BIOLOGICAL WASTE TREATMENT – ORGANIC WASTE COMPOSTING

APPLICATION OBJECTIVE
- Recovery of useful organic and inorganic substances from the biodegradable waste fraction for the generation of a usable humus by biological processes and in conjunction therewith
- a significant reduction of biodegradable waste that otherwise would have to be landfilled or become subject of other forms of waste treatment or
- the reduction of the reaction potential of organic rich waste or of the residues from biological treatment processes such as anaerobic digestion (see factsheet on “Anaerobic digestion”)

OUTLINE ON APPLICATION FRAMEWORK

PARTICULARLY APPLICABLE FOR WASTE TYPES

<table>
<thead>
<tr>
<th>Waste Type</th>
<th>Glass</th>
<th>Light-weight packaging</th>
<th>Biowaste</th>
<th>Paper / paperboard</th>
<th>Mixed household waste</th>
<th>Bulky waste</th>
<th>Lamps</th>
<th>Textiles</th>
<th>Electrical and electronic waste</th>
<th>Scrap metal</th>
<th>Waste wood</th>
<th>C&amp;D waste</th>
<th>Waste oil</th>
<th>Old paint &amp; lacquer</th>
<th>Waste tyres</th>
<th>Branch specific waste</th>
<th>Other waste material</th>
</tr>
</thead>
</table>
| Special characteristics and requirements of the application

Pre-treatment of the input material:
The input material should come from a separate collection, it has to be examined for components which may release hazardous substances (e.g. batteries) and must be freed from them and other disturbing materials such as large foils. Large components usually contained in forest residues, pruning and garden waste must be chopped.

Options for the utilisation of the generated output:
The compost is particularly suited for agricultural applications, the use in gardening and landscaping, for fruit and special cultures, re-cultivation works and home gardening. The mainly wooden screen overflow suits well for use in thermal installations for energy production (biomass power stations). Composting residues may also be utilized as a bio filter material.

Options for the disposal of process output and/or residues:
Residues from composting processes such as foils separated during screening have to be treated with other (e.g. thermal) processes.

Aftercare requirements:
No particular measures required. A sufficient hygienization of the material usually takes place within the composting process. Regular quality control of the compost product should be ensured.

Protective needs:
The exhaust air (especially in the receiving area and from mechanical processing) must be collected and treated, in addition technical and organizational measures for the avoidance and minimisation of emissions (odours in particular) have to be undertaken.

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1 for a limited spectrum of paper waste (e.g. no wet-resistant and technical papers) in small quantities only and never pure but together with other wet biodegradable materials resp. biomass

2 only untreated wood waste which to separate and forward to a material recycling process is not economical or technically possible
**Potential health risks**:  
Especially in the receiving area and during mechanical processing steps a higher risk of air contaminations with germs and spores must be observed. Technical and personal protection measures (wearing of mouth masks, suction removal and air exchange) in these places are highly recommended to avoid potential health risks.

**Employment potentials**:  
Waste composting offers good opportunities for the employment of both, unskilled and higher qualified personnel. In the rather complex processes (e.g. tunnel composting) there is even a need for specially trained and qualified staff to take care for the facility management and operations control.

**Restrictions or influence of externalities on the application**

**Infrastructural conditions**:  
Composting facilities can basically be used in any places, it will be an advantage however to erect them close to the places where the relevant wastes are generated and at locations that have access to the road and transportation network allowing the compost product to be more easily sold. As with any treatment facility for biological waste, a minimum distance to the nearest residential area should be maintained to avoid any potential nuisances by odours, rodents or other unwanted vermin.

**Climatic conditions**:  
Different process arrangements (open/encapsulated) allow composting to be basically used under any climatic conditions, except of very cold climates. Especially in open processes one has to consider that high temperatures cause the waste material to quickly dry out whereas low temperatures hamper the biological degradation. Using an appropriate coverage (for example special membrane foils) can be a way to avoid such disturbances. In areas with generally high precipitation rates or seasonal intense heavy rainfalls, windrows and rotting heaps should be placed under a protection shelter in order to avoid water loggings.

