Module 04 : Planning operations

Week 03A:
Design technology systems for nutrient recovery

cewas
IWMI
International Water Management Institute

Resource Recovery and Reuse (RRR) Entrepreneurship

Week 3.A module 4: Design technology systems for nutrient recovery

“Welcome to week 3.A of module 4: Design technology system for nutrient recovery”.

This week we are going to look at selected **treatment technologies** that convert organic solid waste into compost.

Specifically, I will be talking about composting and co-composting.

Composting is a biological degradation of organic matter into a homogeneous hummus rich product, called compost.

Compost is an excellent product that retains part of the original nutrients present in the waste. When it is applied to soil, it increases its organic and nutrient contents, improving its structure and fertility.

Composting occurs under controlled aerobic conditions, in which air breathing microorganisms, such as bacteria and fungi, mineralize biodegradable organic matter, while carbon dioxide, water and heat are liberated.

Many different types of organic solid waste are suitable for composting, including yard waste (branches, leaves, grass), food waste, agricultural waste and manure. Usually, as input we will need a mixture of **brown** or dry material, and **green** or wet material.

All organic material will eventually decompose. The speed at which it decomposes depends on factors such as:

- Carbon to nitrogen ratio of the material
- -Particle size
- Moisture content
- Aeration, or oxygen in the pile
- Temperature
- pH

Under optimal composting conditions, the degradation happens in three phases:

1. the mesophilic phase, which lasts for a couple of days;
2. the thermophilic, which can last from a few weeks to several months, and finally,
3. a cooling and maturation phase which can last several months.

During the thermophilic phase the temperature can rise up to 55-70 degrees Celsius due to the metabolism of the microorganisms, which contributes to hygienization of the material.

The end of the composting process is reached when the inner temperature of the pile is similar to ambient temperature.

Because the conversion of carbon from the solid to the gaseous state, composting reduces the mass and volume of organic materials. As a rule of thumb, you can estimate a volume and mass reduction of 50%. However, the actual mass and volume loss will depend on the process conditions.

A typical composting system is composed of: pre-treatment, principal treatment and value addition.

Pre-treatment includes:

Sorting of material, which means separating degradable and non-degradable waste like glass, plastic and metal. This can happen at the source, if households are trained to do so, or it can happen in your composting plant. The sorting can be done by hand with rakes and shovels, or with more sophisticated sorting systems like conveyor belts. Keep in mind that all the rejected waste, needs to be **collected and further treated or disposed**.

You might also need to **shred or chop** the waste to increase the surface area of the waste, so the microorganisms can do their job easily.

Finally, you will need to **mix** different types of waste to achieve the needed carbon to nitrogen ratio of about 20 to 1 or 30 to 1.

As a rule-of-thumb, the mixture of **equal volumes of 'green' materials** (such as fresh grass clippings, manure, or kitchen scraps) and **'brown' input materials** (like dried leaves and plants, branches and woody materials) provides an appropriate C:N ratio.

The principal treatment is the step in which the actual composting happens. There are two key technologies that are relevant to you: **Windrow composting and Box composting.**

The windrow composting can also be:

Passively aerated

And **forced aerated,** in which active aeration is achieved by means of blowers. This technology will not be presented in this course.

In windrow composting, the prepared solid waste is piled into long heaps called windrows and left to decompose. In this case aeration is ensured by the addition of bulky materials and by periodical turning.

Composting piles have a width of 1.6 m and a maximum height of 1.6 m. The length of the pile depends on the space available and the amount of the incoming waste, but 2 to 3 m is generally recommended.

The composting area should be a **concrete slab** slightly sloped (1%) towards one side to allow excessive water or leachate from the compost heaps to flow into a drain. This water should be collected and properly disposed of.

The passive aeration enhances the windrow composting technology by means of hollow perforated pipes or other type of passive aerators, that regulate heat and oxygen supply.

While box composting has a lot of similarities with the windrow technology, it is done in containers. These are boxes made out of bricks, wood or mesh with holes in between and a screen at the bottom.

Typical dimensions of the box are 1.5m width and 1.2 m height, with a minimum length of 1.5 m. The box could be longer, depending on the space available. The space between the boxes should be at least 0.75 m.

This technology is preferred in specific environments that are prone to animal invasion, congestion or lack of space.

Now, how do you choose which composting technology to use?

Think about the following factors:

- -Box composting requires less space than windrows. However, ensure that the land is available in the long-term.
- Also, box composting requires a considerable investment in construction.

- However, box composting requires less manpower than windrow composting and is less labour-intensive.

The type of composting technology you choose, will indicate how the waste will be set-up, either in windrow piles or in boxes.

Once your system is in place, it is key to ensure that there is sufficient supply of air.

Initially the material should be **turned** 2 to 3 times per week as the composting process is very active with a high oxygen demand and reaching temperatures up to 70°C. When the temperature starts to drop, the pile still needs to be turned every 10 days. In total 5 to 8 turnings during 40 days are necessary.

Also, you need to ensure that the **temperature** remains at around 65°C for at least 3 days to ensure rapid composting and the destruction of weed seeds, insect larvae, and pathogens. However, if the temperature goes beyond 70°C it might inhibit the microbiological activity.

You also need to ensure that the **moisture** content of the pile is of 40 to 60%. You can add water to the pile while turning the system.

After about **40 days**, the piled material has a soil like colour and the pile temperature has fallen below 50°C. This indicates that the process has entered the **maturing** phase.

At this point you can take the fresh compost from the box or the windrows and transfer it to a maturing area with bigger piles. During about 3 weeks, the microorganisms will break down more complex organic materials until the compost reaches ambient temperature and has a dark brown colour and earthly smell.

The value addition step starts with the **screening,** to remove larger particles, especially if the client requires finer compost.

