Integrating composting into the forestry techniques: the experience at the Mos council (Pontevedra, Spain).

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SUMMARY: The present work shows the results of a project which agglutinate the Mos Council, Mos Forestry Owners and the University of Vigo, into the recovery of a sludge contaminated area and the sludge treatment by composting using only the machinery the Council and Forestry Services already have, based on a deep knowledge of the composting process and integrating the vegetal material produced by the activities of the Forestry Service. A biopile was built with the sludge retired from a contaminated area, due to the accidental breaking of the sludge's pipe, mixed with *Eucaliptus globulus* wood chips as a innovative bulking agent. The temperature and oxygen concentration into several points of the biopile was followed during a seven months period, being necessary to give several turns over to reoxygenate and homogenizate the material. After this time, the material was screened to separate the compost from the remaining bulking agent. The analysis made shows a stabilization and degradation of the material, transformed after this process into usable compost. So, the whole process of restoration and recycling of the flooded sludge was developed by the Council and the Forestry Services by their own, not having to hire an external company to take over this problem, and using only the tools and media they already have. As a result, the total cost of the process was much lower and the Council obtained a compost with enough quality to be used on the restoration of the affected area, instead of having to buy the compost needed.

Composting, sewage sludge, biopile, Eucalyptus bulking agent

1 Introduction

Composting is a process where the organic matter is degraded and stabilized. With this process a volume and weight reduction of the initial waste is achieved, making much cheaper its transport and handle. The result material, denominated "compost", is stable and with value as a organic amendment for soils and cultures.
Scientifically, composting is defined as a biooxidative and controlled process, were a hetereonegenous organic material, on solid state, suffer a thermophilic stage with a transitory production of phytotoxins, having as a result products like carbon dioxide, water, minerals and stabilized organic matter denominated "compost" (Zucconi and De Bertoldi, 1986).
The present work shows a composting process developed at open air, being an open system; this make necessary a periodic oxygenation of the material, to keep the aerobic conditions needed for the survival of the microbiological populations which develops this process. On open systems the oxygenation is achieved by turn overs, which mix the material, and the whole structure of the biopile is destroyed to be build again. This process is also used to control the evolution of the temperatures inside the material, to achieve it correct evolution during the process. Being the temperature one of the keys parameters of composting, a correct control is necessary to know in which stage the process is, and if it evolution is the adequate, this information is also useful to select the proper moments to turn over the material or to add more water. Along with the oxygen concentration, those are the measurements made along the process to develop a correct control of it.
During the turn overs, several samples were taken to analyze physic-chemical and biological key parameters of the composting process, among them moisture content, volatile solids, C/N ratio, pH, organic nitrogen and Rottegrade stability index.
The final product of the composting process, denominated "compost", is stable, humified, easily handle and with a high value as organic amendment.
The experience at the Council of Mos (Spain) was focused on a punctual problem related with a sewage sludge flood of a pasture due to the breaking of the sewage pipe, with the collaboration of another local organism, the Forestry Owners community, and the advising of the University of Vigo. After an initial analysis made to the

sewage sludge, where no high concentrations of recalcitrant contaminants (as heavy metals) were found, the solution proposed by the University of Vigo was a “in situ” treatment by composting. If no external machinery were used, this solution was the cheapest and, as a result, the town council and the Forestry Owners would obtain a compost usable on the town gardens and forest lands. The composting process took 197 days (seven months).

This works shows that a correct composting process can be developed without specialized machinery or high technology facilities, if the key parameters for the correct development of the process are know and controlled all along the time. This way, composting could be easily integrate into the forestry techniques to process altogether both the vegetal materials and organic residues.

2 Material and methods

The sewage sludge was obtained from a pasture field flooded after the breaking of the sewage pipe. Figure 1 shows an aerial view of the affected zone.