**Suitable financing mechanism**:  
Financing can be through a fee charged in conjunction with the delivery of the waste to the composting facility or collection service via the corresponding collection system (separate biowaste container). Alternatively the costs can be incorporated into the charges or a specific fee for general waste collection services or they are recovered over other (e.g. tax-based) mechanisms for waste management financing.

**Technical details**

**General overview**

**Abstract**  
Composting is an aerobic process that requires oxygen and biologically degrades respectively converts organic material under appropriate conditions to CO₂, water and humus. The consumption of oxygen is greatest during the early stages and gradually decreases as the process continues to maturity. Biological processes cause a self-heating of the input material which reaches its highest temperature profile in the early process phase (intense rottin, temperatures up to 65–75°C) and leads to the drying and the killing of pathogens and weed seeds (hygienization). Eventually the temperature curve goes down as a sign that the biodegradation is coming to an end. The spectrum of composting techniques stretches from rather simple, open air arrangements (open windrow composting) up to highly sophisticated and controlled, encapsulated systems such as the tunnel or box composting.

**Basic requirements**  
For a quality compost, the following requirements should be ensured in the input:  
- must be from source-separated organic waste (biowaste) without hazardous components  
- should have a material structure that allows for a sufficient aeration as well as a  
- moisture content in the range of 50–60% and a  
- C/N-ratio in the range from 20:1 to 40:1  

A C/N-ratio in the range 25:1 – 30:1 describes the optimum for a fast composting process, but higher ratios may be possible. Overloads 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 through micro-biological activities. High concentrations of ammonium at a pH>7 can cause unwanted emission of ammonia.
To kill pathogens and weed seeds in the compost material, the process must ensure temperatures of 55°C in minimum for at least two weeks or 65°C in minimum (60°C in encapsulated systems) for about one week. The liquor collected from composting, if it cannot be returned and completely used in the process, must be adequately treated so as to comply with the legal requirements (such as described by Directive 91/271/EEC) before being released into surface water.

**EXPECTED RESULTS**

Output:
- Compost (humus-like product)
- Residues and disturbing components
- Smaller amounts of liquors

Mature compost should meet the following parameters to ensure that it is stable and safe:
- A C/N ratio of less than 25 to be safe for agricultural use
- Not re-heat over 20 °C upon standing
- Reduced volume of raw organic material by at least 60 % of the input.
- Low heavy metal concentrations as prescribed by international standards.

**SPECIFIC ADVANTAGES**
- Generates a product which is scarce and highly needed in many places
- Allows for a high proportion of waste diverted from final disposal with the consequence of saved capacities, costs and emissions for further treatment
- Enhances other waste treatment operations thru either a drying or removal of organic matter from the waste stream
- Relatively simple to perform and safe
- Generally little capital intensive
- Well known and also well investigated technology
- Widely dispersed technique with a generally high acceptance in all areas

**SPECIFIC DISADVANTAGES**
- Can be applied on certain organic waste components only
- Requires separate collection of the organic waste fraction
- Generally very space demanding and time consuming
- Can cause some nuisance to adjacent areas due to occasional odour development
- High quality demands can pose problems to the marketing of the compost

**APPLICATION DETAILS**

**TECHNICAL SCHEME**

The input used for composting should be a source-separated organic waste free of disturbing and harmful components as otherwise an elution and transfer of hazardous substances during the biodegradation process into the end product cannot be excluded. Mechanical pre-treatment before the composting can improve the quality of the input further but does not provide a way to generate a fraction from mixed household waste that is suitable to meet the requirements and safety standards for agriculturally usable composting products.

Mechanical pre-treatment can consist of the steps
- (ii) Separation of foreign matter and contaminants
- (iii) Size reduction
- (iv) Metal separation

These mechanical pre-treatment steps are basically the same as applied in the mechanical-biological waste treatment and are therefore further described in the factsheet supplied on this particular technique (see fact sheet on “Mechanical-biological waste treatment”).