The screening is done either by using a **flat frame sieve** or a **rotating drum sieve**.

As matured compost typically has a nitrogen content of 1-2%, it should not be labelled as fertilizer.

However, you can **enrich** your product by adding supplements of nutrients such as nitrogen, phosphorus and potassium, producing fortified compost.

Finally, the products are either sold in bulk or packaged in bags of 10, 20 or 50 kg, depending on the preferences of your customers.

As you have seen in module 2, composting can include a wide variety of biosolids and organic wastes. In farming, composting of crop residues mixed with manures from livestock production is a common practice on a global scale. However, co-composting of faecal sludge with organic solid waste is less widespread and you must consider the institutional set-up, regulations as well as the socio-cultural conditions, before you plan a co-composting project.

The co-composting system is the same as composting of organic waste that I just introduced, and therefore the control parameters remain the same.

The main difference is that now in the pre-treatment step, besides preparing the **organic solid waste**, you also need to pre-treat the **faecal sludge**, so that its characteristics are adequate for the composting process. One dewatered, the sludge should be **mixed** with the organic solid waste at a ratio of 1:2 to 1:3 for optimal co-composting conditions.

Faecal sludge might content solids such as plastics, rags and other trash that need to be removed before entering to the next treatment steps. These solids usually are removed by **screens** and must be **collected and properly managed**.

Because the moisture content of sludge is usually very high, you need to reduce the water content to ensure aerobic conditions.

This requires the use of **solid-liquid separation** systems and **dewatering**.

Solid-liquid separation happens in **sedimentation or thickening ponds**, in which liquid faecal sludge is discharged and allowed to rest. This way, settleable particles go to the bottom, while the supernatant on the top needs to be decanted and treated separately.

Usually, you will need two tanks operating in parallel, so one can be in operation while the other is emptied. To achieve maximum efficiency, you should plan for a 4-week loading and 4 week resting period.

This process reduces sludge volume, usually by 50 to 90% by allowing the solids' concentration to increase to 5 to 10% in mass.

After the solid-liquid separation, the sludge still needs to be dewatered to reduce its moisture content. This can be achieved by non-mechanical dewatering or mechanical dewatering.

Non-mechanical systems rely mostly on percolation to remove the free water and evaporation to remove the remaining water. Such facilities are recommended for small plants.

Unplanted drying beds are the cheapest and most frequently used technology for faecal drying. These are simple, permeable beds, whose bottom is lined with perforated pipes to drain the leachate that percolates through the bed. On top of the pipes are layers of gravel and sand that support the sludge and allow the liquid to infiltrate and collect in the pipe. It should not be applied in layers that are too thick, no more than 20 cm, or the sludge will not dry effectively. The final moisture content after 10 to 15 days of drying should be approximately 60%. When the sludge is dried, it must be separated from the sand layer and it should be ready for composting. The leachate that is collected in the drainage pipes must also be treated properly, depending on where it is discharged.

To improve drying and percolation, sludge application can alternate between two or more beds.

Mechanical dewatering consists of the use of machines for dewatering and thickening of sludge. Four technologies that are widely used for dewatering sludge from wastewater treatment plants are the belt filter press, the centrifuge, the frame filter press, and the screw press. A preliminary addition of flocculant is recommended for all of them to facilitate the separation of liquid from the solid particles.

You have now learnt about the different technologies available for composting and co-composting with faecal sludge.

When assessing which composting technologies you will use for pre-treatment and treatment, you need to ask yourself the following questions. Use the worksheet below to record your findings.

- What suitable technologies are available locally for the pre-treatment of solid waste and faecal sludge and their composting? What has been the experience with them?
- What is the level of performance and efficiency of the different technologies?
- Are there resource constraints related to labour, land, energy, water or other factors of production?
- If there is break-down in the plant, are there capacities and resources available for the timely repair and maintenance?

To learn more about composting, I recommend you to read the publication “Decentralised composting for cities of low and middle-income countries” by EAWAG and Waste concern 2006.

If you want to learn more about co-composting, the Resource Recovery and Reuse Series 3 by the International Water Management Institute gives a great insight into this technology.

Finally, to learn more about faecal sludge management, I recommend you to read the Systems Approach for implementation and operation, published by the International Water Association.

Now that you have learnt about the different technologies for composting, it is time to plan your own technology system for nutrient and organic matter recovery. Record your findings in the worksheet.

Today you have learnt that as a rule of thumb, composting reduces the mass of solid waste by about 50%.

In module 2, you have calculated your sales volume, which is the amount of compost you need to produce and sell per unit of time, let's say days.

This means that the required amount of organic solid waste to compost is equal to sales volume divided by 0.5.

Assuming the density of the organic solid waste as 0.4 to 0.6 kg/L, you should be able to calculate the number of piles or boxes you need to start each day.

You can also estimate the time of a production cycle, which includes the time it takes to prepare compost from the moment the solid waste arrives until it is ready to sell. Here, you will need to make some assumptions, for instance how long it would take to sort the waste and prepare the pile. This will give you the time of a production cycle.

With this new information it is time for you to describe the specifications of each treatment step: what is the type of technology, the capacity of each step and the list of all equipment needed. Record your findings in the worksheet.

In week 4, I will guide you through the planning of your resources. That's why it is very important to know the specifications of your composting plant.

I will see you there!"

List of Reference:

Graph sources:

- Unless otherwise noted, all graphics and case studies from OTOO, M. (Editor), DRECHSEL, P. (Editor) (2018): *Resource Recovery from Waste. Business Models for Energy, Nutrient and Water Reuse in Low- and Middle-Income Countries.* International Water Management Institute (IWMI). Routledge
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*Information and data were compiled to our best knowledge, but mistakes remain possible. In such a case we apologize and kindly ask for feedback to correct them.