Composting solid municipal waste, a determinant process for an integrated waste management

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Abstract. Composting municipal solid waste is a beneficial recycling tool. Its use in safe conditions in agriculture depends on the quality of the compost. Composting a maximum amount of greenery and food waste (from households and institutions, courtyards, gardens, parks, markets and street waste) is one of the proposed targets for reducing biodegradable waste. The paper aims at presenting a model of the composting process in the best technical and environmental conditions. Considering that for Romania, the most important issue to be addressed is the reduction of the amount of waste to be deposited; this can be done through a real selective collection and the production of compost from biodegradable waste. If the sorting of biodegradable waste is done at the site of production to obtain compost, that means not only the reduction of the amount of waste to be deposited but also a source of money, and the amount of leachate and biogas produced would be much diminished. Also, the presence of the specific creatures of this ecosystem would decrease considerably. Taking into account the limited nature of natural resources, the recovery, regeneration and sustainable use of resources are the essential elements of an environmental policy. Composting thus provides the opportunity to create SMEs as well as to increase employment and professional qualifications. Not all wastes have to be dumped, they can be utilized, separated and thus large amounts of raw materials and energy resources can be saved, and the area occupied by landfills can be reduced. In the waste management process, an important role is played by the local public authorities (municipalities and local councils), who have the obligation to collect selectively and transport in time the entire quantity of waste produced.

1. Introduction
The biodegradable waste consists of:

- Biodegradable household waste collected separately;
- Green waste;
- Biodegradable waste in markets;
- Waste from restaurants.

The objective of the plant described in this paper is to compost this waste in the best technical and environmental conditions. For this purpose, a composting plant is proposed in the form of five fermentation tunnels.
The composting unit includes a reliable and reliable treatment center for a nominal capacity of 52 tons of compost/day and is dimensioned for a maximum flow of 63 tons of compost/day.

For the optimization of the composting process a series of technical solutions have been taken into consideration from the start:

- the reception area was designed based on the "first in, first out" concept, which prohibits any conflict in the management of selectively collected organic waste;
- the feed area where the chopping line is set must be marked separately;
- it is provided a mobile crushing and screening equipment in order to guarantee good material for composting;
- it was established an area of administration and temporary storage of biodegradable input waste;
- there are five insulated aeration tunnel modules with temperature control to ensure organic matter degradation performance and optimized odor management;
- to capture the vicious air from the decomposing processes a a collecting system in the area of reception-chopping and composting tunnels is designed;
- the use of biofilter for air purification in tunnels and the reception-chopping hall is foreseen.

2. General description of the composite installations

2.1 Material and dimension balance
To compile the material balance and the installation sizing, the following hypotheses were considered:

- the presence of at least 30% of green waste;
- porosity of the product after grinding > 30%;
- C/N Report > 30;
- density after grinding:
  - 38-40% DM (dry matter)
  - 75% NSOM (non-synthetic organic matter)

2.2. The flow of the composting process
The proposed biodegradable waste composting plant (Figure 1) is based on a batch process that takes place in concrete tunnels [1]. After visual inspection, and if manual sorting is required by removing bulky objects (metal, boulders, plastic objects) that could damage the chopper, slow chopping, the products are composted in a single step to guarantee a minimum content of matter dry 50% MU (dry mass).
After 4 weeks of composting, the product is driven to the ripening area and then refined / sieved. Here he is subjected to other granulometric reductions to obtain quality compost.

For an active administration of the process, the quantities reached in the maturing stage will be mixed. These mixing operations avoid compaction of the layers, improve air exchange, allow for better product hygiene (destruction of granules, pathogens and larvae).

Moreover, these blends favor granulometric reduction and allow for increased production of good quality compost.

3. Process note
3.1 Receiving products
Organic wastes are discharged into the reception corridor. An operator verifies visually, at loading or loading in the front loader cup, the conformity of the delivered products and, if necessary, manually extracts nonconforming materials, such as objects that can cause blockages, large plastic objects, pieces of concrete, can be found in organic waste and can affect plants (chopper, sieve).

