Vermicomposting of Unsorted Municipal Solid Waste

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Abstract

The Vermicomposting (aerobic composting with red earthworms) of unsorted mixed Municipal Solid Waste (MSW) being pioneered by Lavoisier, a Portuguese enterprise, with the support of the NGO Quercus, is an adaptation of an organic waste treatment technology that has been around for a long time. The innovation is the application of earthworm composting to the treatment of mixed MSW allowing immediate diversion from landfill and high levels of separation of recyclables.

The process, installed by the AMAVE - Municipal Association of River Ave Valley, includes a pre-composting phase in order to prepare the waste to feed the worms. Through pre-composting organic waste is digested by aerobic micro organisms. After this phase worms are fed with waste and digest the remaining organic matter, producing humus and cleaning plastics, glass and metals.

Keywords

Vermicomposting, Earthworms, Biowaste, MBT, Humus, Recycling, MSW, Plastic

1 Introduction

The vermicomposting (aerobic composting with red earthworms) of unsorted mixed MSW, being pioneered in Portugal by the enterprise Lavoisier with the support of the NGO Quercus, is an adaptation of an organic waste treatment technology that has been around for a long time. The innovation is the application of earthworm composting to the treatment of unsorted mixed MSW allowing immediate diversion from landfill and high levels of separation of recyclables.

The development of this technology started in 2005 with some tests in a pilot unit in Palmela, Setúbal. The results were very interesting and proved that earthworms could digest organic matter that makes up mixed MSW. Paper and cardboard disappeared, glass and metals were clean and plastics loose the odour of waste.

After those experiments, some visits to recycling facilities took place in order to check the opinion of recyclers about plastics and glass obtained through this process.

All the nine visited industrials showed saw good perspectives for the materials and so a decision was made to propose a project to the Portuguese Green Dot System (SPV – Sociedade Ponto Verde) to study the feasibility to obtain raw materials for recycling with this new technology on an industrial scale. The Green Dot System approved this project and 79 000 euros were then available to buy equipment for the Vermicomposting facility and to do the tests in the recycling units.

At the same time contacts were made with several multi municipal waste management systems to find out the possibility for construction of an industrial MSW Vermicomposting unit and finally the Municipal Association of the River Ave Valley in Guimarães (AMAVE) decided to go ahead with a project to treat 1500 tons of MSW per year, corresponding to a population of 4000 inhabitants.

The Municipal Association managed to get EU funding for this project in order to cover construction costs (137 000 euros) and so all the conditions were there to start this project: Money for construction, equipment and recycling tests and also a very complete team with an enterprise (Lavoisier), a Municipal Association (AMAVE) and an environmental NGO (Quercus).

The project was ready by April 2008, construction started in July 2008 and the unit started to receive MSW in January 2009.

2 The process in the AMAVE plant

Vermicomposting of MSW is basically the result of combining three waste management pro-cesses:

- Vermicomposting of organic waste
- Mechanical and Biological Treatment
- Plastic recycling

The unit in the AMAVE is prepared to treat 1500 tons of MSW per year in an area of 800 square meters.

The plant has a floor in concrete to prevent leachates polluting subsoil water.

It is covered by a greenhouse-like structure with 3 open walls and a closed area at one end in order to give good conditions to workers and to protect the equipment (Fig 1).

Figure 1 View of the vermicomposting unit

The process includes the following steps (Fig 2):

