adequate waste collection.
- Inadequate pathogen and weed seed suppression.
- Nuisance potential, such as odours and rodents.

- Perverse incentives such as fertilizer subsidies or over-emphasis on more capital intensive projects.
- Land requirements though being often minimal can be a constraint.

4 Dispersion of composting and other methods for organic waste treatment

4.1 Situation in Germany

4.1.1 Organic waste treatment

In Germany, source separation of organic residues from households, gardens and parks (= biowaste) is one of the main measures in waste management. For the moment 7 to 8 million tons are collected separately. The whole potential of organic raw material amounts up to 9 million tons. Today, the participation in source separation of biowaste is up to 60 - 75 % (2001) of all the inhabitants, depending on the region. It is not 100 % because only 80 % of the German municipalities decided to establish separate biowaste collection.

Composting

Between 1990 and 2001 the number of composting plants in Germany amounts to approx. 700 - 900. These 700 to 900 composting plants are producing approx. 4 million tons of compost products.

In early 1998 a survey representing some 535 composting plants in Germany (only plants with a capacity bigger than 1,000 tons per year were considered) presented a total capacity for native-organic material of some 7.1 million tons per year. This means an increase of more than 50 % within two years. The plant's throughput ranges from 1,000 to about 100,000 Mg per year, with the majority operating in a range of 20,000 Mg/a and below. Almost 80 percent of the received input is separately collected material of organic nature. An interesting aspect is the difference in technology and capacity in West and East Germany (former German Democratic Republic). While 75 % of the composting capacity in East Germany is offered in simple windrow technology, two thirds of the capacity in West Germany are in-vesseled plants. [5]

The methods currently applied for composting in Germany can be grouped into the following categories:

- Under roof or open windrow composting (mainly triangle- or trapezoid-shaped)
  Windrows are set up with a height between 1.80 to 3.00 m depending on the shape. About 10-16 weeks are needed for the entire rotting process. Special compost turners or wheel loaders are used for turning.
  61 % of the surveyed plants in Germany make use of this technology, covering about 50 % of the total mass of 7.1 million Mg treated annually. Another 15 % of the plants, making up 1.4 million Mg or 20 % of total mass do composting in tabular-shaped windrows
- Box- or container composting
  Boxes or containers which totally encapsulate the organic material are used for the rotting. Comprehensive supply systems and control equipment integrated into the

boxes allow for a controlled process with the help of aeration, moisturizing and even heating.

About 11 % of the plants surveyed do composting in box or container systems giving a total capacity of approx. 800,000 Mg or 11 % of total mass.

- Line- or tunnel composting
  The intensive rotting phase takes place in a totally enclosed tunnel with an active aeration and normally takes about 10 days. Turning of the compost material is done by a fully automated turner aggregate.

  Line- or tunnel composting is performed by about 4 % of the plants reaching a total capacity of 450,000 Mg (6.4 % of total mass).
- In-vessel or drum composting
  3 % of the plants in Germany with a total capacity of 217,000 Mg (3 % of total mass) use in-vessel or drum technology for the composting.
- Other technologies, such as bricollar-composting

The growth rate of composting plants decreased during the last years on account of a considerable stagnation of source separated biowastes. Changes in waste disposal systems and fees are responsible for the stagnation.

Around 70 % of the German composting (440 in 2001) did join in the voluntary quality assurance system for compost and digestion residuals of the German Compost Quality Assurance Organisation BGK. These are the large and centralised plants and they show 70 - 80 % of the total capacity (Kehres, 2000)

Anaerobic digestion

The number of anaerobic digestion plants lies between 500 and 800, most of these anaerobic digestion plants use agricultural waste like manure, only a few (more than 100) co-digest biowaste. Around 37 large industrial digestion plants treat pure biowaste, in total around 500.000 t, 20 of them are member of the voluntary quality assurance system of the Quality Assurance Organisation BGK.