Mechanical pre-treatment can also be used to attain the optimum structure and C/N ratio in the composting input 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. Bulking agents can be added to the input if it lacks the structure to maintain adequate porosity within the compost pile.
Basically, two different technical arrangements for composting can be distinguished:
- open air (windrow) composting
- encapsulated or box composting systems

Principal differences of these arrangements are listed in the following table:

**Table 1: Advantages and disadvantages of open and box composting**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Encapsulated or box composting systems</th>
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<tbody>
<tr>
<td>- low capital requirements</td>
<td>- optimal process control</td>
</tr>
<tr>
<td>- low running costs</td>
<td>- emissions well captured</td>
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<tr>
<td>- more frequent problems with the emission of odors</td>
<td>- shorter rotting periods</td>
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<tr>
<td>- longer rotting periods</td>
<td>- without additional measures highly dependent from the local climate/weather conditions</td>
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<tr>
<td>- more capital intensive</td>
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</table>

**Open windrow composting**

The material for composting is set up in windrows of different size and shape. Bucket or wheel loaders are normally used to build high windrows whereas turning machines create low and wide windrows. Windrows are set up with heights between 1.80 to 3.00 m depending on the shape. Most common are windrows with a triangular, trapezoid and flat-top profile. The composting process differs in dependence from the applied method of aeration whereas the windrows can be static or physically turned either on a regular basis or when required based on temperature and oxygen requirements. Depending on the applied model about 10–60 weeks are needed for the entire rotting process to be completed.

The arrangements for windrow composting can be of the following type:

**Table 2: Variants of the open windrow composting**

<table>
<thead>
<tr>
<th>Static method or arrangement</th>
<th>Dynamic method or arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Aeration</td>
<td>Active aeration</td>
</tr>
<tr>
<td>Aeration due to natural heating-up (chimney-effect)</td>
<td>aeration with the help of air blower and piping system</td>
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<tr>
<td>aeration by way of regular turning and mixing</td>
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</table>

Typical particle sizes should be approximately 1 cm for windrow composting with forced aeration and 5 cm in case of passive aeration methods.

**Figure 1: Example of an actively aerated, dynamic composting arrangement with frequent turning of the windrows (Picture source: INTECUS GmbH)**

Windrows are typically used for large quantities which can require a lot of space. In addition, windrows can have odor problems and leachate concerns. Covering open windrows with a semipermeable, water-proof layer or foil (e.g. GoreTex®) is a proven way in areas facing extreme climatic conditions.
Encapsulated systems

Composting in encapsulated systems means composting in a closed environment with minimised thermal exchange with the atmosphere and various methods of aeration and mechanical turning to control the process. These systems are designed to minimize odours and process time by controlling airflow, temperature, and oxygen concentration.

Encapsulated systems make it possible to collect gaseous emissions, odours and particulates. The active aeration, watering and mixing enable control and optimization of the rotting process, thus considerably accelerating the main biodegradation phase. Composting in encapsulated systems is more strictly divided into an intensive rotting and a maturing stage. The completion of the composting process lasts only 2 to 5 weeks for the pre-rotting, plus 7 to 26 weeks of secondary rotting.

The initial investment can be high and handling volumes are typically lower than in open windrow composting. The encapsulated composting 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.

The following arrangements are common:

- **Bay composting**

  Figure 2: Technical arrangement of a bay composting with trapezoid windrows (Component design according to Linde KCA)

  [Image of a diagram showing a bay composting system]

  In this arrangement the advantages of a closed system are combined with windrow composting methods. In fully automated rotting bays, the organic materials are (mostly) piled into tabular heaps, force-ventilated, and automatically turned by a turning unit. The material is watered as necessary from sprayer systems set up atop the heaps or during the turning process. A perforated floor space allows the heaps to be vacuum ventilated, the exhaust air is passing through bio filters to avoid odour nuisances. In the course of rotting, the waste "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.

- **Tunnel composting**

  Tunnel reactors works similar to an enclosed bay system. The rotting takes place in fully enclosed tunnels with the waste being continuously moved through the tunnel where it is aerated and watered with respect to the achieved degree of rotting. Perforations in the floor provide for aeration, the moisture content is regulated via nozzles Exhaust air can be optimally collected and treated.
Rotting boxes/ Rotting containers
Rotting boxes are made out of reinforced concrete or steel. They are operated in a batch mode with a stationary or a driveable perforated floor. For controlled aeration air can be introduced via the floor and sucked off from the box from where it goes to treatment.

Similar to tunnel composting, intensive rotting is completed after 8 to 10 days. The rotting material tends to dry easily (this effect is specially used for biological stabilisation in the frame of mechanical-biological treatment schemes (see also fact sheet on "Mechanical-biological waste treatment").