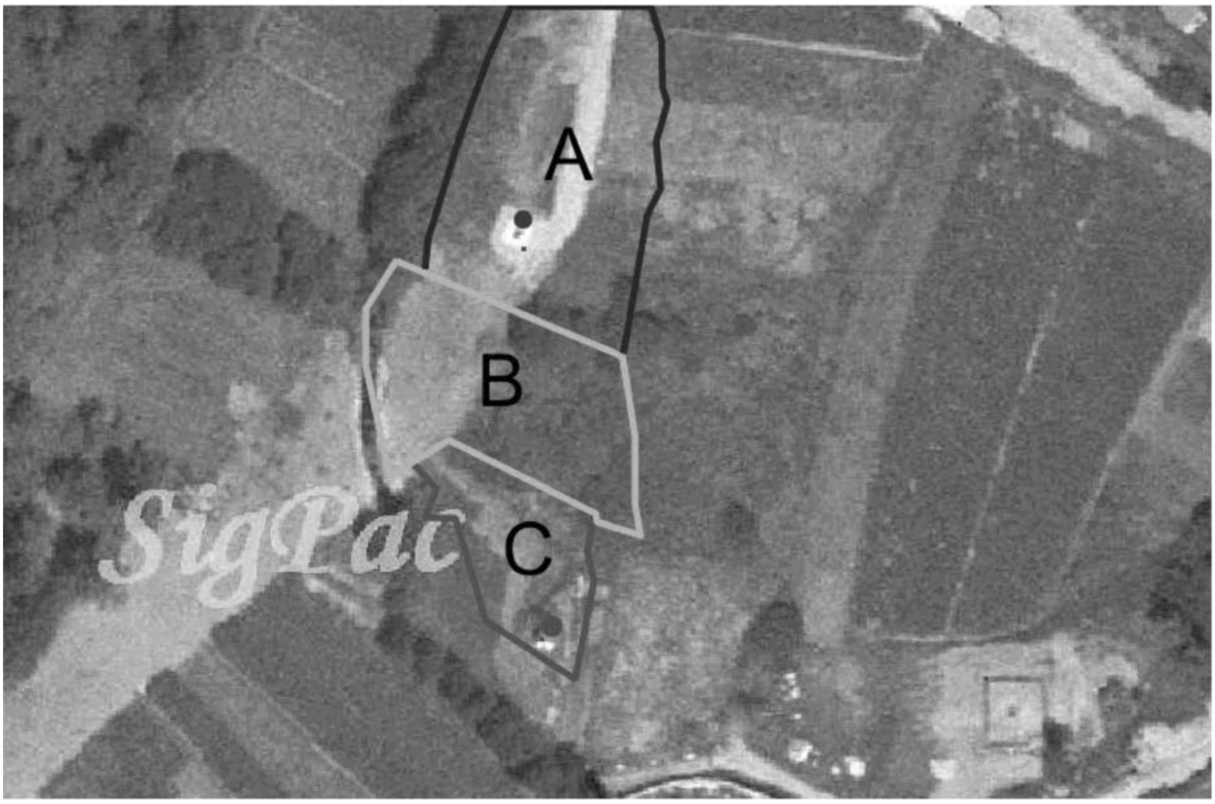

Figure 1 Aerial view of the affected zone

The dot at zone A shows the point were the breaking took place. Zone A and B were scarcely contaminated, being the sludge almost fully mixed with the soil. For this reason, the sludge from those zones was not removed. The most part of the sludge flood was concentrated on zone C, which presented an aspect similar to a damp, as can be see on figure 2. Area C had a surface about 2000 square meters, and all the sludge present there was removed to be processed.

Figure 2 Sewage sludge

The first stage was to develop a complete analysis of the sewage sludge to be composted, the results are show on table 1. No high concentrations of recalcitrant contaminants (like heavy metals) were found, having the sludge a high concentration of organic matter due to its origin from domestic sewage waters. So, the composting process were chosen to degrade and stabilized that organic matter, and to hygienizate the result material.

Table 1 Sludge characterization

Parameter	Result
Moisture (%)	91,77
Volatile solids (%)	94,72
pH	7,76
Electric conductivity (mS cm^{-1})	0,16
Dissolved organic carbon (ug g^{-1} dw)	2122,52
Ammonia (ug g^{-1} dw)	4596,93
Nitrate (ug g^{-1} dw)	1866,39
Dissolved organic nitrogen (ug g^{-1} dw)	3492,96
Total carbon (%)	18,1
Total Nitrogen (%)	1,72
Cu (ug g^{-1} dw)	911
Zn (ug g^{-1} dw)	532
Pb (ug g^{-1} dw)	82,8

176 Tm of sludge were removed from zone C and transported to a pre-conditioned zone facilitated by the Forestry Services. In this zone, a “bed” composed of thick branches was made, to separate the biopile from the

soil and to facilitate the oxygenation of the material from below. Into this bed, several lysimeters were installed to control and analyze the possible leakages from the biopile.