Biological-mechanical Pre-treatment

In order to save landfilling capacity and to meet the requirements of the TA Siedlungsabfall (max. 5 % organics in waste for landfilling) more and more plants are built in Germany to reduce the organic content in the residual waste with pre-treatment composting or digestion technologies. In 2001 around 47 pre-treatment plants process 2,4 Mio. t and several more are under construction.

4.1.2 Legal framework for the organic waste stream and compost production

Biowaste ordinance

Biowaste Ordinance (BioAbfV) from 1998 covers the application treated and untreated bio-wastes and mixtures that are applied on land used for agricultural, silvicultural and horticultural purposes as well as suitable raw material, quality and hygiene requirements, treatment and investigations of such bio-wastes and mixtures. Suitable raw material are mentioned in annex 1, heavy metal contents, harmful substances, hygiene aspects in annex 2 and sample taking and analysis in annex 3.

The Biowaste Ordinance regulates - with a precautious intention - the waste side (e.g. heavy metals) of the application, where as the Fertiliser Law regulates the nutrient part.

Voluntary Standards RAL Quality Assurance System

On account of the very bad mixed waste compost image in the late eighties the German recycling industry started a quality initiative in composting which led to the foundation of the German Compost Quality Assurance Organisation (Bundesgütegemeinschaft Kompost BGK) in 1989. In 1991 a quality standard, a quality label and the RAL quality monitoring system for the composting of source separated organic residues from households and gardens was established. This BGK organisation is the carrier of the RAL compost quality label. It is recognised by the RAL, the German Institute for Quality Assurance and Certification as being the organisation to handle monitoring and controlling of the quality of compost in Germany. In 2000 an additional quality assurance system for digestion residuals was introduced.

Quality assurance system for compost RAL- GZ 251

The standard RAL-GZ 251 contains regulations of the German Compost Quality Assurance Organisation BGK concerning quality criteria and the quality assurance of compost. This is a private, voluntary agreement for a quality assurance system of the composting industry. Several of the RAL-GZ 251 aspects can be found in the a.m. laws and regulations.

Quality assurance system for digestion products RAL- GZ 256/1

Since August 2000 the standard RAL-GZ 256/1 contains regulations of the German Compost Quality Assurance Organisation BGK concerning quality criteria and the quality assurance of solid and liquid digestion residuals. This is a private, voluntary agreement of the anaerobic digestion industry.

Together with the new Biowaste Ordinance (BioAbfV) of October 1998 a multitude of obligations on a proof of investigation and validation has been introduced which are to be executed by the compost plants. The long-standing activities of the BGK for the standardisation, monitoring and declaration of high quality humus products lead to an acknowledgement of these measurements by the law maker as “self obligation of the industry”. In addition the law making body implicates that the biowaste which is under continuous monitoring by and independent organisation is not a product but “likely a product”. So members of the Quality Assurance Organisation which render themselves subject to a voluntary quality monitoring are widely exempted from a control (max. 12 instead of max. 24 analysis/year) and from proof obligation by regional authorities as laid down by the Biowaste Ordinance.

4.2 Situation in Greece

4.2.1 Organic waste treatment

Solid Waste Management in Greece has been remarkably upgraded during the last five years. While it was, generally, considered as a major problem, now it is increasingly becoming a well-organised and environmentally responsible activity with specific goals, at least in the urban area and in large parts of the rural area. A significant improvement can be measured to facility development, collection and recycling. At the same time, it is obvious that management of MSW in Greece has to be further improved and, most important, greatly transformed in order to achieve EC goals.

When it comes to composting, the current situation can be summed up as follows:

- no sorting schemes are in place for the organic fraction of MSW, so therefore no facility is currently producing quality compost;
- big facilities are operating to compost mixed MSW;
- as a consequence, to date standards on compost quality refer to mixed MSW compost.

The very low charges for disposal reduce the financial feasibility of other options such as recycling and composting.

