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Open windrow composting manual

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Open windrow composting manual

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Untitled

(author unknown)

In the soft warm bosom of a decaying compost windrow,
a transformation from life to death and back.
again is taking place.
Compost is far more than a healing agent
for the soil's wounds.
Here in a dank and mouldy pile
the wheel of life is turning.
Nature made compost before
the first woman walked the earth,
before the first dinosaur reared its head
above a primal swamp.
The dead grass of meadow,
Seared by winter's frost,
Is being composted by the dampness
of the earth beneath.

The birds, the insects and the animals
all contribute their bodies
to the vast and continuing cycle of rejuvenation.

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Chapter I Introduction

Pre-face

In times when mineral fertilizer is not available or too expensive, compost is the most important source to provide nutrients for the plants and to adjust the soil conditions. Today many people appreciate compost as a natural source for nutrients and humus.

To compost materials means also to close the natural circle of life.

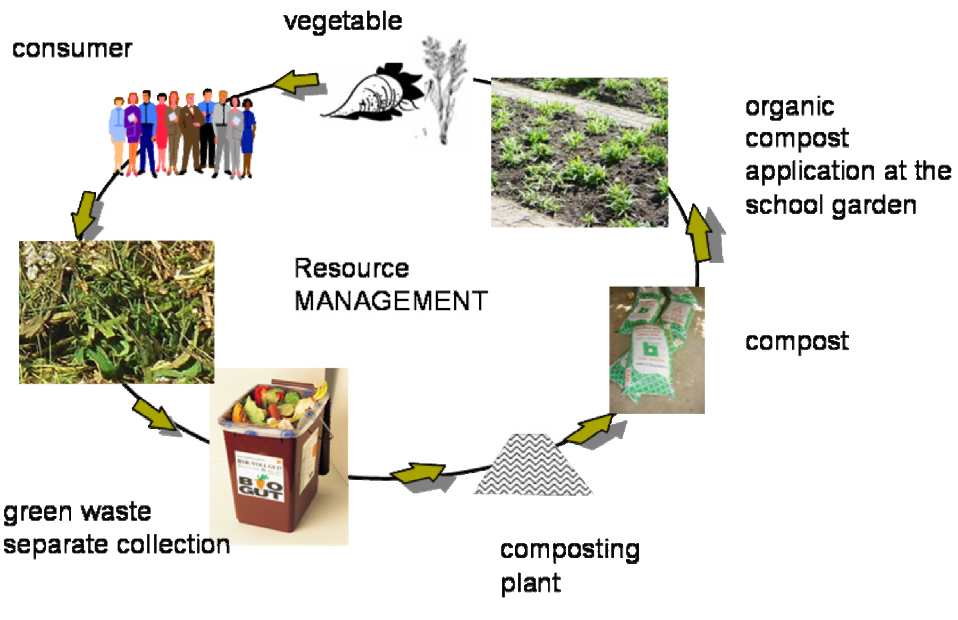


Figure I-1 Resource management [11]

Composting systems can be simple and unsophisticated for countries in early stages of development or mechanized and sophisticated for countries with relatively advanced technical development. In developing countries these treatment of bio waste has many advantages: low equipment and operation costs, in harmony with the environment, and in the end of the process a useful product. These manual try to give a helping hand in designing and maintaining a composting plant in economically developing countries. [5]

The degeneration of biological substance is a natural process. Composting as a kind of utilization of bio waste is very old and was practised by Chinese people long time before Christ's birth. To adjust the process of maturation the understanding of the basic principles during the composting process are necessary.

The adjustment of this natural process in a composting plant by optimizing the natural conditions this handbook gives the knowledge about, the process of composting, the design of a composting plant, the monitoring of the process, same facts about troubleshooting, and so on.

The monitoring of the composting process is very important to provide these optimal conditions in the windrow and to get a good and useful product, the compost.

Helpful information about the manual

The composting manual consists of the following three levels:

Basic Level:

Head of workers
Project responsible person

- It is the lowest stages for maintaining a composting plant. With this stage, it is possible to produce compost in a good quality and short time.
- Mainly this level is about, a good composition for the input material by volume; monitoring the temperature and moisture, volume reduction during the composting process and the compost volume determination.

Advanced Level:

Responsible engineer
Project manager
Compost plant Designer

- This Level includes all the steps in the basic level.
- Additionally this level is about, the bulk density, the composition of the input material by mass, and the total mass as well as volume and mass flow during the compost process.

Research Level:

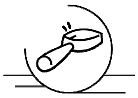
Head of project

- This Level includes the basic and advanced level too.
- The differences to the advanced level are the chemical analyses. The optimizing of the nutrient content and suitable nutrients ratio in the compost is the objective for this level.

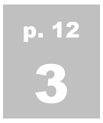
HELPFUL ICONS

Note the collected information in the data collection sheet

Calculate the results with the given formula



For more or detailed information look at another page or chapter



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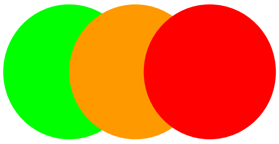
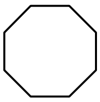


By using a coloured version, the colour describes the level too



Treatment stage during the composting process

Chapter
2

Chapter II Basic knowledge – composting

Aerobic treatment – composting

Definitions composting, compost

Degradation of biodegradable substance means the natural decomposition process. If man influences the process is called composting. The final product of aerobic biological treatment is the compost.

Composting

> *„Composting is the biological decomposition of biodegradable solid waste under controlled aerobic conditions to a state that is sufficiently stable for nuisance-free storage and handling and is satisfactorily matured for safe use in agriculture"*

Luis F. Diaz, 2003 [5]

Keywords of the definition

Biological decomposition

- Only wastes of plant or animal origin can be broke down biologically through the living activity of micro-organism.

Biodegradable solid waste

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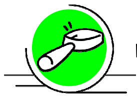
- This manual is mainly about use of plant origin for the composting process. To adjust the fertilizer quality the addition of animal origin can be useful.

- The composting of municipal solid waste (mix waste) as a kind of pre-treatment before incineration or land filling does not describe this manual.

Under controlled aerobic conditions



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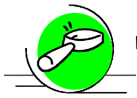
4

- The adjustment of the process by providing good conditions for the composting process mainly, air (oxygen), water, and a good input material composition, and the monitoring to get a quality product.

Safe use in agriculture



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4

- The final product compost should be harmless for the nature without dangerous compounds as heavy metals and the decomposition process should be nearly finished.

Open windrow system

Put the material together to build a windrow or heap, the system is called windrow system.

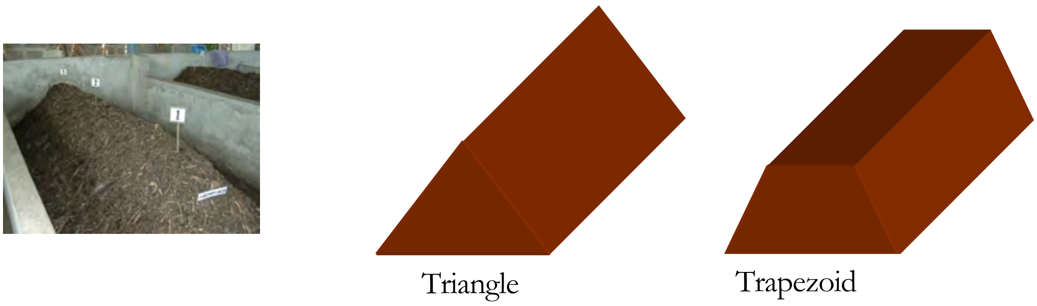

Figure II-1 Shapes of a windrow

Open windrow composting means that the windrow is normally not covered with a plastic foil or something like this.

Look for the next figure to see a manual windrow building.

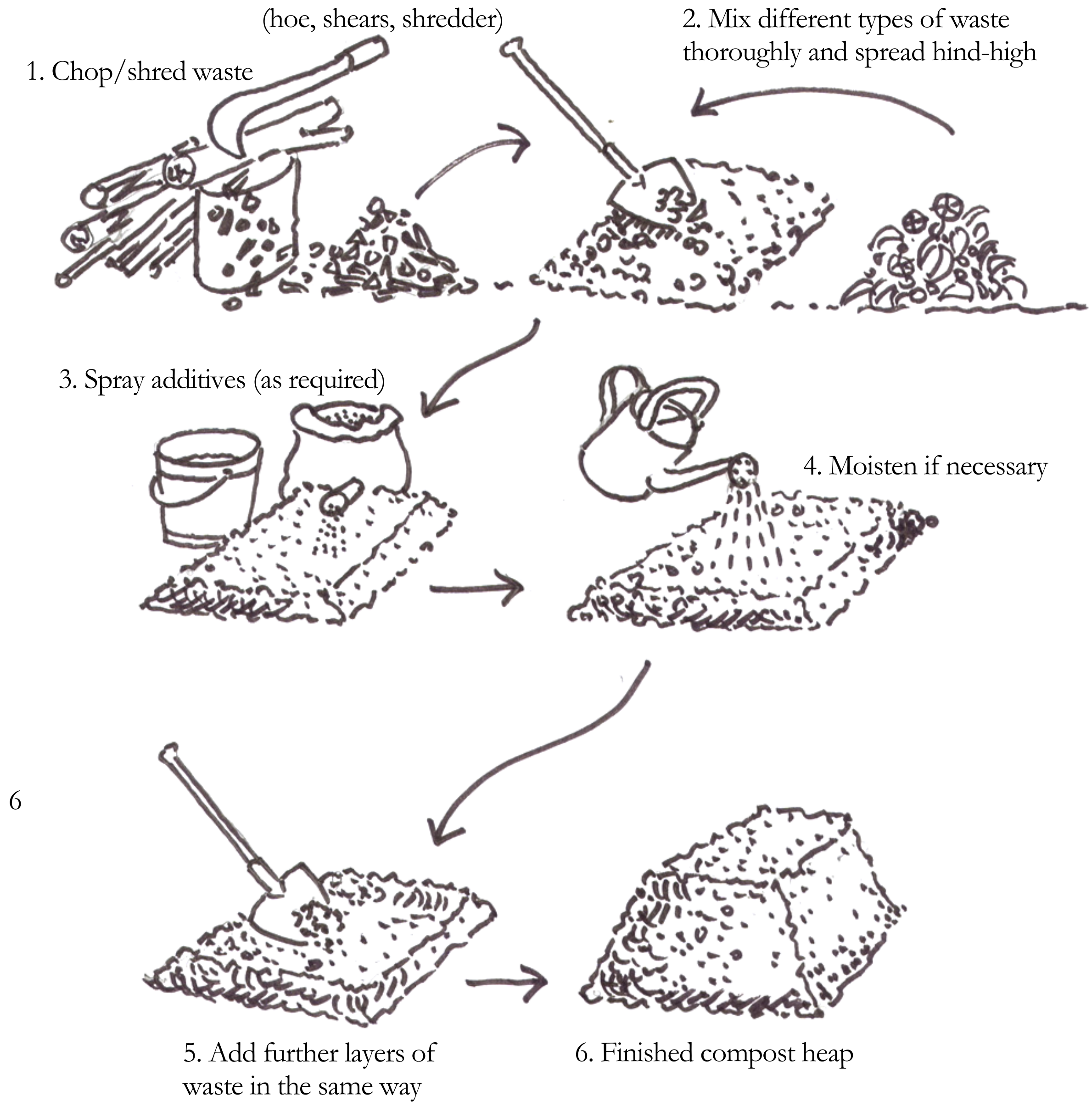

Figure II-2 Manual stacking of a windrow [6]

It is possible to use boxes or to build a windrow without a box.