The bulking agent used was *Eucalyptus globulus* wood chips, obtained from the cultures the Forestry Services have. The wood from this tree has high levels of vegetable alkaloids, some of them with negative effects over the bacteria populations. This is the main reason very few studies about the suitability as bulking agent for composting has been made with this specie (Yadav et al, 2002). Most of those alkaloids are found on the bark, which peels regularly and naturally from the tree and avoid the growth of competitors around the base of the tree. That's the reason on the present study only wood will be used, which has a lower concentration of those substances.

Those materials (bulking agent and sludge) were deposited over the bed as alternate layers, being the bottom layer bulk agent. The layers of bulking agent had double thickness than the sludge ones. Once the biopile was finished, it was completely covered over the top and sides by a final layer of bulking agent. At the end of this process, 66 Tm of bulking agent were used in total.

This design allowed the layer of bulking agent situated under a layer of sewage sludge to receive all the possible leakages produced during the first phases of the composting process, were a strong hydrolysis of the organic matter takes places and water and CO_2 are produced. The layer of bulking agent situated under the layer of sludge received this water, acting as a "sponge" and keeping that water within it matrix, to relieve it again on later stages of the composting process were more water is needed, helping to maintain a correct moisture level along all the process.

The final cover with bulking agent gave thermal isolation to the biopile and, being the *Eucalyptus globulus* an aromatic wood, acted as a biofilter agent during the first stages of the process, when some undesirable smells, due to the presence of crude sludge, could be produced.

The figures 3 shows the appearance of the sludge and bulking agent prior to the built of the biopile. And figure 4 shows the initial aspect of the biopile, with the several layers of bulking agent and sludge, prior to be covered with bulking agent.

Figure 3 Sludge and bulk agent

Figure 4

Once built the biopile the control process was started. Several measurement points were chosen depending on the shape and size the biopile had, always being enough to assure a correct control of the thermal and aerobic conditions into the material. Each point was analyzed at two depths, 1 and 1,90 meters. After each turn over, a different shape was gave to the biopile due to its mass reduction, always attending to achieve the best shape to minimize the surface/volume ratio, thus minimizing the border effect and obtaining a better development of the process.
During the first 112 days, a weekly control of temperature and oxygen was made. Then, a control each two weeks was made till the end of the process at day 197. That day the biopile was destroyed and the material transported to a nearby compost factory to be screened, separating the compost from the remaining bulking agent.
Samples were taken at the beginning of the process, on each turn over, and at the end. For each sample several parameters were analyzed: pH, electric conductivity, microbial respirometry, moisture content, volatile solids, C/N ratio, phytotoxicity index, and microbiological analysis (salmonella, clostrodium, E. coli). The analytical methods were taken from the FCQAO and CENAN. The biopile was sampled on three different zones: east, medium and west, to achieve a correct representation of the whole material.
The turn overs were made when the temperature and oxygen concentration measured indicated that the conditions within the material were not the adequate to achieve a correct microbial activity, due to high temperatures or to low levels of oxygen. On each turn over, the whole biopile was destroyed and built again over the bed, thus mixing all the material, reoxygenating the interior of the biopile and cooling the zones with higher temperature. Another effect of the turn overs was to homogenizate the final result of the composting process, due to the fact that only the material within the interior of the biopile is under the process, being the outer material acting as a isolation layer. A temperature and oxygen control was made prior and just after each turn over, to know the efficiency of each mixing process. The turn overs were made at 35, 64 and 142 days from the beginning of the process, and three samples were taken at different zones of the biopile (east, centre and west) to be subjected to analysis.

During the last turn over, at day 142, 5 cubic meters of water were added to the biopile, because the previous moisture results showed a low moisture content, which could affect the correct development of the microbial activity.

When the organic matter is fully degraded, a decrease on the microbial activity rate is detected (low oxigen consumption and temperature). These conditions were detected after 197 days of process, not being able to detect any physical or chemical parameter which could cause this restrain of the process except the almost complete degradation of the labile organic matter. The material was transported to a nearby composting factory to be screened to separate the remaining bulking agent from the compost. This compost was introduced into small bags (25 litres) to be given to the neighbours affected by the sewage sludge flood.