In-vessel composting/composting drums
In-vessel systems use perforated barrels or drums which can be easily turned. These drums are highly suitable for the pre-rotting as a good homogenization and mechanical disintegration can take place. However several moving parts on it lead to high wear. As such, the drums should be preferably be used for relatively short time pre-rotting. As rather simple installations drum composting can be specially suitable for small-scale applications.
Windrow composting and composting in encapsulated systems are often done in combination. Whereas encapsulated systems are best suited for the intensive rotting of the input material, open windrow composting can be well applied for secondary rotting and maturing.

### QUANTITY ASPECTS
- **Input:**
  - 100% biodegradable waste
- **Output:**
  - 10–20% screening residues from input
  - 35–40% finished compost product
  - (the remaining 40–55% is the loss of weight as result of the biodegradation process and evaporation of water and from gas emissions) ³

### SCALE OF APPLICATION
The capacity of composting installations varies vastly, minimum throughput can be as low as 300 Mg/a, whereas the upper range of throughput is at around 100,000 Mg/a. Most plants in Germany have a throughput capacity between 3,000 and 10,000 Mg per year. Tunnel composting usually has a higher throughput than container composting. Tunnel composting can become economically viable with an input from about 3,000 Mg per annum. A single rotting box may have a capacity between 50 and 250 m³, aerated rotting drums capacities in the range from 20 to 150 m³.

### INTEROPERABILITY
Composting can be a preceding step to waste disposal operations and is then part of a mechanical-biological treatment operation (see also fact sheet on “Mechanical-biological waste treatment”). Most preferable is to establish composting as part of an integrated waste management concept which comprise of separate collection and various activities for material recovery and recycling. Compost that can be utilized as a fertilizer in agriculture and home gardens can only be obtained from biodegradable waste components separated at source!

### OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION

| **ENERGY BALANCE** | Intensive rotting systems have an energy demand in the range from 15-65 kWh/Mg, whereby mechanical pre-treatment usually takes about 10 kWh/Mg. An active aeration normally causes the highest demand in energy, otherwise it is only mechanical processing which consumes a significant amount of energy, depending on the required intensity of pre-treatment this step takes for example 2–15 kWh/Mg.  
- The aerobic decomposition generates 0.6-0.8 g water and 25.1 kJ thermal energy per gram of organic matter. |
| **CO₂-BALANCE** | Significant emissions of CO₂ and other (greenhouse) gases occur during the biological treatment, however, unlike in incineration or with untreated waste on landfills carbon is to a larger extent also bound for a long term in the stabilised organic material and wont thus get released into the atmosphere |
| **AIDS/ADDITIVES NEEDED** | No other than specified |
| **HUMAN RESOURCES** | The demand on labour force depends largely from the capacity of the installation. The demand of an average plant size in Germany is about 10 persons (1 foreman, 6–8 personnel for operations/maintenance, 1 for gate control/sale). Integrating a mechanical pre-treatment, especially with manual sorting, requires a larger workforce. |
| **SPATIAL NEEDS** | The space demand for installations with an intensive rotting is in the range of 0.2–0.3 m² per Mg and year. |

Open systems do have a considerably higher space demand which is mainly determined by the windrow type, the windrow dimension and the applied turning method. For example a triangular shaped windrow with a basis width of 3 m requires 1.40 m²/m³. If handled without a self-propelled turning machine, the space requirements may go down to 1 m²/m³. A windrow of trapezoid shape with a basis width of 10 m and a height of 3 m requires 0.45 m²/m³. The available space often determines which arrangement/windrow type will be used.

The space demand for the operations area can be broken down as follows:
- 5% receipt area
- 10 % storage area for compost
- 10 % temporary storage area
- 75 % rotting area (of which 40% are reserved for movements of equipment)

Aftercare measures respectively subsequent treatment must be applied on excess liquor (e.g. taken to waste water treatment) and screening residues from the process.