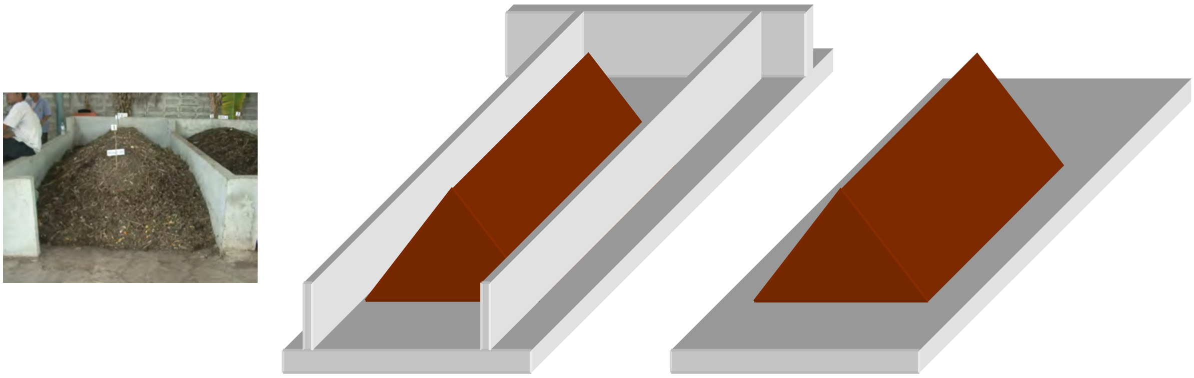

Figure II-3 Open windrow composting with and without the use of boxes

The use of boxes is more practical for small or middle composting plants. By using turning machines, boxes are mostly unsuitable.

Two versions of windrow system are divided and practiced. The distinguishing feature is the aeration, passive and forced.

Passive aeration systems

Passive aeration is at first the natural aeration. During the composting process, the carbon dioxide concentration in the windrow rises and the oxygen concentration goes down. The concentration of carbon dioxide is higher in the windrow than in the surrounding atmosphere. Because of this difference and the higher temperature in the windrow, oxygen is able to enter into the windrow. Therefore, it is possible that oxygen can enter the windrow up to layer thickness of 80 cm (general rule, depend mainly on the structure material ration).

In addition, the used method known as the Chinese method with aeration through pipes counts to the passive aeration systems. The moving force is the chimney effect. [5]

Forced aeration systems

During the composting process the oxygen concentration in the windrow is falling. To provide more oxygen ventilation systems or material turning is useful. Ventilation systems forcing air up so the pressure in the windrow is higher than the surrounding pressure or pulling the pressure in the windrow down. Both systems are able to raise the oxygen concentration in the windrow by mechanically air pumping.

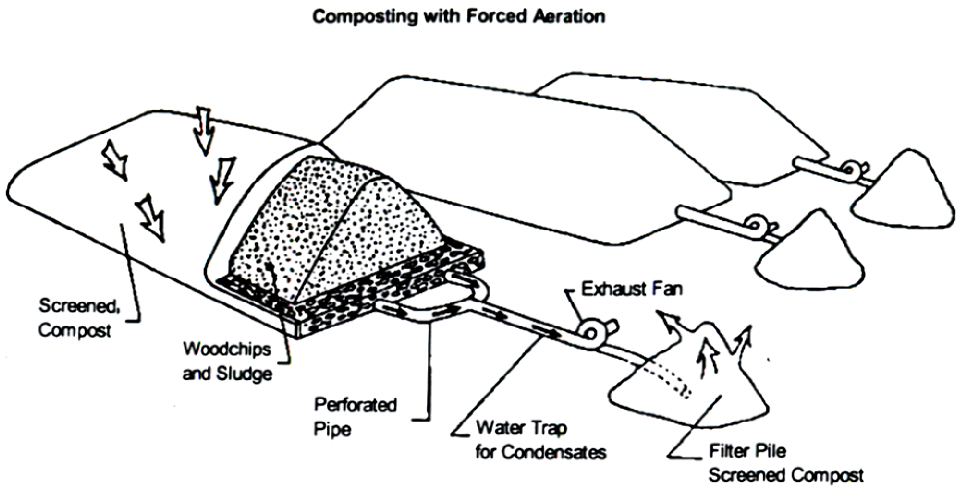

Figure II-4 Forced aeration composting, source Composting and recycling municipal solid waste [4]

Turing the material is also possible to lift up the oxygen concentration. The turning can be hand made or with the use of machines.

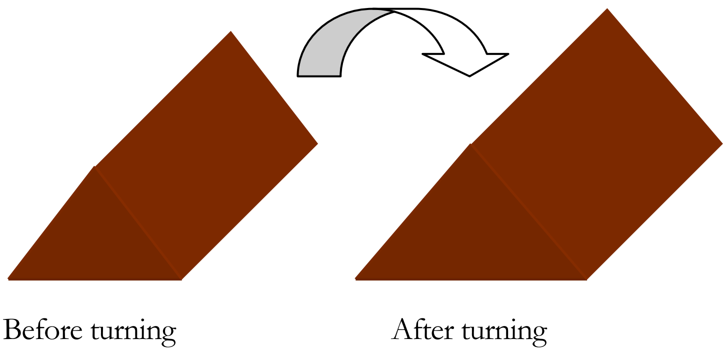

Figure II-5 Process of windrow turning

Recommendation for aeration systems

The combination of the natural aeration and the turning of the windrows is a very good method. The advantages of this combination are the avoiding of pipes and the cost for machines (price and maintenance). Using pips courses many problems, taking care by building and removing the windrows, leachate in the pips, and so one. The disadvantage is the monitoring of the process to decide the turning time for the windrows.

Micro-organism

The degeneration process of biodegradable solid waste depends on the living activity of micro-organisms. That is why Mr. Luis F. Diaz gave an ecological definition of composting:

> *"Composting is a decomposition of process in which the substrate is progressively broken down by a succession of a population of living organisms. The breakdown products of one population serve as a substrate for the succeeding population. The succession is initiated by way of the breakdown of the complex molecules in the raw substrate to simpler forms by microbes indigenous to the substrate"*

Luis F. Diaz, 2003 [5]

Bacteria, fungi, protozoa and actinomycea are the most common miro organism during the composting process.

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During the process, the population of micro-organisms change because of the different temperature stages in the process. Most of these active organism act in a special temperature range.

Process factors

As it was mentioned in the section before, micro-organisms degenerate the input material and the breakdown products of the former population serve as substrate in the next stage of the decomposition process. The degeneration process depends on different factors. These factors, and their relation each other, influence the speed of the decomposition process, the stage of decomposition, and the activity of micro-organisms.

These process factors are useful to monitor and control the composting process.

4

Find descriptions for the optimum of all process factors during the composting process in Chapter IV

Kind of substrate

As the definition of „composting“, describes the substrate has to be biodegradable. With the use of a special input material or a mixture of different kinds of input materials, many properties for the process and the quality of the compost are fixed, like the interstices volume, the moisture, or the particle size of the input material. That is why the mixture of the input materials (used substrate) is the most important step to produce good compost.

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For suitable and unsuitable input material, suitable mixtures look at Chapter IV

Temperature

The active organisms are the reason for the production of thermal energy. This energy is measurable in the windrow or heap by the determination of the temperature inside a windrow. The temperature influences the degeneration process mainly the speed of degeneration because the general rule is that the activity of micro-organisms rise with an up growing temperature (the temperature should never rise over 70°C).

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The temperature is a suitable value for the determination of the stage of degeneration and the rotting degree.

Moisture

Micro-organisms need water to survive. The providing of water is necessary to keep the degeneration process running.

The problem is the very close relation between water and aeration. Both need interstices between the particles and the interstices can be filled with "free" water or air. The amount, the size, and the distribution of the interstices depend on the used input material. [5]

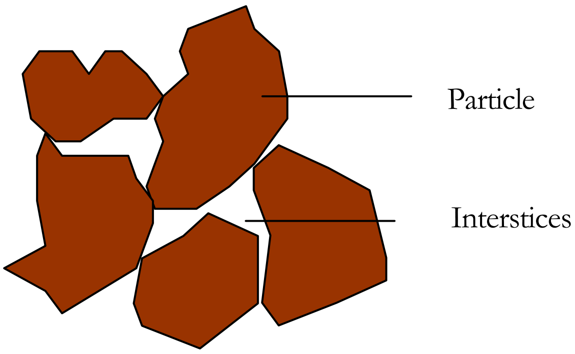

Figure II-6 Enlarged illustration of particles and interstices

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Because of this relationship, the monitoring of the moisture is very important.

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Aeration

Aeration (passive or forced) has many different functions during the composting process:

- Supply with Oxygen to keep the micro-organisms alive
- Taking away the carbon dioxide
- Reduction of water to dry the material
- Leading away the heat to prevent temperatures over 70°C

The oxygen demand depends on the activity of micro-organisms.

Very important for the proving of oxygen is the mixture of the input material, especially the amount, the size, and the distribution of the interstices.

Please note the every close relation between the moisture and the aeration, which is described in the former section.

pH – Level

The activity of the micro-organisms is close related to the pH – Level of the input substrate. Good for biological activity are pH – Levels between 7 and 11.

