Methodology to determine the categories of environmental impact in composting plant

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ABSTRACT

The main objective of this methodology is to evaluate the environmental impacts produced in the biological treatment of Municipal Solid Waste (MSW), focused in the atmosphere emissions, NH_3, volatile organic compounds (VOCs), N_2O and CH_4. This methodology will give the identification of improvements as a result in the treatment processes and the advantages and disadvantages in the efficiency among the different types of mechanical biological treatments. The study includes composting plants, windrows and tunnels technologies. The methodology is based on sections of the life cycle analysis, and gives as result the impacts in the categories of global warming (GWP100), ozone layer depletion (ODP), human toxicity, photochemical oxidation, acidification and eutrophication. After this analysis measures to improve the operation can be implemented in the areas where the biggest impacts for emissions or unnecessary energy expenses have been detected.

1. Introduction

The treatment of Municipal Solid Waste (MSW) has evolved in the last decades, from a non selective treatment in landfills to a selective treatment and use of each one of fractions of this waste category. Before as some 15% of the total MSW flow then has redirected from landfilling to other treatment, these institutional changes will most probably lead to major changes in European waste management [1]. Without a doubt the treatment technologies have gone improving in their efficiency, yield and environmental impacts control product of their activities.

One example of this type of systems is the composting treatment technology that has improved their processes to give a more effective treatment to several types of residuals. Inside the composting there are different types of facilities to treat the solid waste: static piles, aerated piles, tunnels system, and combination of the previous ones, among others [2]. These are the most common composting plants in the present, for this, the politicians and laws in environmental matter at European level have been focused in the impact of this facilities type.

In the last years the different matter and energy flows of this type of treatment systems have been studied and they have been carried out matter and energy balances to see the true contribution to the residuals treatment. Also the greenhouse gases (GHG) emitted in the processes (NH_3, VOCs, N_2O, CH4, among other nitrogen compound) that contribute to the climatic change, global warming, acid rain, human toxicity, photochemical oxidation have been studied [3]. On the other hand the hydrosphere emissions have also been studied, to identify impacts by eutrophication, soil acidification, among others [4].

The methodology developed in the present work has as primordial objective to identify the environmental impacts coming from the emissions to the atmosphere. The methodology leaves of an outline of life cycle analysis, leaving of a general point, analyzing energy consumptions of the machineries that intervene in the process of composting and the facilities of the same plant.

After having the previous data, the methodology is focused to make a matter and energy balance considering the main impact categories.

2. Instruments and Methodology

2.1 Instruments

For the atmosphere emissions analysis are used sensors to obtain data in-situ. To identify NH_3 emissions it was used an ammonia iTX T82 Multi-gas Monitor of Industrial Scientific. To obtain the air velocity it was used a hot-wire anemometer VelociCalc Pro Model 8386 with 0.0015 m/s error. Sample of the gases emissions for VOC analysis were taken using a sampling bomb with an air flow of 12 l/min and Teldar® bags for sample collection and transportation.

2.2 Methodology

The methodology follows in four main steps:
1. Check list: collection of relevant data on plant operation;
2. Emission measurement;
3. Analytic of the samples;
4. Final matter and energy balances.

1. Check list: This methodology section implements a check list that has as objective to identify general data of the process in the composting plant and particularly in energy types and fuels used.
The check list has the following parts:

- General data;
- Socioeconomic data: it includes workers references and hours worked per week.
- Process data: this section is divided in five main parts: *1.* Identification of the entrance waste quantity; *2.* Waste treatment type reception (trommel, manual separation, etc), type and quantity of yard waste that was added for waste conditioning and piles dimensions; *3.* Pursuit of the composting process. This part identifies the quantities that have been entered by each one of the piles or tunnels, the consumptions of water, aeration, the temperature, oxygen and humidity percentages; *4.* Pos-treatment operations that are carried out to the compost (trommel of 25 mm, 10 mm, etc), quantity of leached, quantity of green waste recycled; and *5.* Identification of the compost quality and analytic on the humidity, organic matter, pH, nitrogen, heavy metals, among others.
- Machines data: this part obtains data of fuel types, theoretical consumption, used time and capacity of the machines (trommel, shovel, etc) as well as the electric consumption in the offices (illumination).
- Emissions data: this section identifies the available data on atmosphere and the hydrosphere emissions. This last section is very important because most of the facilities do not have these data.