### Operational Benchmarks: Cost Dimensions

#### Investment Costs
The main part of the investment comprises the following positions
- Costs for area purchase and development: depending from local conditions, planned capacity and technical arrangement
Further must be considered capital expenses in the following minimum range (price level of 2008)
- Constructional elements: 70 to 100 EUR/Mg*a
  costs to pave the surface of the rotting area may reach 20–45 EUR/m²; costs for a simple roof atop the rotting area may reach 70–90 EUR/m²
- Machinery: 110–140 EUR/Mg*a
  (with purchase price of a simple turning aggregate starting at approx. EUR 2,000)

#### Operating Costs
Are incurred for
- Daily operations (consumption of fuel/electricity, insurances etc.)
  The minimum costs for the turning operations are
  - 0.25 EUR/m³ if done with a turning aggregate hauled by a tractor
  - 0.40 EUR/m³ if done by a wheel loader
- Repair and maintenance
  - for each structural element approx. 1% of the initial investment
  - machinery and electronic: 3–4% of the initial investment
  - mobile equipment (e.g. wheel loader): 8–15% of the initial investment
- Personnel (depending on the local labour market)
In the overall for
- Open windrow composting: 35 EUR/Mg (www.kompost.de)
- Encapsulated composting: 65 EUR/Mg (www.kompost.de)

#### Possible Proceeds
- From the sale of the compost product

#### Mass Specific Overall Costs
- In the range from 30–70 EUR/Mg
  Composting of biowaste from households generally results in higher costs (50-70 EUR/Mg) as compared to green waste (30–50 EUR/Mg).
  Unlike in other waste treatment plants no significant degression in the specific costs can be observed with an increasing plant size. This is because construction expenses grow almost proportional with the throughput capacity in such simple installations.

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*H&K aktuell 03/10, p. 1-4*
Composting shall be applied under consideration of the international compost standards (such as those developed and described by the European Compost-Network ECN or in Germany by the Federal Association for Quality Assurance of Compost-BGK) in order to ensure that a safe end product is being generated.

**MARKET INFORMATION**

Installations and applications for biowaste composting exist everywhere in the world. Germany counted 915 composting plants in the year 2010. The arrangements used by these plants for the main rotting phase was of the following division:

<table>
<thead>
<tr>
<th>Container/Box</th>
<th>Tunnel</th>
<th>Trapezoid windrow</th>
<th>Triangular windrow</th>
<th>Semipermeable cover</th>
<th>Other forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 %</td>
<td>9 %</td>
<td>40 %</td>
<td>26 %</td>
<td>4 %</td>
<td>8 %</td>
</tr>
</tbody>
</table>

Examples for such facilities are:
- Humuswirtschaft Kaditz GmbH, Dresden www.humuswirtschaft.de
- Kompostwerk Hellefelder Höhe GmbH, Sundern www.kompostwerk-online.de
- Kompostwerk Olpe GmbH, Olpe www.oez-olpe.de

**RECOGNIZED PRODUCER AND PROVIDER FIRMS**

Recognized producer/provider firms for components or turnkey solutions for organic waste composting are for example:

**Screening, shreeding, turning equipment/air treatment systems**
- Komptech Vertriebsgesellschaft Deutschland mbH, Oelde www.komptech.de
- BACKHUS GmbH, Wardenburg www.eggersmann-recyclingtechnology.com/backhus
- Doppstadt GmbH, Calbe www.doppstadt.com
- Jenz GmbH, Petershagen www.jenz.de
- Biosal Anlagenbau GmbH, Bad Lausick www.biosal.de
- EuRec Technology Sales & Distribution GmbH, Merkers www.eurec-technology.com
- J. Willibald GmbH, Wald-Sentenhart www.willibald-gmbh.de

**Turnkey installations:**
- Strabag Umweltanlagen GmbH (former Linde-KCA), Dresden www.strabag-umweltanlagen.com
- Komptech Vertriebsgesellschaft Deutschland mbH, Oelde www.komptech.de

**ADDITIONAL REMARKS AND REFERENCE DOCUMENTS**

Relevant organisations and contact points for further information about the production and use of quality compost from waste are:
- Bundesgütegemeinschaft Kompost e.V. www.kompost.de
- Arbeitskreis für die Nutzbarmachung von Siedlungsabfällen (ANS) e.V. www.ans-ev.de
- Verbände der Humus- und Erdenwirtschaft www.yhe.de
- European Compost Network ECN www.compostnetwork.info