3 Results and discussion

The initial moisture content of the sewage sludge was 91,77%, with a volatile solids content of 94,72%, pH of 7,76 and electric conductivity of 0,16 ds/cm. The high concentration of organic matter (measured as volatile solids), pH next to neutrality, low electric conductivity and low concentration of heavy metals, made this sludge a proper waste to be treated by a biological technique as composting.

Once mixed with the bulking agent, the result moisture content was a bit low, with a value of 48,3%, but this parameter wasn't inhibitory for the a proper development of the process (Miller, 1989), as the evolution of temperature showed on figure 6 shows. This means that the mixture of sludge and bulking agent had the proper conditions to develop microorganism populations.

After 142 days of process, the moisture content was of 32,5%, a value too low for a correct evolution of the microbial activity. 5 cubic meters of water were added to the material as the turn over was made, to integrate this water properly into all the biopile and achieve a homogeneous moisture.

The pH evolution showed the normal trend during a composting process, as show in the figure 5, with a initial acidification (from 7,5 to 5,0), due to the momentary liberation of organic acids as products of the organic matter degradation. Once this organic acids are degraded, the pH raised again towards neutral values, having the final compost a value of pH of 6,5.

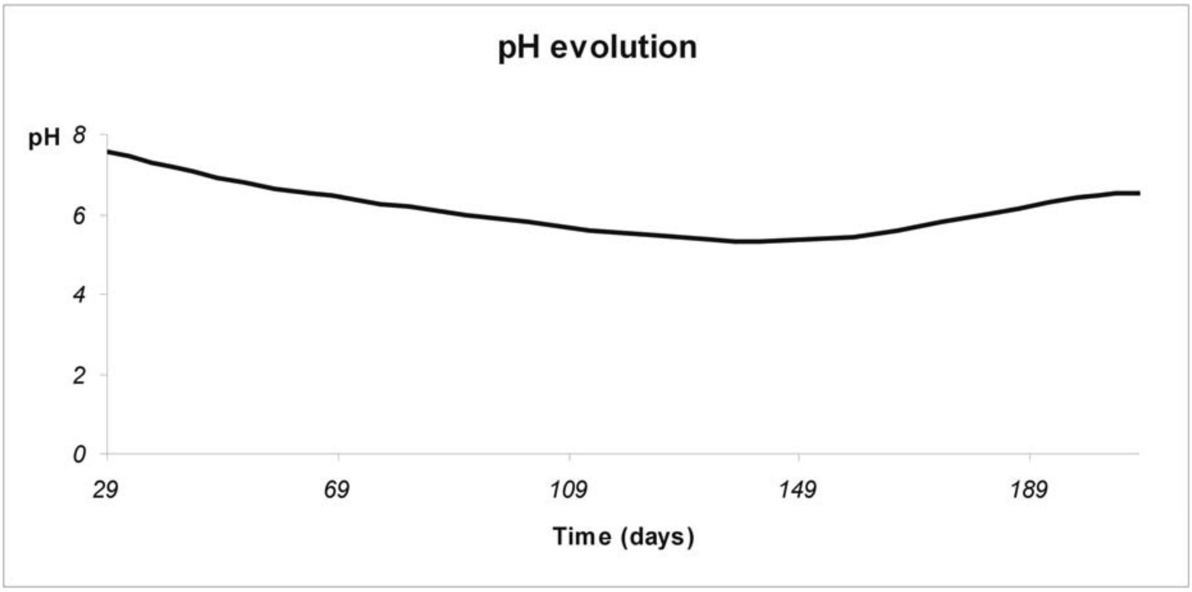

Figure 5

The electric conductivity didn't varied much along the composting process, evolving from a initial value of 0,44 dS/cm to 0,22 dS/cm on the final compost.

The temperature is a key parameter on the composting process, being possible to separate the microbial populations regarding to the temperature range they are active on mesophilic and thermophilic bacteria and fungi. The temperature rising is related to the metabolic heat produced during the microbial activity, and its conservation due to the isolation effect produced by the outer layers of material. The figure 6 shows the evolution of the temperature inside the biopile along the process, meanwhile the figure 7 shows the evolution of the oxygen concentration into the biopile. The arrows show the moment a turn over of the material were made.