Values under 7 are leading to a speed reduction during the first steps of degeneration. If the pH – Level is under 5 a strong inhibition in the initial (until fast temperature rise) stage can be noticed. Hence, the period between collection, storage, and treatment start at the plant should be short. Uncontrolled natural anaerobic digestion, because of oxygen lack, during the collection and storage timeframe leads to low pH – Levels. [2]

C/N – ratio

The ratio between carbon and nitrate atoms in the input material has a very close relation to the speed of the degeneration process. It should be between 20:1 until 35:1 (carbon to nitrogen – optimum). If the ratio is under 10:1 carbon is the up growing inhibition and if the ratio is over 40:1 to less nitrate is available. Out of this range (1:10 until 1:40) the micro-organism population is not able to grow up. The activity of the micro-organisms is the same but without an up growing population the time for the degeneration process rise.

Very important for the C/N – ratio are not the results of the chemical analysis it is more the ratio of biologically (short) available carbon and nitrate atoms.

Chapter 3

Chapter III Design of a composting plant

Minimum requirements for a composting plant place:

- Suitable access for delivery vehicles
- Access to water
- Covered with a roof
- Water impervious surface or concrete surface

Construction elements of a composting plant

The following descriptions are basic, for more detailed information look at [3]. Often it is better to combine steps, especially for small plants.

1

Input material supply

The interface to notice all the incoming materials and the leaving materials like the compost is the first point at the composting plant. It is a very important point for big plants, for small plants, this station is not really necessary.

For the determination of the input volume, count the incoming delivery vehicles and estimate the volume. To get better information use a big scale to measure the mass of the trucks (full and empty). For the leaving materials like compost, use the same method.

2

Input material storage

This part of the composting plant has different functions [3]

- Optical controlling availability and sorting of unsuitable materials
- Buffer space for a high delivery of input material or a process breakdown (outage)
- Continual flow rats for next steps
- Separate storage availability for different materials

The size of the storage area depends on the size of the composting plant and the kind of input material.

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3

The storage time for garden waste or green waste should not be longer than one day. In times (especially at small plants), if this is not possible, cover the material with sieved structure as a bio filter to limit environmentally harmful emissions and odour.

Structure material (fresh or sieved) is storable over weeks (without a roof).

For special situations like a small material flow or very good continual flow rates, it is possible to run the plant without a storage area.

3

Pre-treatment

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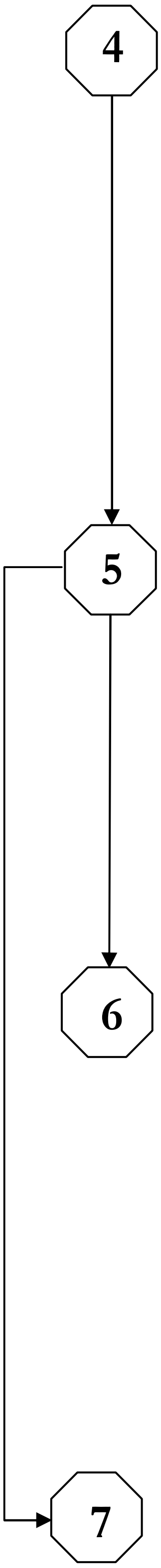
2

The objective in this section at the plant is:

- Adjustment of optimal conditions for the composting process (reduction of the particle size, mix of different input material, optimal water content, and optimal structure material content)

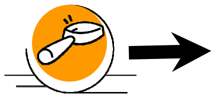
This is possible with machines or manual. As recommendation, it is suitable to use small transportable machines for a few small plants.

This is the last chance to sort out unsuitable materials. Do not forget to think about a place where the collection and storage of unsuitable materials is possible (sometimes it is only a dustbin required; it depends on the pollution with unsuitable materials in the input material).



Composting process

Design the composting process that optimal process conditions are measurable and adjustable.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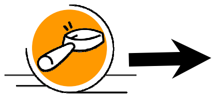
2

Find the description of all parameters like the turning frequency, the moisture, and so on, during the process in Chapter IV Operation at a composting plant.

The biggest influence on the required space is the composting time. The required area for the composting process grow up with the needed process time. Hence, optimal composting conditions lead to a short composting time and a small space for the windrows.

Compost preparation

After the maturation process is mostly finished, the compost is ready for the preparation, sieving the material to get the compost separated from the structure material.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The used diameter of the sieve depends on the operating range of the compost. For example, a grass fertilizer needs a very small diameter and a soil conditioner a big diameter.

Compost storage

Because of an inconstantly compost selling during a year, the compost storage area is necessary. The area should be big enough to storage compost for about 1/3 (or 1/2) year. Cover the storage area with a roof to avoid the loss of substances and nutrients during a heavy rain and to keep the moisture constantly. Before selling the compost bagging, nitrogen addition and or shredding can be adjusting the fertilizer quality (it is also possible to do this step simultaneous to the compost preparation).

Sieved structure storage

The sieved structure is useful as mulching for tree and hedge or as compensation if new structure material is not available, mostly during the cold period because there are no cuttings of trees and hedges at this time. That implies that the storage area has to be big enough to storage structure material for about 1/3 of a year (composting process needs also structure during the cold season). It is practical to storage this structure material together with new structure material at the same area. Hence, the flashover value for the dwelling time for the structure input material is so high.

Area requirements

The next numbers give an approach to calculate the area for a composting plant. Because of the complexity of the biological process, these numbers are not scientific values. All theses flashover values came from practical experiences in Germany, Cambodia and Thailand as well as from the technical literature.

Composting plants are divided in free categories. The belonging category depend on the operating capacity

- Small composting plants until 5,000 Mg/a
- Middle composting plants until 10,000 Mg/a
- Big composting plant until 25,000 Mg/a

DESIGN THE FOLLOWING DIFFERENT AREAS

- Storage areas for the input material, the structure, and the compost
- Rotting area
- Pre-treatment and preparation areas
- Traffic ways for the machines and the workers

It is possible to calculate the required area for a composting plant with the given flashover values in the next chapter. However, it would be much better to use measured and calculated values out of own tests in your region.

Design flashover values

THE STORAGE AREAS

The calculation instructions are the same for all storage areas. Pay attention on the different kinds of input materials and their different storage times. Calculate the complete input storage area with the addition of the single calculated area for every kind of input material.

Table III-1 Flashover design values

Kind of material	Average bulk density	Dumping height	Dwell time
	[kg/m³]	[m]	[d]
Structure material	**300**	**2,5 – 3**	**until 90**
Green waste	**300 - 600**	**2,0**	**~ 1 – 3 (7 for small plants)**
Garden waste	**200 – 600**	**2,0**	**~ 1 – 3 (7 for small plants)**
Compost	**650**	**2,5**	**until 90**

Because of the wide range of the bulk density, the big amount of different kinds of input materials, the close relation between the water content and the bulk density and their chancing during the seasons (hot, rainy and cold period), flash over values cannot be given.

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It is possible to calculate the storage area for the input materials with an average of 600 kg/m³ but it is better to measure own results in according to Chapter V Analyses at a composting plant.

If the composting plant is running with manual turning and sieving, the dumping height should be less than 2 m.

The given dwelling time is a design value; structure material and compost are storable over one year.

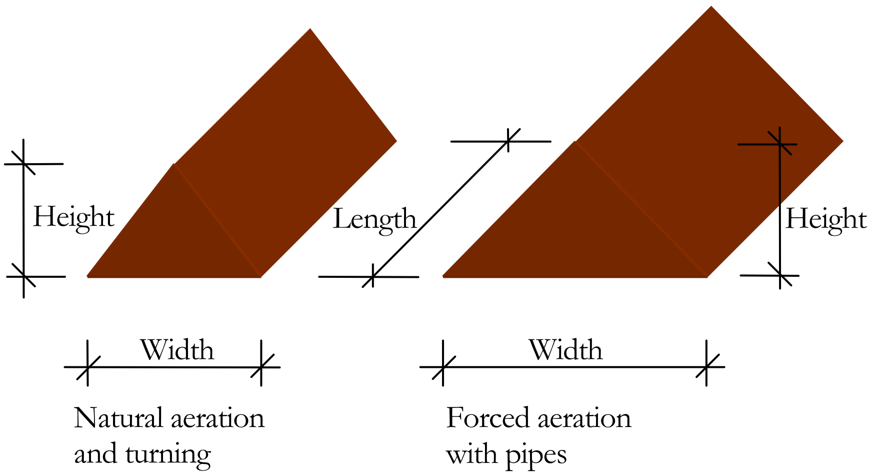
About 30% by mass (design value) of the input material is compost.

ROTTING AREA

The process time is between eight and twelve weeks, depending on several conditions. The usage of the average, 10 weeks, is suitable.

In addition, the dimensions of the windrows can be different. The windrow height and width depend mostly on the used aeration method and the structure material ratio.

For the determination of the required area, a suitable value for the bulk density is 400 kg/m³.



	Natural aeration and turning	Forced aeration with pipes
Height	≤ 1.2 m	≤ 2.5 m
Width	≤ 1.8 m	≤ 3.5 m
Length	unlimited	

Figure III-1 Wndrow dimensions depending on the aeration system

Please note that the dimension of the windrows also depend on the used input material as well as the use of machines or men. In addition, it is possible to build windrows with a trapezoid shape.

PRE-TREATMENT AND PREPARATION AREAS

Only for big composting plants, which uses many big machines this is an important point. Calculated the area out of the technical drawings and add the area to the storage and rotting area.

For small composting plants without machines or small moveable machines, it is not necessary to calculate this area.

TRAFFIC WAYS

For “normal” composting plants, it is enough to add 25% of the whole area (storage areas and rotting area) as additional area for traffic ways.

Area calculation

Preliminary remark

By the calculation of the total required area of a composting plant, the most influencing value is the flow rate of the input material. The amount of input material in a year or a week is measurable with waste analyses.

If some data are not available, it is possible to calculate the required area with flashover values out of the former chapter.

For further information, look in the attachment in the table sheet and the example.

Required data	Steps
Input material mass and bulk density, dwell time and dumping height	**Step 1:** ▪ Calculate the storage area
Input material mass and bulk density, dwell time and dumping height	**Step 2:** ▪ Calculate the rotting area
Dimensions of the used machines; for small plants not necessary	**Step 3** ▪ If it is necessary, calculate the area for machines (pre-treatment, compost preparation, belts, big shredder, turning machines, …)
Add 25% of the whole area out of Step 1-3	**Step 4:** ▪ Calculate the area for traffic ways.

Evaluation

- Add the four kinds of areas together. The result is the total required area for a composting plant.

Remarks

- After the determination of the total area, think about a practical material flow and draw a picture of the new plant.