The overall production of MSW in Greece is estimated around 4.000.000 tons for the year 2000. Until 1994 waste disposal was characterised by the thousands of dumpsites (4850 were recorded officially), 70% of which were uncontrolled (corresponding to 35% of the total waste quantities). The proportion of the population served by regular collection system was around 70%, while in numerous small islands and isolated villages collection was poorly organised.

Recycling activities were relatively developed with remarkable results, mainly due to private sector efforts, providing a separate collection rate of 5,96 (To my knowledge the informal sector recycles about 30% of packaging waste and the official numbers for recycling paper-metals-glass-plastics is 7.88%. 0.81% of the mixed waste is composted at the Kalamata plant)%. Regarding MSW composition some difficulties have been faced in monitoring the time variations due to seasonal different MSW productions.

According to the consulted sources there is no specific national policy in Greece regarding collection and treatment of organic waste but there is a regulation about compost application.

Composting plants

Up to now, there is only one composting plant in operation, in the city of Kalamata in Peloponese. This treats mixed MSW (i.e. there are processes for mechanical separation of MSW and tunnel composting of the organic fraction). The capacity of the plant is 31500 t/a. The mechanical separation in early process steps, combined with the refining step may give a fairly acceptable material in terms of impurities, and tests have shown the heavy metal content to be well below the Greek limits.

A new large plant is being built in Athens and will soon go into operation. It will also treat mixed MSW (mechanically separated) and it will include a DANO type drum, and tunnel composting. Its daily capacity will be 1200 tons MSW. To this will be added 300 tons primary sludge from Psytalia treatment works and 130 tons of shredded green waste. This results in an input of 1000 tons per day of organic materials to the composting unit and final production of 500 tons compost daily, after refining.

There are no facilities processing source separated organic waste as yet, although it would be fairly easy to do as green waste is collected separately anyway. Some municipalities have thought of doing this, but they have not been able to secure funding as yet.

In the next 5-10 years several composting facilities for mixed MSW and sludge will be funded (to a large extent by EU subsidies the 3rd Community Support Framework) and possibly some for green waste. Source separation of MSW is not foreseen to occur on a wide scale, though some pilot-scale projects might start in the same period. At present, there is no feeling that standards are to change or to be completed with limit values for high-grade compost to be used as products, unless EU legislation requires this. First of all this will be the EU landfill directive and secondly the EU Biowaste Directive, depending on the date when it will come into force

4.3 Situation elsewhere in Europe and the world

The application of the various composting methods differ mainly in the time span for the stage of intensive rotting and the targeted maturity of the compost product. Intensive rotting aims either to a matured compost whereas main rotting and curing phase are integrated into one process or it ends up with a stabilised fresh compost which need to be forwarded to additional curing to reach a mature state. In terms of applied technology there is not much difference in the curing stage. Almost all plants use triangle or trapezoid-shaped windrows for that.

Intensive rotting processes are characterized by substantial outlays for machinery and control technology, both for the rotting process itself and for emission control purposes.

Across Europe, stringent emission control laws and regulations for the technical constructions and operations are in force in favour of intensive processes. Since the biological treatment stage is very cost-intensive, the mechanical conditioning stage normally involves substantial material and work inputs for separating the incoming waste according to various recycling options and forms of treatment (material-flow steering). In general, only the high-organic fractions of the incoming waste are put through a biological treatment stage in covered bays, drums, tunnels, containers, etc.

Extensive industrial and semi-industrial composting of waste material from various sources is also known from Canada, the United States and the UK.

Developing countries should exercise caution if applying industrialized country compost standards because these measures are site specific and may be inappropriate. The World Bank in 1997 has recommended compost standards for Indonesia which could be applied to other developing countries as well. Heavy metal standards may not be needed if the compost is going to be used in non-agricultural land uses, e.g., rehabilitation of mine sites or landfill cover. However, it is prudent to design a waste management system that has the potential to produce good quality compost with unlimited marketing potential. With proper attention to source separation and compost process control, these standards can readily be achieved with current technologies.