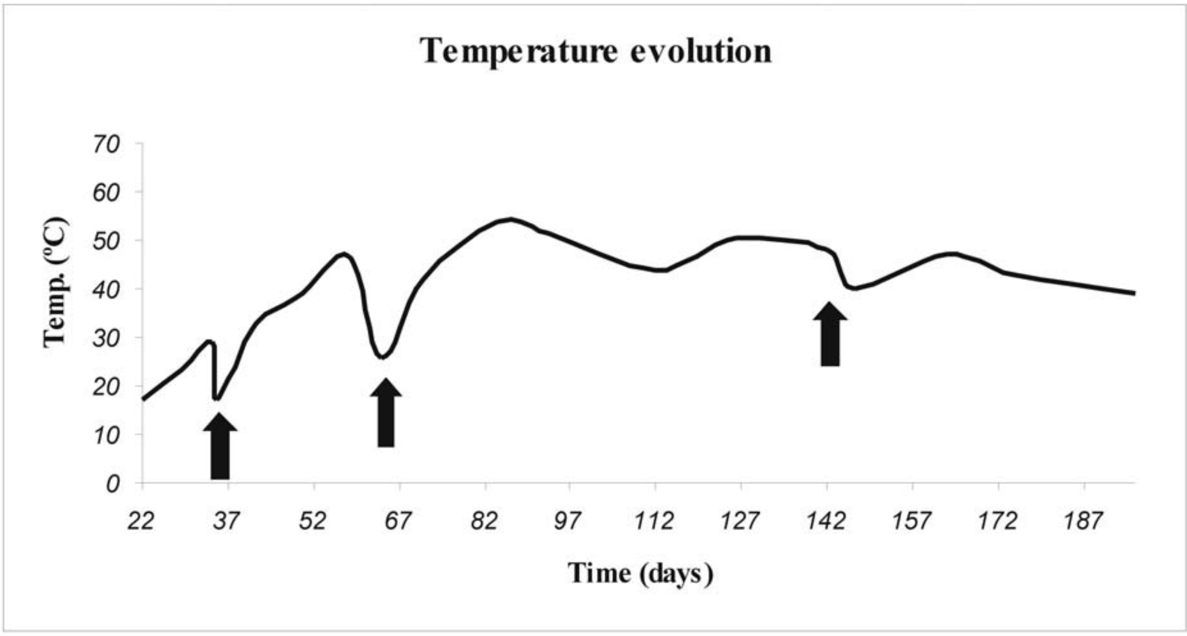

Figure 6

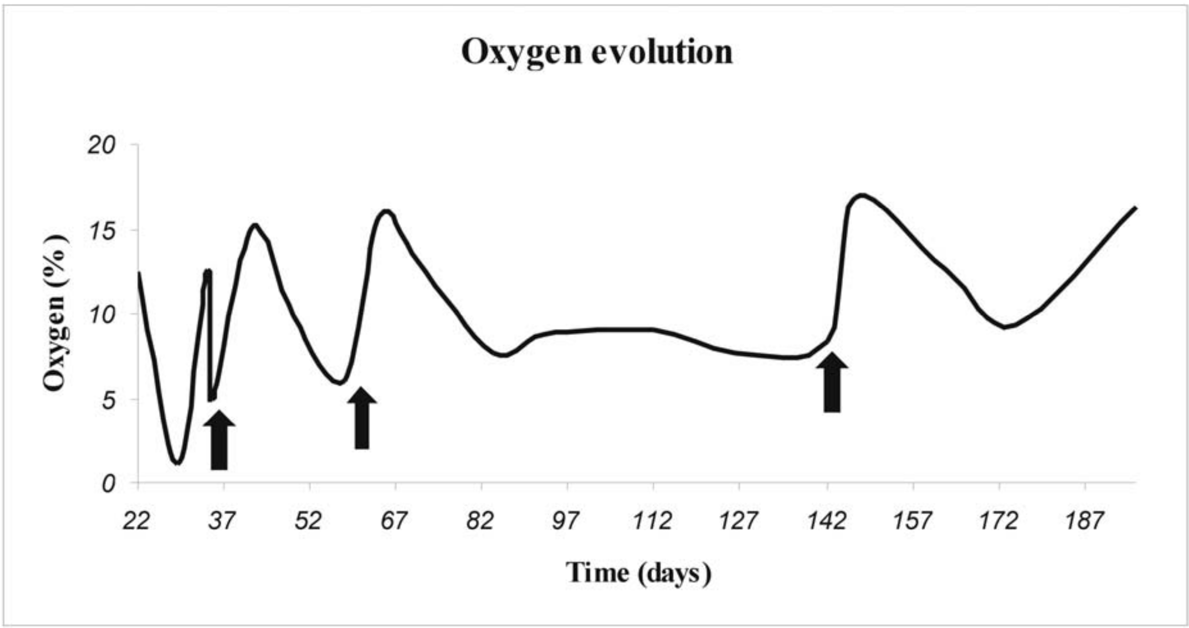

Figure 7

At the beginning of the process a temperature rise and oxygen decrease could be detected, which indicates that the microorganism are degrading the organic matter from the waste. Just after each turn over, the temperature decrease and the oxygen concentration was increased, this indicates that the turn overs were effective and the biopile was oxygenated and homogenized. The turn overs were made when the measures indicated a slow down on the activity of the microbial populations within the material. At the beginning of the process, the oxygen uptakes are faster than at the end, being this reflected on the fast decrease on the oxygen concentration detected. As the organic matter was degraded and less easily degradable materials were at the disposal of the microbial populations, the oxygen uptake rate was slower, until finally the oxygen concentration became almost constant at 7%. This indicated the finalization of the composting process, the moment all the easily degradable organic matter had been transformed by the microbial populations into more stable compost. The temperature could

present high values even in this phase, due to the adiabatic nature of the material and the lack of looses by convection with the ambient, but the oxygen uptake rate is a direct measure of the microbial activity rate.