Material flow

The adjustment of the material flow is important to avoid unnecessary ways and work. It is possible to save time and money with a good and uncomplicated material flow. Some examples for a good material flow are

Material flow in a line

- It is a very easy and simple material flow.
- The disadvantage is the long way back for the sieved structure material (7).

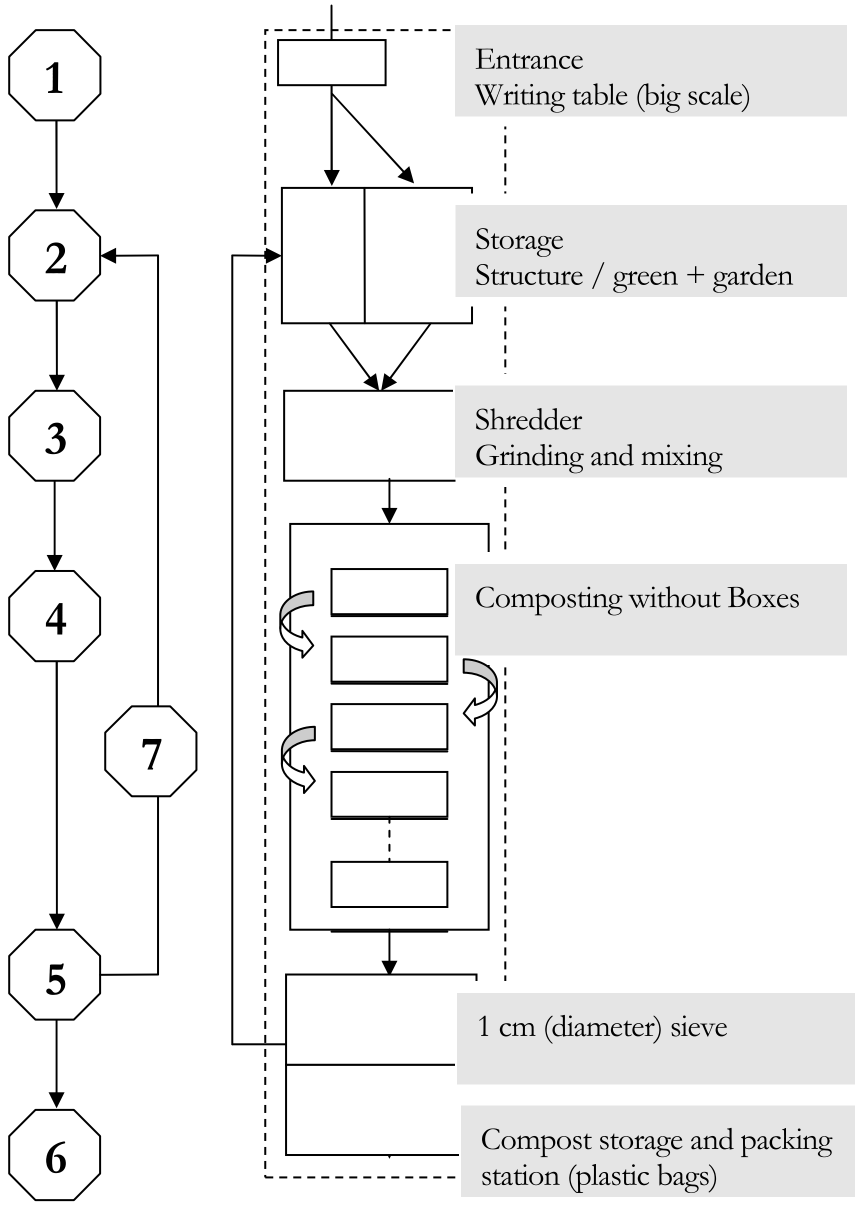


Figure III-2 Exemplary material flow at a big composting plant (turning windrows) – in a line

Material flow in a rectangle form

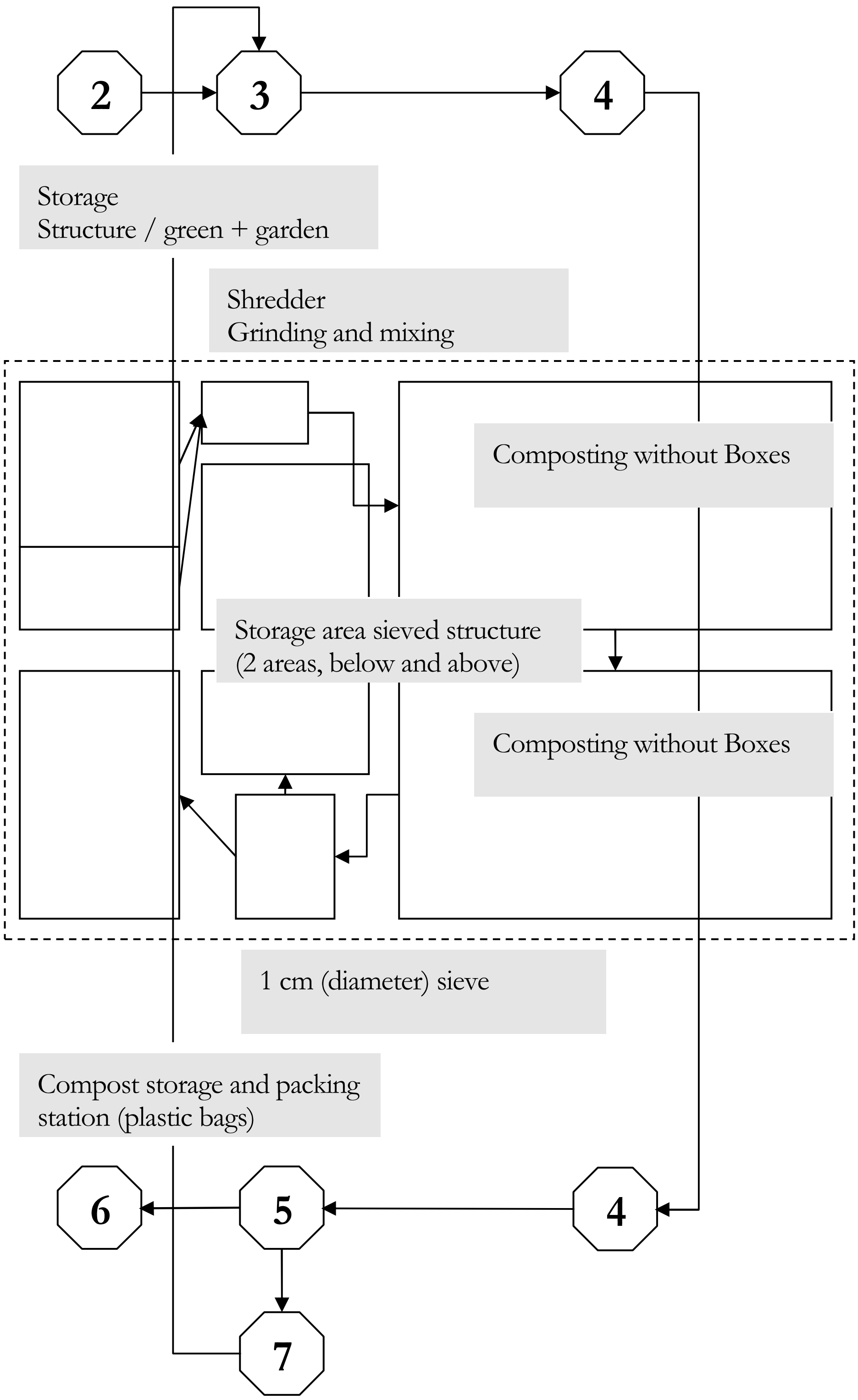


Figure III-3 Exemplary material flow small composting plant (without input material supply) – rectangle form

Mass balances

Preliminary remark

Use the advanced level to draw up an own mass balance. Additionally helpful information can be found in the appendix. The use of the designed sheets for the calculation, the following text, the flow plan, and the example are given to understand the calculation procedure.

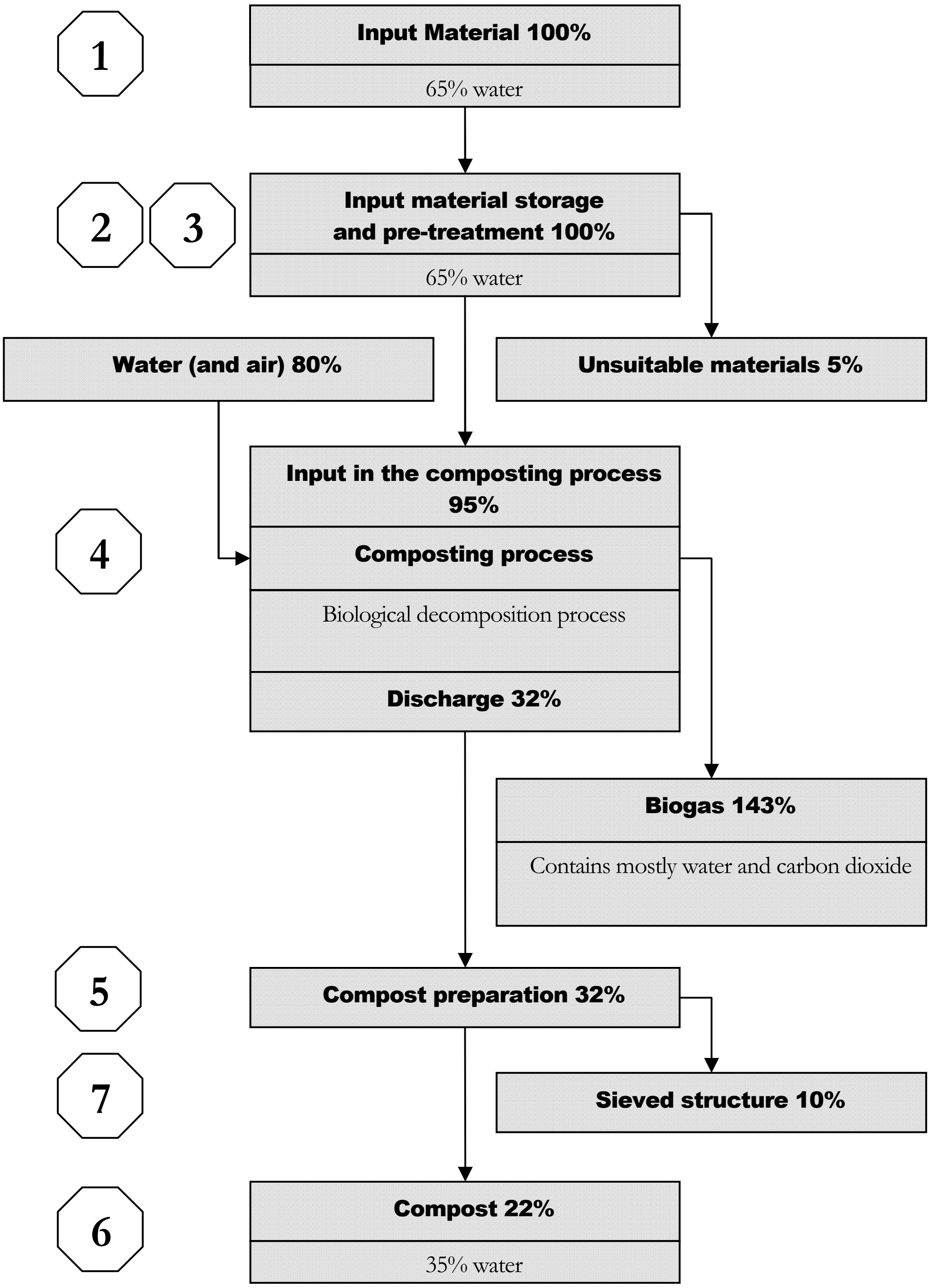


Figure III-4 Exemplary mass balance with flashover values by mass percent, modified [2]

The given example shows an easy mass balance. The objective is to get more information about the required irrigation mass and the expected compost mass (or volume) after the composting process is finished. With such mass balances, it is possible to get flashover values about the composting process with different kinds of input materials.