The reception area is surrounded by 4 m high concrete walls. The product is placed in piles along these walls to minimize the scattering of waste.

3.2 Supplying the chopper
The waste is then taken with a charger and poured into the 6 m³ load hopper of the Chopper. The shredder deflects green waste, opens plastic bags, and reduces waste granulometry. Upon leaving the crusher, a buffer deposit of 3.5 x 7 m (about 100 cubic meters) is provided before feeding the composting tunnels (Figure 2).
3.3. Description of the composting installation

After grinding, the products are transported in composting tunnels (Figure 3). The station consists of 5 concrete tunnels with each interior dimensions of 38 x 6.75 x 5 m. Fermentation reactors are modular, with forced ventilation, controlled and modeled. The identification of the products that have reached the final fermentation deadline is carried out throughout the process through a careful management of the batches, respectively checking the control parameters (temperature and humidity).

The air emitted at the fermentation layers is captured for treatment in an air treatment plant. In the case of a composting corridor, the air emitted through each compartment is present in the corridor being sucked by the ventilation system. There is, therefore, a difficult working atmosphere for the charger driver. This equipment must, therefore, be equipped with air filters and air conditioning.

As in the case of tunnels, the vague air emitted by the fermentation layers is directly captured in the air treatment station without any escape to the charging corridor as the tunnels are closed in front of a door. In the case of compartments, the structure of the building is subjected to strong stress related to the air (moisture, pH, acidic CO₂ molecules), which require costly measures (double lining, lacquering), thus rendering the tunnels cheaper of concrete. In addition, due to the low volume in tunnels and the phenomenon of series volume, the air flow to be treated is much less important in the tunnel, involving lower air handling capacities and thus lower costs.
Figure 3. Composting tunnels under construction and view inside the tunnel

The tunnels are designed to control the degradation of organic matter. If the fermentation is not well controlled, degradation of organic matter would not be optimal and the production of smell molecules increases significantly. In this context, efficient oxygenation of matter in the fermentation process is a priority.

To facilitate this, 3 rows of pipes into the concrete slabs of each tunnel were chosen. The 3 rows, due to the small gap between the perforations, guarantee a homogeneous diffusion of air into the product, representing a necessary factor in temperature control.

The two ventilation lines for the extraction of vicious air are fed by a direct high-pressure centrifugal fan with a flow rate of 4,700 m$^3$/h and a static pressure of 5000 Pa.

The advantage of blowing ventilation is that the heap is avoided, as opposed to suction, which tends to compact the heap, making access to oxygen more difficult.

An irrigation ramp is attached to the upper tunnel. The design of the holes distributed along the ramp length ensures humidification of the entire tunnel. Irrigation is done automatically due to the presence of solenoid valves on all ramps. Each fan in the tunnel is automatically controlled based on the measurements transmitted by a temperature probe located in the material of each tunnel.

Temperature monitoring (Figure 4) is important for automatic regulation of ventilation and irrigation according to the needs of micro-organisms.

Figure 4. Compost measuring rod
The control system for composting management and traceability provides the following functions:

- Automatic compost control;
- Measurement and recording of T °C;
- Batch management with recording and graphical display;
- General supervision report in the Control Center.

The adjustment system is made by the associated programmable automatic software.

The tunnel doors are in direct contact with the atmosphere inside the tunnel (Figure 5). For this reason, their conception must ensure:

- A Longevity of the equipment against the vicious air currently emitted by the fermentation layers inside a tunnel;
- Absence of vented air emissions to the circular corridor.

![Figure 5. Example of gates in the compost tunnel](image)

To ensure that the two above mentioned points will respect the mounting characteristics, the installed gates will be secured and sealed to the top and sides. They will be moved using a rack mounted carriage.