After the last turn over, all the key parameters were set at the optimal conditions for the continuation of the microbial activity. But the measures of temperature and oxygen indicated a very low activity rate, as a result of the high degree of degradation already achieved.
The results of the microbiological analysis made to the material are show on table 1. After 163 days of processing, the material was completely disinfected, due to the high temperatures achieved during the composting process, with a peak of 60ºC.

Table 2 Microbiological analysis

Patogen	Result	Units
Enterobacteria	43.10^4	(cfu/g)
Salmonella spp.	Ausencia	(/25g)
Clostridium perfringens.	<10	(cfu/g)
Fecal streptococo	210	(mpn/g)

The C/N ratio suffered a continuous degradation along the time of the process, being 19 at the middle of the process and having a final value of 8,3. The initial C/N ratio was suitable to develop a correct composting process, and it evolution reflected the degradation suffered by the organic matter.
The figure 8 shows the evolution of the organic carbon during the composting process. There is a continuous descent of this fraction of the carbon during the first stages of the composting process, until day 144. This reflects the degradation suffered by the sewage sludge during the first stages, when the microbial activity was higher. This is also reflected on the evolution of the microbial biomass (Figure 9), with an important development of those populations during the first 144 days. Those parameters reflect that the main stages of the degradation took place during the first 144 days, being a much slower process from that day on.