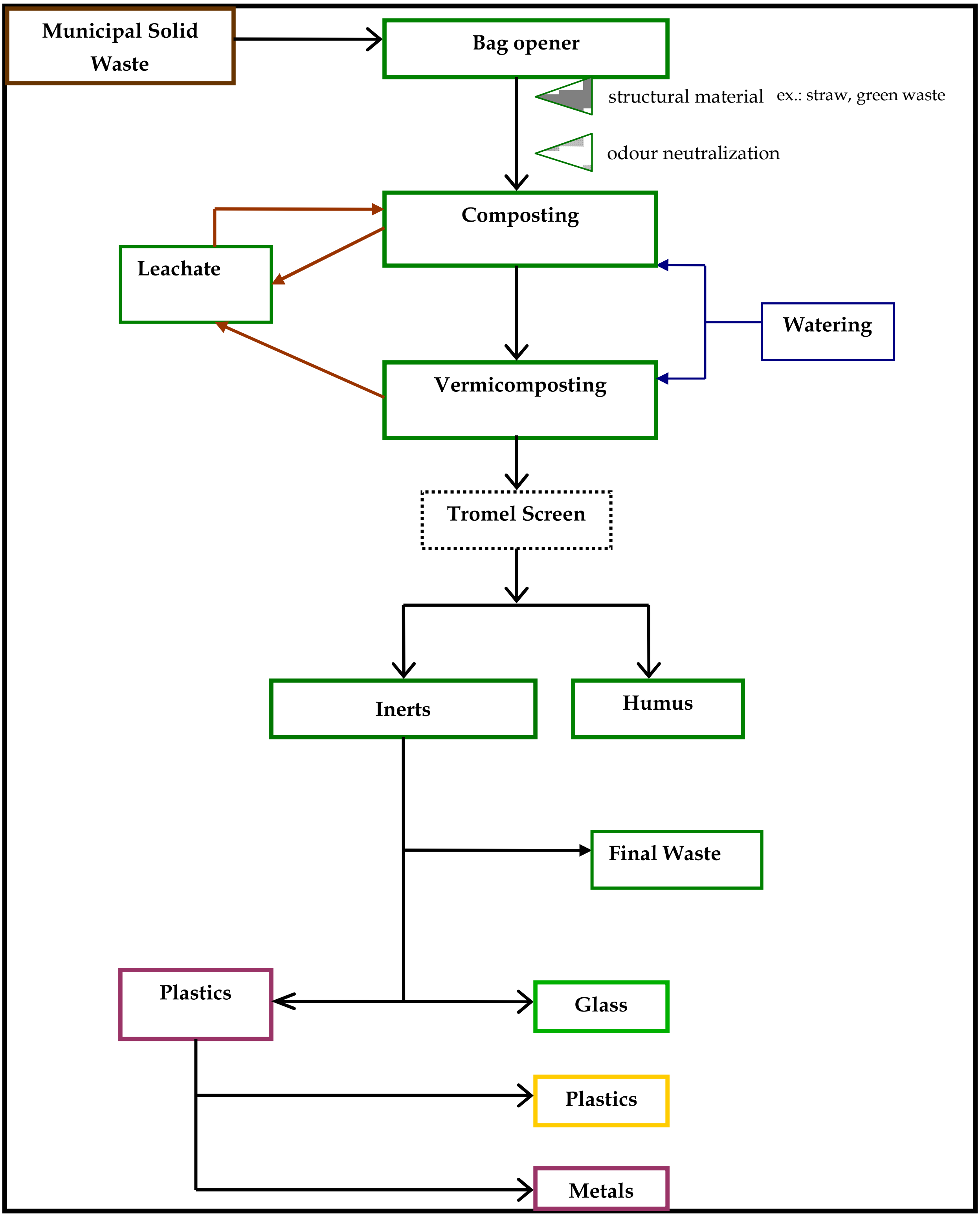

Figure 2 Schematic representation of MSW vermicomposting

a) Bag opening

Plastic bags are opened by a rotating open cylinder (Fig 3) with knifes inside to open the bags. In order to avoid breaking the glass the inner surface of the cylinder is protected with a rubber liner.

Figure 3 Bag opener

b) Pre-composting

After bag opening, waste is transferred to a windrow pre-composting system (Fig 4) where it stays during 3 to 4 weeks.

Waste is covered daily with shredded garden waste in order to prevent release of odours and other nuisances. After 3-4 days temperature rises to 60ºC or 65ºC and stays in this level during 2 weeks assuring destruction of pathogens and weeds.

Waste water is collected into a tank and lately re-injected in the windrow composting system, consequently assuring the total recovery of organic matter and avoiding the need to install a waste water treatment plant. Humidity is controlled with the daily addition of water or waste water.

The composting system is composed by 5 blocks with 24 m^2 each and built with bricks that are placed in a way that allows air circulation. Composting piles achieve 2 to 2,5 meter high. These blocks are protected from rain in order to control humidity.

Figure 4 Pre-composting pile

c) Vermicomposting

The pre-composted waste is then delivered to the vermicomposting beds (a series of modular units) (Fig 5) for another 3 to 4 weeks. As already mentioned the leachates are recirculated into the composting system avoiding the need to a waste waster treatment plant. The process is protected from direct sunlight and rain to ensure ideal conditions.

These vermicomposting beds are built the same way as the composting blocks and have the same type of irrigation system.

The process starts with a first layer of waste with 25 cm high where the worms are already in it. Then successive layers of 25 cm are applied up to a thickness of 2 metres. Worms tend to hide from light but also to move to the new added food, so after 3-4 weeks most of the worms are living in the upper layer, a few centimetres below the top of the pile.

When this happens it is time to take out the upper layer and move it to the bottom of a free bed where the process starts once again.

Through this process, earthworms digest almost all organic matter including paper that is transformed into humus or worm casts, a well known soil improver.

Figure 5 Vermicomposting bed

Before the beginning of this project there was a big question about how would worms deal with packaging like Tetrapak. The answer was quite astonishing because the worms managed to digest all the paper part of this beverage packaging, leaving only the tiny layers of plastic and aluminium.