Table 3: Global compost standards as of April 1996

Country	**As**	**Cd**	**Cr**	**Cu** **(mg/kg dried matter)**	**Pb**	**Hg**	**Ni**	**Zn**
USA(S)	41	39	1200	1500	300	17	420	2800
Canada (MO)	13	2.6	210	128	83	0.83	32	315
Ontario (SSMO)	10	3	50	60	150	0.15	60	500
Austria (MO)	--	4	150	400	500	4	100	1000
Belgium (SSMO)	--	1	70	90	120	0.7	20	280
Denmark -	--	1.2	--	--	120	1.2	45	--
France (MO)	--	8	--	--	800	8	200	--
Germany*	--	1.5	100	100	150	1	50	400
Switzerland	--	3	150	150	150	3	50	--
Spain	--	40	750	1750	1200	25	400	4000
Indonesia (proposed)	10	3	50	80	150	1	50	300

(S) refers to sewage sludge, (MO) refers to mixed organics, (SSMO) refers to source-separated mixed organics, (proposed) refers to standards proposed by the World Bank-suggested for all developing countries as a good starting point. (World Bank, 1997a).

*Guideline of the Federal Association for Compost Quality in Germany (Bundesgütegemeinschaft Kompost)

5 Relevant resources identified

Our search for useful information sources led us to a number of very interesting links and publications. As one of the main information source identified as being relevant to this project also due to its worldwide accessibility we found www.compostnetwork.info . Large parts presented under chapter 4 of this document, specifically those concerning the legislative framework and general situation of organic waste treatment in Greece and Germany, have been obtained from this reference.

Further to this, we can recommend the consultation of the following sources:

Internet:	
http://europa.eu.int/comm/environment/waste/compost/index.htm http://europa.eu.int/comm/environment/waste/publications/compost_el.pdf (Greek version of a case study document on composting)	
Organisations	
Greece	*Germany*
Harokopio University Dr Katia Lasaridi 70 El. Venizelou GR 176 71 Kallithea, Athens, Greece E-mail: klasaridi@hua.gr	**Bundesgütegemeinschaft Kompost e.V. (BGK)** Wilhelm-Jakob-von-der-Wettern Str. 25 51149 Köln-Gremberghoven EMail: info@bgkev.de **Bauhaus-Universität Weimar** Abfallwirtschaft, Prof. Dr. W. Bidlingmaier Coudraystr. 7 D-99423 Weimar, Germany EMail:waste@bauing.uni-weimar.de Internet: www.bionet.net

as well as the references cited in the different sections of this document.

[1] Hoornweg et.al., (2000): Composting and Its Applicability in Developing Countries. Waste Management Working Paper Series 8 published by World Bank

[2] European Commission, (2000): Biological treatment of biodegradable waste. Working document of DG ENV, E.3 Waste Management as basis for the elaboration of the technical ordinance on biological waste treatment.

[3] INTECUS, Universität GhK (2001): Untersuchungen zu den Auswirkungen einer mechanisch-biologischen Abfallbehandlung (MBA) auf die Errichtung und den Betrieb einer Deponie in Al-Salamieh/Syrien hinsichtlich ökonomischer und ökologischer Kriterien

[4] Kebekus, Drees, Dilewski (2000): Mechanical-Biological Waste Treatment - Introduction and Decision-Making Tools for Application in Developing Countries

[5] Kern, Funda, Mayer (1998): Stand der biologischen Abfallbehandlung in Deutschland. Published in Müll und Abfall 11/1998

[6] Gronauer, Helm, Popp, Rittel (1993): Planerische Anforderungen an Kompostierungsanlagen. In Kompostierung und landwirtschaftliche Kompostverwertung; KTBL-Arbeitspapier 191; Münster-Hiltrup; 152-170

[7] http://www.ces.uga.edu/pubcd/B1189.htm