2. Emissions measurement: this point has as objective to identify the emission areas (atmosphere, hydrosphere). As it was mentioned in the introduction, the main types of composting plants are based on piles systems that can be treated in tunnels (closed system and with emissions control) or piles in the bleakness (static, aired, turned or combinations of these), equally it exists mixtures of both types, tunnels in the first stage and maturation in piles. For this study these 2 main types of plants have been identified.

- Piles system: Due to the core high temperatures it is suggested that in composting piles there is a convective air movement that allows air to enter the piles though the low part of pile sides while air exist at the upper part. As piles usually proceed in an open area, the emissions to the atmosphere are not collected and treated and their amount is directly related to the convective air flow. To corroborate this fact and ensure that the maximum emission is located at the top of the pile, a number of emission profiles should be performed along the length of the pile.

The next steps should be followed: the pile should be measured (high, wide, and long) to make an outline and define, in function of its dimensions, the number of profiles that will be carried out (see Figure 1 a). A distance between profiles of 4-5 meters has been established, always subtracting of the longitude the ends of the pile (inclination area). For the case of the points around the pile, it should be considered at least 5 points, one in the superior part (most important) because the velocity is highest at the start of composting and gradually declines, and 2 in each pile side (as shown in Figure 1b). The velocity of natural convection is determined by the permeability of the compost bed and the temperature difference between the surroundings and the compost bed, as can be derived from the general Ergun equation [5].

After determining the number of profiles and points in each of them, the following step is to carry out the analyses of the ammonia emissions with the ammonia sensor and air velocity measure. Temperature and the oxygen in each profile are also determined. At the same time a gas sample is collected in Teldar® bags in at least three points of the superior zone (to the beginning, half and final).

The measures are carried out during the whole composting process, especially in the first 3 days and later weekly until the final of the process.

- Tunnel system: for this type of plants, as the system is usually closed and the gases emissions are usually led to a scrubber and later to a biofilter or directly are passed to the biofilter, the sample is taken on the biofilter. The area of the biofilter (long and wide) is measured and a matrix of sampling points is determined to ensure that there are not differences on emissions from the different points. Like in the case of the piles, it should be taken the ammonia and air velocity measure.

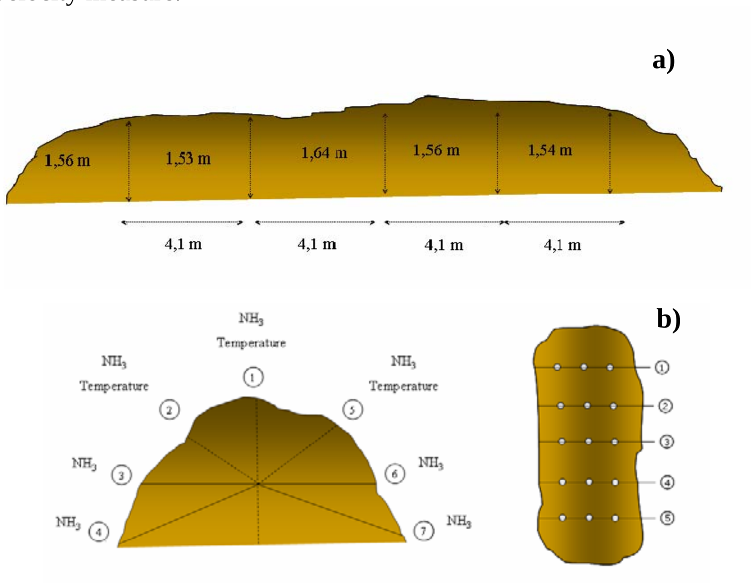

Figure 1: Scheme of pile profiles. a) Lateral side; b) Superior and frontal sides

3. Analytic of the samples: For this point, the analytic of bulk density, porosity and water retention capacity are described by the U.S. Department of Agriculture and U.S. Composting Council like quick and approximate tests of compost analysis [6]. For other hand the analysis of the humidity (100 ºC during 24 hours) and the organic matter (550 ºC during 1 hour and 30 minutes) are carried out. The method used for the organic nitrogen is the Kjeldahl method and for the carbon content it is dear by means of the Haug equation [7]. The gases were analyzed by a chromatographic method of VOCs detection in compost matter [8].