The result of the vermicomposting is a mixed material composed of humus and inert materials like plastics, glass, metals, textiles and others that need to be separated.

d) Drying process

Humidity can not be very high during the operation of separation of humus from other materials. This means that in winter time there is the need to dry the humus with mechanical means, while in the summer it is possible to use the suns heat to achieve this goal. In the AMAVE unit there is an electric drying device, but in future biomass energy will be used to produce the heat needed to dry the waste (Fig 6).

Figure 6 Dried materials ready for sorting

e) Sorting of humus and other materials

Once humidity is low enough waste passes through a rotating grate that separates packaging and other materials from humus (Fig 7).

Figure 7 Rotating grate and sorting table

In the AMAVE plant humus is separated into 3 categories of granules:

- <2 mm;

- >2mm and <5mm;

- >5mm and <20 mm

Humus granules smaller than 2mm is the best product and it will be used for more noble uses depending on its chemical characteristics.

Humus of medium size will be used mainly for forest purposes and land reclamation.

The category between 5 and 20 mm is composed by humus, earthworms and inert materials (glass, ceramics and stones) and therefore must be submitted to a further treatment so that collection of the worms and separation of inert material from humus are ensured.

On the other end of the rotating grate the bulky materials are dropped in a sorting table were the following materials are separated by hand:

- Four types of plastics: Polyethylene Film, PET, Rigid Polyethylene and Mixed Plastics

- Glass

- Metals

Final waste is collected at the end of the sorting table and sent to landfill. This waste is composed mainly by textiles, shoes and other non recyclable materials and has no or negligible biodegradable fraction, so it produces no methane when placed in a landfill.

f) Plastics preparation for recycling

After being sorted the plastics still have a tiny layer of humus dust attached that must be removed in order to avoid too much work for recyclers and also to recover the humus.

With this in mind some tests have been carried at a plastic recycling plant to find the most suitable way to recover the humus dust. The result shows that two operations are required: shredding and washing of plastics.

These operations remove all humus content from the plastics and make them ready for recycling (Fig 8).

Shredding and washing machines are not installed in the AMAVE plant because the total amount of plastics that can be sorted in that unit are not enough to justify that investment, but it seems reasonable to expect that units with a capacity above 10,000 tons of MSW per year can produce enough plastics to justify the installation of plastic shredding and washing equipment.

Waste water from this process and humus sludge can be reused in order to recycle organic matter, to reduce water consumption as much as possible and to avoid the need to have a waste water treatment plant.

Figure 8 Plastics after shredding and washing (mixed plastics, polyethylene film and PET)

g) Waste water management

As said before, waste water from pre-composting and from vermicomposting is collected in two tanks and reused later in the pre-composting process. Sludge accumulated in those tanks is also pumped back into the pre-composting process.

3 Mass balance

The AMAVE unit started to receive MSW in the beginning of January at a rate of 5 tonnes per day, 5 days a week.

The first sorting operations showed the following results regarding the mass balance:

- Original waste weight loss: 35%
- Humus production: 25%
- Recyclables collected: 20%
- Final waste: 20%

This unit will start to operate under normal conditions in March 2009 and a much bigger quantity of data will be available after April 2009.

4 Humus quality

Compost resulting from MBT units is normally seen as a product that has strong limitations for soil application because of contamination with heavy metals. In the use of humus from vermicomposting of unsorted MSW precautions must also be taken in order to know exactly the characteristics of this product and to find out what would be a proper application for it.

The first set of analyses of humus produced through this process show a higher quality than compost from what is usual in MBT units (Tab 1).

Table 1 Analyses of humus and Portuguese proposed legislation for compost

Parameter	Jan 2008 (Pilot unit Palmela) (mg/kg)	Mar 2009 (AMAVE) (mg/kg)	Category I (mg/kg)	Category II (mg/kg)	Category III (mg/kg)
Cd	1,3	(*)	0,7	1,5	5,0
Pb	51	< 80	100	150	500
Cu	69	64	100	200	600
Cr	(*)	(*)	100	150	600
Hg	0,2	(*)	0,7	1,5	5,0
Ni	19	(*)	50	100	200
Zn	379	(*)	200	500	1500

Legend: (*) data not available

The humus shows very low Pb, Cu, Hg content and a medium Cd and Zn content that, according to Portuguese legislation, would classify this product as compost of category II. Data for Cr are not yet available.

Low heavy metal content in humus may be due to the following reasons:

- Bioaccumulation of heavy metals by earthworms;
- High production of humus from paper and cardboard;
- Higher proportion of humus produced per volume of waste input through vermicomposting compared to normal MBT.

5 Costs of the process

The first data concerning the investment costs of MSW vermicomposting can be obtained by the analyses of the AMAVE project (Table 2).