The used balance was calculated with the following flashover values for the composting process.

Please note the given values in percent by mass.

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Required values for the draw up of a mass balance

To set up a mass balance do the next step with one heap or windrow during the whole composting process. It is very important to record the data carefully. Look at Chapter V Analyses at a composting plant, to get additionally helpful information about the tests.

Step 1:

- Record the total mass and the moisture content of the input material

Step 2:

- Note the input material mass and the mass of unsuitable materials after the storage and (or) pre-treatment area as well as the moisture content.

Step 3:

- Record the irrigation of water by volume or mass.

- At last step, record the mass and the moisture content of the sieved materials (structure and compost).

Evaluation

- Determinate values after the calculation procedure in the data collection sheet or in the example.

- Draw an easy material flow plan like the example (Figure III-4 Exemplary mass balance with flashover values by mass percent) with the important steps at the composting plant and calculated the values in percent by mass.

Remarks

- With such a balance it is now possible to say that about 22% (numbers out of the example) of the input material by mass is compost and the irrigation mass during the process is 30% of the input material mass.
- By 10.000 mg of input material the irrigation mass is about 3.000 mg and the expected compost volume is 2.200 mg.
- Pay attention, the numbers can be quiet different for different input materials, different surrounding conditions, and so on.

Chapter 4

Chapter IV Operation at a composting plant

Input material

The input materials and the composition of them are very important for a fast composting process and good product quality. As an easy rule says, “Good compost needs a good composition of the input materials”.

Suitable and unsuitable materials

Organic waste consists primarily of organic substance. This term does not describe if the waste is natural or artificial origin. In addition, the description does not indicate if the waste is compostable or not. By the use of this definition also paints and oils belongs the category organic waste. [6]

In this manual and in special literature the name bio waste is used to describe waste, which can be broke down by the activity of micro-organism (biological decomposable).

The division of bio waste in different categories depend on the water content. [6]

- Suitable waste for anaerobic treatment like liquid waste and waste with a high water content and/or less structure material
- Suitable waste for aerobic treatment (composting) like solid waste, particular bulky materials

Bio waste is allocated on the source. Hence, the bio waste can be divided in waste from households (and markets), form gardens (and parks, roadsides) and from stockyards (and slaughterhouses).

The following information on bio waste concentrates on waste, which is suitable for composting.

This manual describes mainly the composition of green bio waste. To adjust the fertilizer quality, parts from animal origin can be add as well.

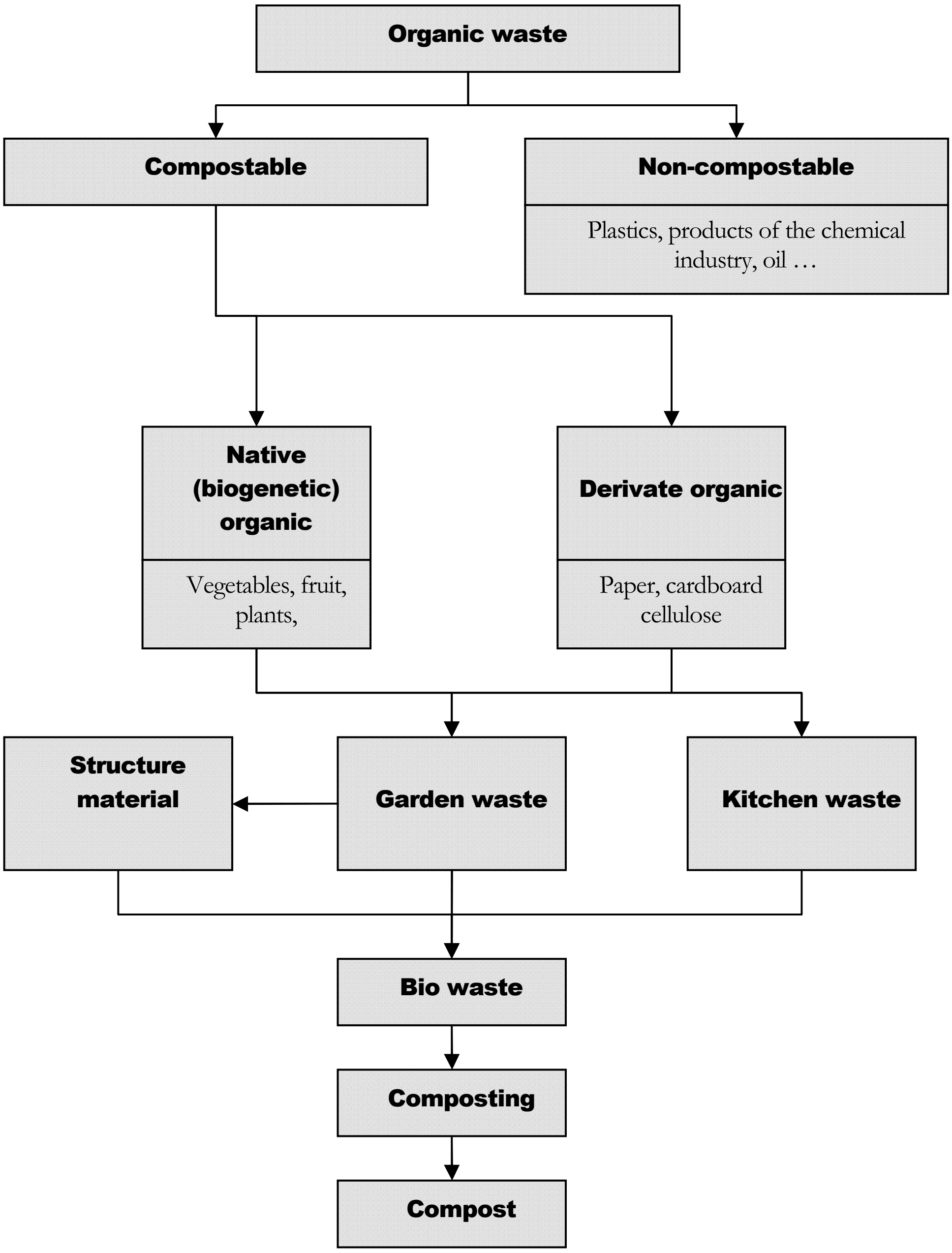


Figure IV-1 Categorisation of organic waste, modified [6]

SUITABLE INPUT MATERIALS

Structure material

(Organic) kitchen waste

- Leftovers form fruits, vegetables, and salad
- Fruit remains
- Coffee and tee bags, coffee and tee ground with paper filters
- Egg and nut shells
- Bread crusts
- Potato peelings
- Cut flowers
- Paper napkins (tissue), kitchen role and packing paper

(Organic) garden waste

- Grass cuttings
- Leaves
- Bark
- Tree and hedge cuttings, wood chips
- Roots
- Grinded coconut shells and shredded palm leaves
- Herbs / seeding weeds
- Flowers and plants, part of plants and diseases part of plants
- Moss
- Windfalls
- Green cuttings (parks, sports ground)

UNSUITABLE INPUT MATERIALS

Recyclable materials

- Plastics, plastic foam, polystyrene and plastic foil, plastic bottles and cups
- Metals, cans, compound materials and used glass
- Drink cartons, paper in bulk, used and polluted cardboard boxes

Harmful substances

- Batteries, paints and oil
- Medicines
- Glue, alkaline solutions / acids
- Pesticides and herbicides

Residual waste

- Cooked and prepared food (meal, fish and fruits) as well as leftovers (bones)
- Nappies / hygiene articles
- Glossy paper
- Cigars and cigarettes ends
- Pet litter

TOTALLY UNSUITABLE MATERIALS FOR COMPOSTING

- Treated wood (painted, woods preservatives)
- Kitchen waste with high fat content
- Polluted input material in general

Additives

Additional materials, which increase the fertilizer quality, the speed of decomposition and/or reduce the loss of nutrients, are called additives.

They are helpful but with a good input material composition, they are not necessary.

Table IV-1 Suitable Additives, modified [6]

Additive	Application
Additives out of the composting process	
Standard compost	**Rich in micro-organism for inoculation of the input material during the starting phase**
Mineral (inert) additives	
Rock phosphate flour	**Phosphate becomes during the composting process more soluble in water through the living activity of micro-organisms** **Useful for tropical soil with low availability of phosphate**
Sand	**In small amounts useful for its silica acid content, which plays an important role in plant growth and is set free by soil organisms**
Lime	**Stabilizing the pH – Level** **High calcium lack in the compost**
Rock dust (basalt meal, calcium, clay granulate)	**Contains minerals and trace elements** **Improves the biological stabilization of decomposed material**
Alginic chalk	**Fertilizer from harvested living chalk algae** **Excellent bacteria nutrient** **Suitable for neutralizing acidity of peat and bark**
Algae flour	**Fertilizer from harvested living chalk algae** **With much less calcium than alginic chalk** **Trace elements source**
Bone flour	**Consists mainly of phosphorous acidic chalk** **Increase the content of calcium and phosphate in the compost**
Blood meal	**Organic nitrogen fertilizer** **Used if no animal waste is available Similar to**
Horn flour	**Blood meal but with lower effect** **More suitable for the composting process**
Decomposable additives	
Animal dung (dairy cow, horse, water buffalo, sheep, pig, hen, duck rabbit)	**Organic nitrogen fertilizer**
Liquid manure	**Organic nitrogen fertilizer**

Structure material is necessary to improve the oxygen supply. Composting without structure is not possible. Hence, structure does not belong to the additives.