Tightness is possible due to a rubber seal on which the gate is closed. As the vicious air is sucked into the tunnel, fresh air needs to re-enter. At the bottom of the gates, a few inches of clearance allows the air in the central circular area of the charger to re-enter the tunnel.

This interspace is at the bottom of the gate, because the vicious air emitted by the fermentation layers ascends to the upper part of the tunnel because of its relatively high temperature. Thus, air circulation is logical: from the bottom of the gate to the roof of the tunnel where the air intake is located in the direction of the air treatment plant; the airflow created by forced ventilation is the same as the natural airflow created by the temperature difference between the layers and the height of the tunnel.

The chassis assembly will not be able to undergo corrosion under these conditions and will withstand the constraints imposed by the air from the fermentation.

3.4. Compost maturing and refining
After 28 days of fermentation, the product is transferred to the ripening area for a period of 56 days. After maturation, primary sieving using the second mobile site allows grain size separation by square meshes of 0-40mm.

Parts larger than 40 mm will serve as structures for the composting process in tunnels, ensuring a consistent process and balance of climate and micro-organisms. The parts with a diameter smaller than 40mm will be sieved in a second sieve, depending on the user needs. A 20 mm square sieve allows this refining to be accomplished.

Although the second gravel was not foreseen by the specification, its presence in the technological process is particularly important because it is necessary to separate the coarse material, which will be reused in the composting process, by the fine material to be sold. Without using the second gravel the process would be incomplete resulting in very poor, unusable quality compost. The fraction of more than 40mm can be used, depending on the quality, either in the composting process or will be transported to the landfill. The fraction between 20-40mm will be used either in the composting process or will be sold for land fertilization in agriculture. The fraction of less than 20mm will be marketed as a flower and fertilizer land.

3.5. Levigation management. Extracting air and odor treatment
The leachate recovered from the composting compartments, the biofilter and the air extraction nets will collapse into a buried tank of 50 m³. This tank is equipped with a pumping well that allows the use of the leachate in the composting tunnels.

All susceptible operations are carried out in closed and deodorized corridors. The air treatment system fulfills three functions:
• Dust catching,
• Deodorizing vicious air,
• Maintaining good working conditions for staff.

The principle we promote for air management in the unit is dictated by:
• Limiting olfactory emissions in the periphery of the installation,
• Capture as close as possible to the emission sources: suction line above the reception, preparation, fermentation zones in the closed tunnel.

Some principles will be observed for optimizing the installation:
• Places where smell removal is possible are put into the depression by suction through the openings (unavoidable in industrial construction but reduced as much as possible) by an important airflow from the outside.
• The most polluted air, especially the waste from fermentation, is directly sent for deodorization.
• A minimum flow of circulating air is maintained in each room.
• Polluted air is captured as close to the source as possible: dust capture near equipment, capturing air from fermentation directly into the tunnel.
• In large halls, the natural movement of the smoothest air masses is directed to the suction points due to a push-pull system that allows fighting the natural strains of heat stratification and external wind movements along with the leakage between protective elements.

Areas involved in air treatment are:
• The receiving and preparation area (grinding) of the composting material
• Fermentation tunnels

The air in the reception area is rehabilitated due to:
- A pipeline under the roof that aspires 20,000 m³/h.
- A helical fan of 5,000 m³/h that transfers the air to a biofilter, depending on the operation of the fans.
- An opening of air access in tunnels through gates between 6,500 m³/h and 30,000 m³/h depending on the operation of the composting fans.
- The rehabilitation rate is 2.5 volts/hour (calculated for an empty reception corridor).

In composting tunnels, around 6,000 m³/h of vented air emitted by fermentation is continuously sucked into each tunnel, or 30,000 m³/h in total. The 6,000 m³/h of each tunnel provides for the formation of the depression and a good capture and direction of the vicious air to the treatment zone. The number of rehabilitation per tunnel is 5 volumes/hour.