Table 2 AMAVE vermicomposting unit costs

Designation	**Cost (euros)**
Construction	137 000
Equipment – Bag opener, rotating grate and sorting table	50 000
Equipment – Bob Cat and shredder	100 000
Others – Construction and equipment	20 000
Technical work	10 000
Total	**317 000**

According to the available data, investment costs of this unit were 317 000 euros for a treatment capacity of 1500 tons of MSW per year, hence corresponding to an investment cost of 211 euros/ton.

This is clearly an interesting value because contrary to what was possible with this unit there are opportunities of economies of scale which can be easily be achieved in units with capacity above 10 000 tons/year.

In this units costs of plastic shredding and washing were not included, because it is not viable to include those equipments in such a small project, but for bigger units, like those above 10 000 tonnes/year, the increase of costs obtained by the inclusion of those equipments is largely surpassed by the reduction of costs achieved through the scale effect.

Costs for the operation of the AMAVE unit are still not completely clear because of the still short working time of this unit, but is has been already identified that human resources are the most relevant cost. In fact, according to the two months working experience, there is a daily need of two workers to operate the unit and another worker once a week to help in the sorting process.

This results in more or less 2, 3 workers for 1500 tonnes/year, but in bigger units, because of the use of more mechanical means this number of workers would be significantly reduced.

The high rate of plastics, metal, glass and paper (into humus) recycling brings important incomes from the Portuguese Green Dot Society and the sale of humus is also an interesting source of income to cover operation costs.

According to investment and operating costs and expected incomes, the treatment of a tonne of MSW in a unit like the AMAVE one will range between 35 to 40 euros. In bigger units it is expected to reach below 30 euros/tonne.

6 Greenhouse gases emission reductions

One tonne of mixed (residual) MSW sent to vermicomposting avoids approx 119 kg CO_2 eq./tonne. The equivalent tonne of mixed (residual) MSW sent to mass burn incineration and to landfill (using Portuguese energy mixes) produce net emissions of 247 kg CO_2 eq./tonne and 486 kg CO_2 eq./tonne respectively. (E.Value 2008)

In other words, comparing 1 tonne mixed MSW sent to vermicomposting with 1 tonne sent to mass burn incineration, the vermicomposting results in 336 kg CO_2 eq./tonne less emissions than the mass burn incineration.

7 Future projects

Vermicomposting of unsorted MSW is now seen in Portugal as an alternative to landfill for waste that is not collected at source. As a result, some municipalities have shown some interest in this technology and new projects are coming soon.

The first project in line, expected to start working in August-09, is located in Beja, a town in the southern part of the country in the region of Alentejo. This project will treat five thousand tonnes of MSW in the first phase, to be increased to fifteen thousand tonnes in a second phase.

The second project is expected to be operational by September-09 and is located on the Island of S.Miguel in the Azores in the municipality of Nordeste where it will treat 2.5 thousand tonnes of MSW.

Other projects are also in sight but their design and funding are still under discussion.

8 Vermicomposting and MSW management

Municipal Solid Waste management is a problem that still needs to be fully addressed in order to ensure environmentally, economically and socially sound solutions.

In spite of all efforts to reduce waste and to increase selective collection, in many countries there is still a high percentage of final waste that needs to be treated and for which several methods have been used like landfill, incineration and more recently MBT.

Vermicomposting of unsorted MSW can be classified in the family of MBT solutions, because it uses mechanical and biological processes to treat waste that wasn't separated at source.

This technical option appears to offer several advantages compared to more conventional treatment solutions.

First of all, it shows an interesting mass balance, with a very low final waste percentage of only 20% of the original waste, which means that it can significantly contribute to increase recycling rates, especially for plastics, and reduce the need for landfill and incineration.

Secondly, it is a low cost solution, which may be helpful in many countries where governments are now facing economical problems.

Thirdly, this solution can work in a small scale, which means that it can be installed closely to the waste source, thus reducing transport costs.

And finally, because it is a modular solution, vermicomposting of MSW can also receive and treat separately organic waste from selective collection thus increasing humus quality.

As a conclusion, this process seems to be a good opportunity to those countries that still have a low recycling rate of packaging and don't have many plants to recycle organic waste.

Climate conditions are also an important factor. Earth worms cope better with the mild climate conditions so we think that besides Portugal, this process fits particularly well in countries like Spain, France (South part), Italy, Greece and other countries in the Mediterranean Basin.

For countries with colder weather it is still possible to use this technology but it must be adapted to protect the worms during winter time.

Out of Europe, and in some cases using different species of earthworms, there are huge opportunities for this process in regions were temperatures are not very cold, like Southern USA, Central and South America, Africa, South and South West Asia, Australia and the Pacific Islands.

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