4. Final matter and energy balances: The balance is developed starting from the values of the emissions of each process to obtain the environmental impacts. For atmosphere impacts it is necessary to transform the fuel and electricity consumption values into CO_2 units and to count the different emissions in the piles and biofilter. For the impact to the hydrosphere, leachate and waste water flows should be considered. Finally, the indicators are analyzed with Sigmapro software in the next categories of environmental global impacts: global warming (GWP100), ozone layer depletion (ODP), human toxicity, photochemical oxidation, acidification and eutrophication.

3. Results

This methodology has been proven in real composting plants, piles and tunnels. In reference to NH_3 the results indicate that during the first piles stage (thermophilic period) after tunnels composting during 15 days, are emitted the biggest quantity of NH_3, VOCs and other nitrogenous compounds due to the high temperatures, high biological activity and high aeration rates. There is a relationship between the temperature and NH_3 emissions because in the first parts and in areas where the temperature was higher, the ammonia emissions are bigger. Equally there is a relationship between air velocity and temperature in the first weeks.

Figure 2a shows the ammonia emissions profile obtained at day 2 of aerated pile and figure 2b shows the ammonia emissions profile obtained at day 21. Almost no NH3 emissions can be detected at day 21. Figure 2a shows that mainly ammonia emissions take place from the upper part of the pile.

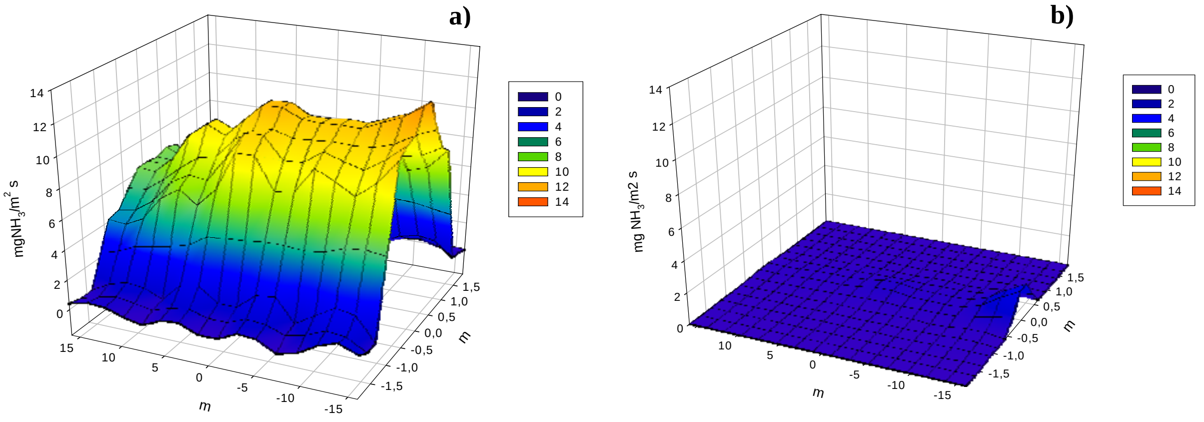

Figure 2: Ammonia profiles. a) After 2 days; b) After 21 days

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References

[1] O. Eriksson, M. Carlsson Reich, B. Frostell, A. Björklund, G. Assefa, J.-O. Sundquvist, J. Granath, A. Baky, L. Thyselius, 2005 Municipal solid waste management from a systems perspective. Journal of Cleaner Production 13, 241-252.

[2] Haug, R.T., 1993. The Practical Handbook of Composting Engineering. Lewis Publishers, Boca Raton, Florida.

[3] Dimitris P. Komilis, Robert K. Ham, Jae K. Park, 2003. Emission of volatile organic compounds during composting of municipal solid wastes. Water Research. 38, 1707–1714.

[4] U.S. Environmental Protection Agency, 2006. Solid waste management and greenhouse gases. A life-Cycle Assessment of Emissions and Sinks. 3rd Edition.

[5] Beukema, K.J., Bruin, S., Schenk, J., 1983. Three-dimensional natural convection in a con-fined porous medium with internal heat generation. Int. J. Heat Mass Tran. 26, 451–458.

[6] U.S. Department of Agriculture and U.S. Composting Council, 2001. Test method for the examination of composting and compost. Houston, TX: Edaphos International.

[7] Haug, R.T. 1993. The Practical Handbook of Composting Engineering. Lewis Publishers, Boca Raton, Florida.

[8] Estela Pagans, Xavier Font, Antoni Sánchez, 2005. Emission of volatile organic compounds from composting of different solid wastes : Abatement by biofiltration. Journal of Hazardous Materials B131, 179-186.