The air collection network is equipped with low points that allow condensation recovery (Figure 6, 7, Table 1).

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**Figure 6.** The air collection system inside the composting installation.
Figure 7. The air treatment system inside the composting installation

Table 1. Reception/chopping area and composting tunnels

|                         | Surface  | Volume    | Rate of rehabilitation | Suction flow |
|-------------------------|----------|-----------|------------------------|--------------|
| Reception/chopping area | 1700 m²  | 17000 m³  | 2,5                    | 50 000 m³/h  |
| Composting tunnels      | 1282.5 m²| 6412.5 m³ | 5                      | 30 000 m³/h  |

The design of the air extraction process is carried out in such a way that:

- Guarantee an optimal rehabilitation rate depending on the use of buildings.
- Reduce electricity consumption.
- Perform air purification to generate working conditions in accordance with work code recommendations, including dust handling.
- Direct air from less polluted areas to the most polluted.

The odor treatment system consists of an organic biofilter. The air is directed to a ventilating floor in a biofilter (composed of marine pine bark and peat) that allows the destruction of organic molecules. It is important to use a filter medium with a specific exchange surface for:

- Increase the phenomenon of absorption of odorous molecules before destruction.
- Increase the number of microorganisms responsible for destroying the molecules.

This biofilter is sized (308 m², 2 meters filter medium height, passage time: 44 seconds) to ensure efficient absorption and smell removal (Figure 8, Table 2 and 3).

An irrigation system will guarantee optimal humidity for the microorganisms responsible for destroying the smell molecules. The volume of the filter medium provided is approximately 612 m³.
Figure 8. Example of a biofilter

Table 2. Biofilter dimension note

| Parameter                | Value            |
|--------------------------|------------------|
| Flow                     | 50 000 m³/h      |
| Temperature              | 20-30 °C         |
| Relative humidity        | 100 %            |
| Nature of pollutants     | NH₃ and amines; H₂S and mercaptan |
| Washing reagents         | water            |
| Dimensions L x l x H (m) | 22 x 14 x 2      |
| Surface (m²)             | 308              |
| Time to pass             | 44 s             |
| Crossing speed (m/s)     | 0,05             |

Table 3. Parameters concentration at the exit of the biofilter

| Parameter | Concentration |
|-----------|---------------|
| NH₃       | < 15 mg/Nm³   |
| H₂S       | < 5 mg/Nm³    |
| RSH       | < 1 mg/Nm³    |
| UO        | 1000 UOE/Nm³  |

Various factors have an influence on the effectiveness of the composting process. Among them are: temperature, oxygen supply (i.e. aeration), moisture content, pH, C/N ratio, particle size and degree of compaction [2]. During composting, microbes break down organic compounds to obtain energy for metabolism and acquire nutrients (such as N, P, K) to sustain their populations [3]. C, N, P and K are the major nutrients needed by the microorganisms involved in composting [4], with C and N being the most crucial: C is used as an energy source while N is used for building the cell structure. Most scientist stated that when the amount of N is limiting, microbial growth decreases and thus result in slow decomposition of the available C.

The three major challenges associated with the composting process, including emission of odorous gases [5], [6], [7], difficulty in defining a parameter for assessing compost maturity [8] (and leachate production [9], are addressed in the proposed model of the composting installation including a suitable bulking agent and a large space required for operation.

4. Conclusions
Government has a role to play in supporting composting as an alternative to landfill by setting up programs and initiatives charged with providing loans and grants for composting facilities, together with the sustainability of composting processes. Such a long time approach can create job
opportunities in the communities. Another way government can support composting is by encouraging organic farming; creating a favorable market to promote the use of composts over traditional soil amendments and soil fertilizers as pointed out by specialists.

An equally important aspect is the assurance of all the necessary measures to avoid the pollution of surface water, soil and subsoil, for the protection of environmental factors, in the proximity areas taking preventive and control measures of accidental pollution, both during execution and exploitation of the works.

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