Composition of the input material

p. 42
5

For analysing the composition of input material by volume or mass, look at Chapter V Analyses at a composting plant.

Suitable compositions

The easiest composition by volume is to mix the garden (without the structure material) and the green waste together and than mix the garden and green waste one by one with structure material.

Because the bio waste characteristics are quiet different, it is not possible to give exact numbers about a suitable composition of the input materials. Hence, it depends on the maintaining person to find out which mixture is suitable or not. However, it is only possible to give some ground rules.

Some rules for a suitable composition (percent by volume)

- Do not add less than 40% and more than 60% as structure material.
- Garden waste or kitchen waste can be mixed until 60% (it is possible to mix only garden waste with structure or only kitchen waste with structure).
- If only grass cutting available uses below 50%. If the calculation is in percent by mass, structure material share should above 30%.

Carbon – rich and nitrogen – rich input materials

Look in the following table (Table IV-2 Nitrogen- and carbon- rich input materials) to get information about the C/N – ratio of some input materials.

p. 11 2

p. 53 5

Find a description of the C/N – ratio in the Chapter II Basic knowledge – composting and look in Chapter V Analyses at a composting plant to get information about the analyses of the C/N – ratio.

Table IV-2 Nitrogen- and carbon- rich input materials, modified [4] [6]

Kind of waste	**C:N – ratio**	**Kind of waste**	**C:N – ratio**
Nitrogen – rich waste		**Carbon – rich waste**	
Liquid manure	**2 – 3**	Fruit wastes	**35**
Chicken droppings	**10**	Leaves	**40 – 60**
Grass cuttings	**12 – 15**	Straw, oats	**48 - 60**
Vegetable waste	**13**	Bark	**100 – 130**
Kitchen waste	**23**	Bush pruning	**100 – 150**
Potato plants	**25**	Sawdust	**100 – 500**
Horse dung	**25**	Paper / cardboard	**200 – 500**

With this information, it is possible to adjust the C/N – ration if it is necessary by changing the composition of the input material [2].

Degeneration process

Range of process factors (monitoring values)

The keeping of the monitoring values is important to have optimal conditions for the composting process. If this is not possible, the composting process takes more time or stops. In problematic situations can be found some solutions in Chapter VI Trouble shooting.

As proposal, it is good to copy the table sheet with the monitoring values and put it on the first side to keep an eye on it every time.

p. 9 2

Find the description of the given parameters in Chapter II Process factors.

p. 38 5

For the determination of the monitoring values look at Chapter V Analyses at a composting plant.

Monitoring values

Table IV-3 Monitoring values during the decomposition process [11]

Parameter	**Composting**
Environment	**Aerobic** (with air)
Turning frequency	**Depend on the used method** **1. weekly method;** turn the windrows every week **2. temperature method;** turn the windrow if the temperature sinks below 40° to 30° degrees
Temperature	in the feedstock never rise above **70°degrees** **no rise above 40°C after turning the compost can be safely used or stored**
Moisture	Optimum according to the **fist probe** analyses (Chapter V
Rotting degree	Determination of the **rooting degree** (Chapter V Rotting degree / Dewar – Test)
Water content	**40 – 70 %WS**
pH -value	**7 – 11** (light alkaline)
Air avoiding volume	**30 – 50 %** (interstices volume in the windrow, depend on the composition of the input material)
C : N -ratio	**20 – 35**

Changing of composting parameters during the composting process

Monitoring the composting process is necessary for a good compost product and a short composting time. The knowledge about the temperature curve or the development of the total volume can greatly help to understand the underlining principals for composting. In addition, problems during the rotting process can be found and solved to get a satisfactory product.

TEMPERATURE

The temperature is the most important monitoring value during the composting process because it is very easy to measure and it shows the success of the process. Degradation of organic substance, through the living activity of micro-organism because of the self heating capacity, is the reason for differences in the temperature in the windrow (heap) centre (nucleus) and the surrounding temperature. The temperature curve goes also hand in hand with the mineralization and rotting processes.

The figure shows the characteristic temperature curve during the composting process in South – East Asia.

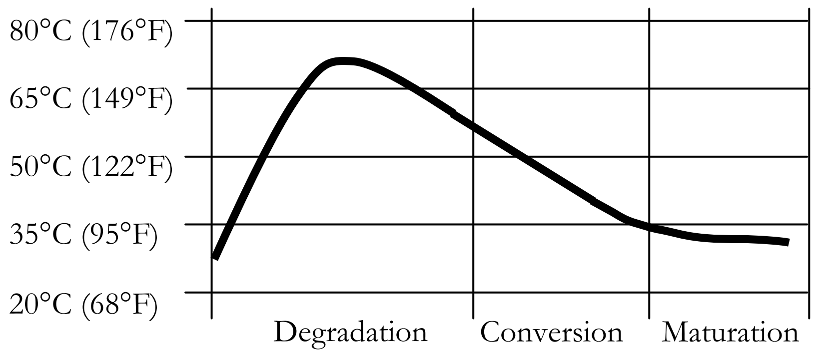


Figure IV-2 Characteristic temperature curve, modified [2]

As the figure shows, the composting process can be divided into three phases [2]

- A degeneration phase
- A conversion phase
- A maturation phase

High temperatures during the degradation phase are very important because if the temperature reaches and even surpasses 60 – 70°C the destruction of weed seed and pathogens takes place. The length of the first phase is decided by: [2]

- A suitable composition of the input materials with regard to the particle size and homogeneity
- Good environmental factors like a suitable moisture content, existence of oxygen and climatic influences

The time to reach the maximum temperature is about 2 – 5 days. At this stage of the composition process, the lightly breakable substance (hydro carbonate) is degraded.

The degradation of components, which are difficult to break down, occurs during the conversation phase. The duration time depends on ambient conditions. Hence, no specific timeframe can be given for this stage.

During the maturation phase, the activity of bacteria slows down. At this period, soil organism and worms populate the material and mix the mineral with the organic components. Clay-hums complexes are formed, which increases the nutrient content of the compost (especially plant available nutrients). At the end of this period (the final temperature do not rise above 40°C), the material is ready for compost preparation.

TOTAL VOLUME, TOTAL MASS AND BULK DENSITY

During the composting process, the total volume and the total mass of the windrow decreases. Because of the abrasion by other materials and of maceration, the size of particles decreases. Hence, the total volume becomes smaller and the bulk density increases. [5]

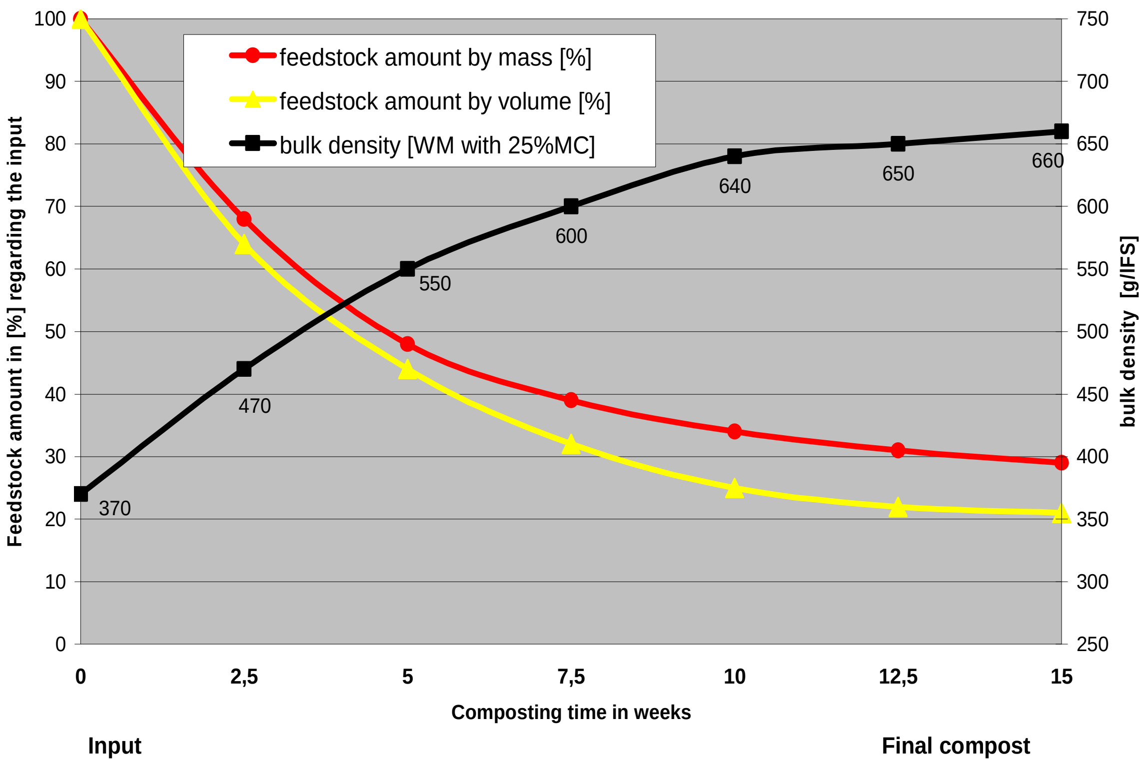


Figure IV-3 Volume reduction during the composting process, example form the pilot composting plant in Phnom Penh [8]

Bio-oxidation through the living activity of micro-organism to carbon dioxide is the reason for the mass reduction.

MICROBIOLOGICAL AKTIVITY

The direct determination of the microbiological activity is not possible. The temperature development as well as the total volume or mass reduction can be used to measure the activity.

As both figures show, at the first phase of the composting process (degeneration phase) the degradation of easy decomposed organic materials takes place and the activity of micro-organism increases rapidly. From there, the temperature increases to a high level and decomposition rate is very high. This leads to a rapid reduction in volume and mass. Because of the high activity, the oxygen demand is high.

During the conversation phase, the activity of micro-organism becomes less intensive. The temperature level drops and the decomposition rate becomes slower too. At this phase, components that are more refractory remain. Consequently, the total volume and mass reduction increases slower. The oxygen demand decreases as well. If the temperature in this stage does not rise over 40°C the compost can be used safely or stored.