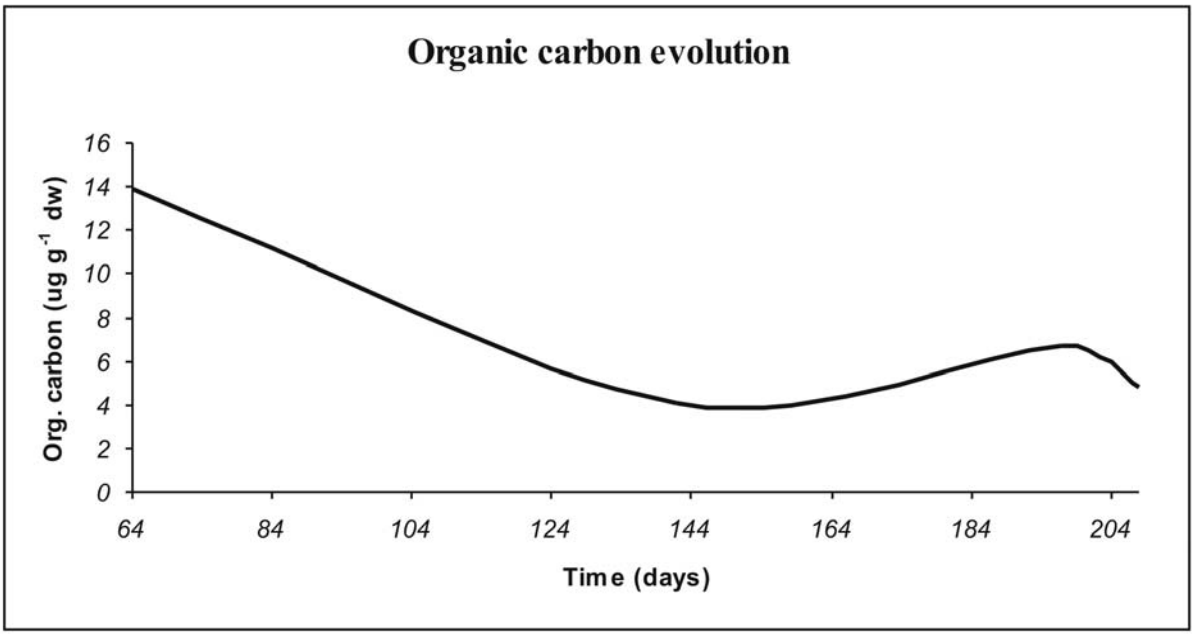

Figure 8 Organic carbon evolution

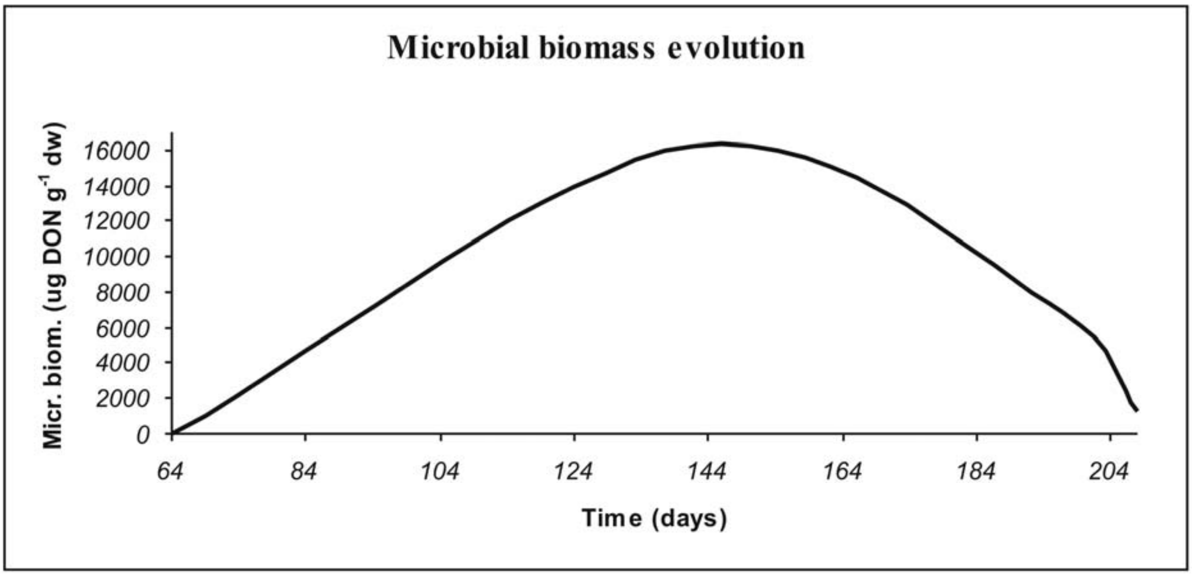

Figure 9 Microbial biomass evolution

4 Conclusions

The composting process was developed in a correct manner, being obtained a final compost with enough quality to be used as organic amendment.

The *Eucaliptus globulus* wood proved a suitable bulking agent for composting, with the added effect of being able to control effectively the odours produced during the first stages.

The composting process can be developed, even at high scale, with simple machinery, not being needed specific machinery except for the final screening if the compost must be separated from the remaining bulking agent.

Composting can be easily integrate into the forestry works, and can be a cheap and worthwhile solution for small amounts of organic wastes punctually produced.

References

Miller, F.C. (1989):"Matric water potential as an ecological determinant in compost, a substrate dense system". Microbial Ecology, vol 18, issue 1, pp 59-71.

Yadav, K.R.; Sharma, R.K.; Kothari, R.M. (2002):"Bioconversion of eucalyptus bark waste into soil conditioner". Bioresource technology, 81, pp 163-165.

Zucconi, F. & De Bertoldi, M. (1986) : "Compost specifications for the production and characterization of compost from municipal solid waste" Compost Production Quality and Use. De Bertoldi, M.; Ferranti, M.P.; L^Hermite, P.; Zucconi, F. editors. Elsevier Applied Science Publishers, pp 30-51.