At the end, the maturation stage, the temperature and the other indicators for the microbiological activity decline. If the lack of degradable organic substance as limiting factor is reasonable, the completion of the composting process and the increase of stability are reached. The material is ready for the compost preparation.

Pay attention, the former descriptions are all for optimal composting conditions. A lack of water inside the windrow, for example, leads to a decreasing activity and a falling temperature without finishing the composting process. If water is add the composting process starts again.

Compost

Advantages of the compost use as soil conditioner

- Increase of nutrient and organic content in the soil
- Improvement of the soil texture (better aeration and water retention)

Compost, the product out of the composting process, has different possibilities in use. However, before the compost is ready for sale or use, a basic quality should be guaranteed. The product quality depends on a number of factors like the input material, the maintaining and monitoring of a plant and the compost preparation).

The largest market for the compost is the agriculture industry but sometimes it is difficult to get in this market. Hence, study the minimum requirements and analyse the compost carefully.

"[..]Experiences indicate that the compost mass can be safely used or stored after the temperature has finally dropped to about 40°C."[5]

Compost quality

Minimum requirements of compost quality

- Save use in agriculture and horticulture
- Low content on potential harmful substances
- Constantly good compost quality
- Well-balanced nutrients content
- Storage able

Fertilizer application

The application of compost depends on the stage of maturation. Pay attention, never mix fresh compost with the soil and cover this layer with soil because the natural decomposition process is not finished. With a lack of oxygen (by covering the compost – soil mixture with soil) anaerobic processes start and this is harmful for the plants.

The main application of compost is soil conditioning and fertilizing.

Application	**Description**
Soil conditioner	**Use a 1 – 2 cm thick layer of compost and cover the soil Work the compost slightly into the soil**
Mulching	**3 cm thick compost layer 5 – 10 cm thick sieved structure layer Use (compost or structure) layer and cover the area around trees, hedges, …,**
Hence fertilizer	**2 cm thick compost layer to cover the soil**
Flower fertilizer	**Use maximum 4 l of compost for 1 square meter**
Grass fertilizer	**Sieve the compost with a 0.5cm (diameter) and use 2 l of compost for 1 square meter.**
Vegetables fertilizer	**It depends on the vegetable As flashover value use a 2 cm layer and work the compost slightly into the soil**
Room plants	**1 part of compost 1 part of potting soil Mix the two parts for fertilizing**

Table IV-4 Compost applications, modified [9]

"Golden rules" for the use of compost

- Never use only compost for seeding plants or vegetables, mix the compost with soil, because the fertilizer is to strong for young plant and germs.
- Do not storage the compost more than one year because the valuable humus – clay complexes degenerate into their inorganic components.
- Never use musty or festered compost.
- Do not use to much compost, because the fertilizer effect is may be too strong.

The given examples are flashover values from Germany. It is also possible to analyse the soil and in interdependency between the soil conditions and the plant requirements, to calculate the amount of compost, which is needed for optimal plant growing.

Compost quality in Germany

In according to the German Federal Quality Association Compost find attached in the table the quality guidelines for compost in Germany.

For more or detailed information, look at special German literature.

Table IV-5 Compost quality criteria in Germany [7]

Criteria	Description	
Hygiene	**A hygienically unreproachabel product with assure the exclusion of germs**	
Impurities	**Content of impurities (glass, plastic, metal) lager than 2mm is maximum of 0,5% by mass of dry matter**	
Stones	**Stone content shall not exceed 5% by mass**	
Plant compatibility	**Mature compost in the intended rage of application no content of phytotoxical substances (no nitrogen immoblilsation)**	
Degree of decomposition	**Matured Compost: stage IV or V (Dewar – Test / rotting degree)**	
Water Content	**Loose material ≤ 45 %DS** **Bagged material ≤ 35 %DS**	
VM	**Matured compost ≤ 20%VM**	
Heavy metals	**Zinc (Zn)** **Lead (Pb)** **Copper (Cu)** **Chromium (Cr)** **Nickel (Ni)** **Cadmium (Cd)** **Mercury (Hg)**	**400 mg/kg DS** **150 mg/kg DS** **100 mg/kg DS** **100 mg/kg DS** **50 mg/kg DS** **1,5 mg/kg DS** **1,0 mg/kg DS**
Declarable parameters	**1.) compost type and input material** **2.) maximum particle size** **3.) bulk density** **4.) salt content** **5.) pH value** **6.) plant nutrients** **7.) total content: N, P_2O_2, K_2O, MgO, CaO** **8.) soluble content: N, P_2O_2, K_2O** **9.) organic matter (VM)** **10.) net mass** **11.) name and address of the responsible dealer** **12.) advice for correct application**	

All these criteria can be analysed e.g. according with the German regulations, which can be found in the book: "Methods book for analysis of compost" [7]. If the analyses were sending to labs, check the analyses regulations.

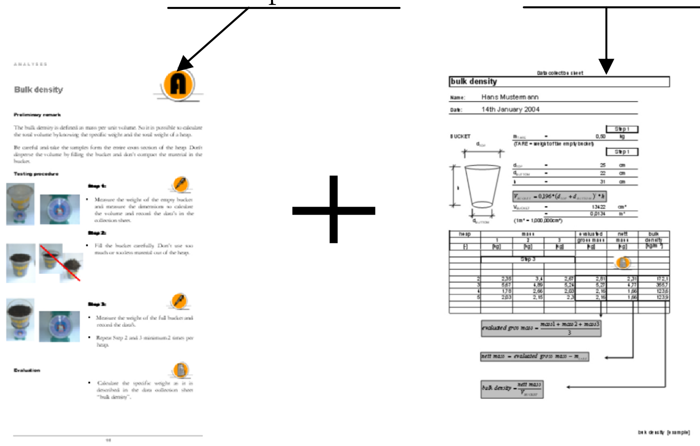
Chapter

5

Chapter V Analyses at a composting plant

The following table (Table V-1 Analyses at a composting plant) gives an overview, which analyses are important for the maintenance of a composting plant and in which timeframe they have to be done.

Descriptions and remarks for all tests are in the next pages. To get a better understanding use the description of a test and the sample in the data collection sheet.



Most of the given samples at the data collection sheet show real examples analysed at the composting plant at assumption college Thonburi, Bangkok Thailand. Hence, look at the appropriate chapters to get more information about composting and suitable solutions. These examples are at first given to get an imagination about the calculation procedure and to show that often it is not as it was expected.

The data collection sheets for every test find at the last pages with examples.

Please note the importance of sample taking at the page after the next page.

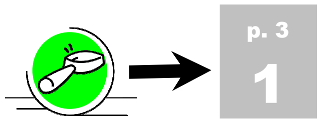
The chemical analyses (pH – value, C, N, P, K,) could be done e.g. according with German regulations, which can be found in the book: "Methods book for analysis of compost" (check the lab about the analysing procedure, that the analysed results can be compared with German results and values at this manual). [7]

Table V-1 Analyses at a composting plant

Analysis	**Time**				**Page**
	start	daily	weekly	End	
sample taking					**40**
input material					
Composition	B				48
total windrow Volume	B				42
bulk density	A				51
moisture content	A				52
pH - Value	R				
total C	R				
total N	R				
operation					
Temperature		B			46
fist probe		B			47
total windrow Volume			B		48
rotting degree			B		49
bulk density			A		51
moisture content			A		52
Compost					
total Compost Volume				B	44
bulk density				A	51
moisture content				A	52
pH – Value				R	
total C				R	
total N				R	
EC				R	
Available P				R	
Exchangeable K				R	

Explanation

B	Basic level
A	Advanced level
R	Research level



Sample taking

Preliminary remark

The compost sample should, supply a representative sample, be able to be carried out, and not require a major technical expenditure. [7]

If you like to analyse every parameter in according to the German regulations out of the table sheet you need about 20 l of fresh material.

Materials

Use only materials for sample taking and transport, which are not able to change the results of the analyses you want.

Carrying out the sample taking

Figure V-1 Sample taking skittle

- Take the samples from the entire profile section as a fine layer (not less than 30l) or use a drill (next item). Put the material on a cleaned concrete surface or a plastic foil.
- If a drill, (screw borer) is available take 5 borings out of one cross section and put the material on a cleaned concrete surface or a plastic foil.

Individual samples

It is taken out in one work step like a sample out of one cross section. The minimum amount of individual samples can be calculated with the following formula:

$$G\ [kg] = 0.06 * d\ [mm]$$

d … particle size

The coarser and less uniform the material, the larger the sample, which has to be collected. [7]

Collective samples, reduction of the collected material

A collective sample consists of well mixed (put the individual samples together and mix them with a shovel) individual samples. To reduce the amount use of the following method:

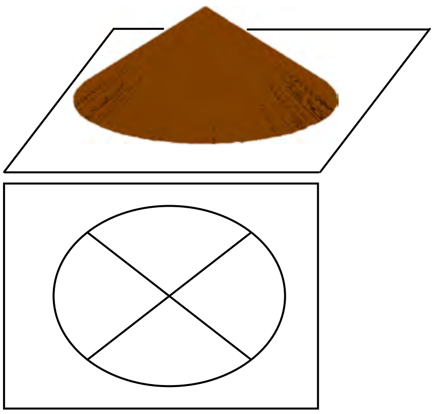


Figure V-2 Division of collective sample

Step 1:

- Put all the individual samples together and mix the samples very well on a plastic foil (or a cleaned concrete surface).

Step 2:

- Divide the well-mixed material in quarters by drawing a line with a shovel. Choose a quarter (25% of the material) and put it away.

Step 3:

- Do Step 2 repeatedly until you have reached the required volume.

Transport

The samples should be transported in well-sealed PE containers and should be in the laboratory after 24 hours. If it is possible, try to transport the samples cooled.

Remark

Any deviations from the described methods should be noted very carefully.

These steps are very important to avoid analysing mistakes.

Input material

Preliminary remark

The data collection sheet "composition input material" is divided in three parts like the three levels. For every part or level, a separate data collection sheet was designed.

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4

Look at the Chapter IV Input material about a good mixture for the input material. Do not forget to name the windrow with a sign.

Ratio of input material by volume

Testing procedure

Step 1:

- Measure the dimensions of the bucket (or something like this) you use for transporting the input material and calculate the volume of the bucket
- Describe the different kinds of input materials after their optical properties.

Step 2:

- Fill the buckets up to the top and count every bucket to build the windrow.
- By using pre-treatment, count the buckets before the treatment.

Kitchen waste
(Only green cabbage)

Evaluation

- Calculate the volume of the different kinds of waste and the input material ratio by volume.
- Calculate the amount of piled waste as it is described in the data collection sheet "total windrow volume".

Bulk density and total mass

Testing procedure

Step 3:

p. 51 5

- Measure the bulk density of every kind of input material.

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- If it is possible, analyse the MC of the input material.

Evaluation

- Calculate the input mass of the different kinds of waste and the input material ratio by mass.
- Calculate the total mass of the piled waste

Remark

- If a big scale is available, it is also possible to measure the whole charge. Then calculate the total mass by sum up all charges.

Chemical analyses

Remark

- Inscribe the samples carefully and note the given name in the table. Also, make a note of the laboratory.
- Take the sample as it is described in this chapter.
- Look after the testing procedures in the laboratories and compare these with the German regulations. If they are different, use specific literature to compare the results with the expectations.
- For the determination of the organic carbon look at the test in this chapter.

Compost

Preliminary remark

The data collection sheet "compost" is also divided in three parts like the data collection sheet "composition input material".

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4

Look at Chapter IV Input material for good compost properties.

Total compost volume

Testing procedure

Step 1:

- Measure the dimensions of the bucket you use for transporting the compost.

Step 2:

- Note in the sheet from which windrow the compost is.
- Fill the buckets up to the rim and count every bucket of compost

Evaluation

- Calculate the total volume of compost by multiply the number of buckets with the bucket volume.

Bulk density and total mass

Testing procedure

Step 3:

p. 51 5

- Measure the bulk density of compost.

p. 52 5

- If it is possible analyse the MC of the compost

Evaluation

- Calculate the input mass of the compost by multiply the bulk density with the total volume.

Chemical analyses

Remarks

- Inscribe the samples carefully and note the given name in the table. Also, make a note of the laboratory.
- Take the sample as it is described in this chapter.
- Look after the testing procedures in the laboratories and compare these with the German regulations. If they are different, use specific literature to compare the results with the expectations.

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- For the determination of the organic carbon, look at the test in this chapter.

Temperature and fist probe

Temperature

p. 9
2

Preliminary remark

The temperature is a very important indicator in the composting process. Measure the temperature in nucleolus (centre) minimum three times per windrow. The outside temperature is also important to judge the rise and fall during a week.

Testing procedure

Step 1:

- Divide the windrow in (minimum) tree section to measure the temperature on the same point every day

Step 2:

- Put the thermometer into the windrow and wait five minutes if you use a normal thermometer without an electronic display. Then pull the thermometer out of the windrow and look immediately for the temperature.

- By using a thermometer with electronic display wait, until the temperature value is constant.

Remark

- In the same data collection sheet please collect also the data about, the fist probe, the irrigation of water, and so on (look at the sample in the data collection sheet or in the description of the moisture content).

Fist probe

Preliminary remark

The importance of water for the composting process

p. 10
2

It is very easy and fast test to measure the moisture content of a compost windrow. Please note your results (wet, dry, good) in the data collection sheet "temperature, fist probe, and irrigation of water".

Testing procedure

Step 3:

- Remove the first dry layer of a composting windrow and take a sample with the fist out of the windrow.

Step 4:

- Close the fist and press the sample in the fist.

- If water comes out of the fist the material, it is too wet.
- If the material crumbles or fall apart when you open the fist the material is too dry.
- By realising the hand, the material should be hold together and feel moist.

Remarks

- If the result shows that, the material it is, too wet stop irrigation and open the windrow or turn the windrow.
- If the material is too dry irrigate and note the volume of used waster in the table sheet

Total windrow volume

Preliminary remark

To calculate the total windrow volume approximately, use the following easy method.

Testing procedure

Step 1:

- If it is a triangle windrow measure, the length, the bottom width, and the height.

- If it is a trapezoid windrow measure, the length, the bottom width, the top width, and the height.

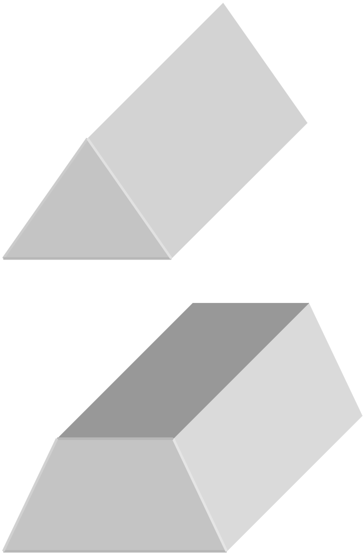

Figure V-3 Triangle and trapezoid shapes

Evaluation

- Calculate the volume as it is described in the data collection sheet "total windrow volume"

Rotting degree/ Dewar – Test

Preliminary remark

The self-heating capability of fresh compost substance through the degeneration processes is used to measure the compost degeneration quality. Very important for this test is an optimum and standardize water content. This can be checked by fist probe.

Testing procedure

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5

Step 1:

- Sieve the fresh original sample to < 10mm and check the water content of the sieved material with the "fist probe" (if the material is too wet dry the material to adjust the water content, if it's too dry add water)

Step 2:

- Fill the sieved and checked fresh material without pressure in the dewar vessel. Bump the vessel with careful pushes on the ground.

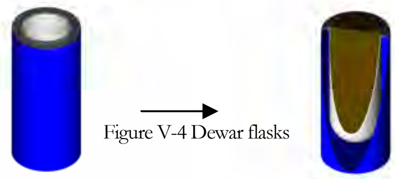
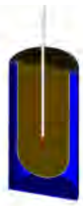


Figure V-4 Dewar flasks

Step 3:



- During the test, take the vessel to an air-conditioned room with 20°C room temperature. Every day measure minimum two times with a difference of eight hours per day, the temperature.
- The test is over after the temperature goes down. Normally it takes two until five days to finish the test.

Evaluation

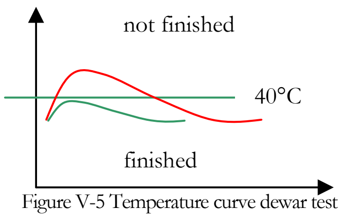


Figure V-5 Temperature curve dewar test

- If the maximum temperature is below 40°C degrees, the compost is ready to work out.

Remarks

- In according to the German regulations [7] to compost quality was divided in 5 stages of rotting degree. The criterion to judge to compost quality is also the maximum temperature (T_{max}).

Rotting degree I:	T_{max} = 60 – 70°C
Rotting degree II:	T_{max} = 50 – 70°C
Rotting degree III:	T_{max} = 40 – 50°C
Rotting degree IV:	T_{max} = 30 – 40°C
Rotting degree V:	T_{max} = 20 – 30°C

Please note, “compost with rotting degree II and III is designated as fresh compost, compost with rotting degree IV and V as finished compost” [7].

Bulk density

Preliminary remark

The bulk density is defined as mass per unit volume. Therefore, it is possible to calculate the total volume by knowing the bulk density and the total mass of a windrow.

Be careful and take the samples from the entire cross section of the windrow. Do not disperse the volume by filling the bucket and do not compact the material in the bucket.

Testing procedure


Step 1:

- Measure the mass of the empty bucket and measure the dimensions to calculate the volume and record the data's in the collection sheet.

Step 2:


- Fill the bucket carefully. Do not use too much or too less material out of the windrow.


Step 3:

- Measure the mass of the full bucket and record the data's.
- Repeat Step 2 and 3 minimum 2 times per windrow.

Evaluation

- Calculate the bulk density as it is described in the data collection sheet "bulk density".

Moisture content

Preliminary remark

The importance of water for the composting process

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The moisture content is the mass of water in the windrow/sample to the mass of the dry substance in percent.

To measure the optimal moisture conditions the fist probe is useful as a first approach. Some materials like paper and wood are able to save quiet lot water and so the bulk density of dry and wet material can be varying.

Testing procedure

Step 1:

- Measure the mass of the empty suitable (porcelain, aluminium) vessel. The used scale should be able the measure exactly 0.1g.

Step 2:

- Fill a fresh representative sample in the vessel and measure the mass of the fresh sample including the vessel.
- Dry the sample in an oven until the mass of the sample is constant (normal rule after 24 hours) by 105°C / 221°F.

Step 3:

- Measure the mass of the dry material including the vessel.

Evaluation

- Calculate the moisture content as it is described in the data collection sheet

Organic carbon

Preliminary remark

In according to the German regulations the organic carbon can be calculated out of the result of the determination of the volatile matter. That is why the following description is at first about the volatile matter and afterwards about the calculation of the organic carbon.

Testing procedure

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Sample preparation:

- Dry the unscreened fresh material by 105°C in an oven until the dried mass is constant.
- Use a suitable grinder to grind the material of at least 30g dry substance.

Step 1:

- Measure the tare mass of the empty porcelain vessel. The scale should be able to read 1 mg exactly.
- Measure the mass of the porcelain vessel including the prepared sample (approx. 5g dried and ground sample)

Step 3:

- Burn up the material at 550°C in a box type furnace, until the mass is constant.
- Cool down the hot porcelain vessel with a desiccators and afterwards measure the mass again.

Evaluation

- Calculate the volatile matter at first.
- Multiply the volatile matter with the factor 0.58 to calculate the organic carbon.

Chapter 6

Chapter VI Trouble shooting

Problems with the composting process, maybe the answer is in this chapter:

Table VI-1 Trouble shooting

Problem	***Reason***	***What to do***
Bad smell / odour	Aeration is to less Too much water inside the windrow	Turn the windrow and mix wet sections with dry material Add structure material to lift up the natural aeration Cover the windrow during heavy rain periods (only if the composting plant is not covered with a roof) Stop irrigation and open the windrow until the moisture is optimal again
A lot of animals in the windrow	The ratio of cooked waste or parts from animal origin is to high	Avoid cooked waste and parts from animal origin Loosen up the material by turning the windrow
Slowly decomposition process	Bad composting conditions	Adjust the process factors
Slow temperature in the initial phase	low pH-Level	Reduce the storage time for the input material Add stone flour ($CaCO_3$) to rise the pH-Level

Low temperature during the composting process	To less "green" waste	Change the composition of the input material because the structure content is to high
High temperatures at the end of the process	Degeneration of strong degradable substrate	Sieve the material and storage the compost separately and monitor the temperature
High temperatures in the compost	Degeneration process is not "finished"	Do not pack the compost into bags wait until the temperature goes down
Bad compost quality	high moisture content Less nutrients because of the input material	dry the compost Add dung (manure) to lift up the nitrogen content

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