Monitoring of the composting process through "respirometric" method

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Abstract

In the search for solutions to the disposal of solid waste, composting as an important tool for the treatment of organic fraction of urban solid waste, they use sustainable technologies that process the organic residues origin of agriculture, agribusiness and forestry. In the process method called "respirometric", uses a new methodology in which the parameters of biological degradation of waste is not measured in the solid phase, but in the gas phase. The analysis performed in the gas phase have advantages such as greater representativeness, precision and reliability, because this has to be totally homogeneous. In addition, the gaseous medium allows the analysis to be performed in real time and continuously, which is fundamental to the operational monitoring "on line" process. The parameters measured in the gas phase consisted in determining the temporal evolution of O2 consumption and their CO2 generation, these gases are analyzed and recorded by the meter continuously throughout the process, its data is sent to a computer. Measurements of parameters in the gas, proved to be far superior in terms of representativeness, precision and reliability when compared to the traditional method, which makes the evaluation of the degradation process second analysis of the solid phase, and provide answers "on line" in small time intervals, allows a transaction set and much more efficient, including the possibility of interventions in a timely manner to correct certain errors or failures that may eventually occur in the course of the process. The application of data obtained through the analysis of compost in the gas phase, allows the planning of projects for operation of the process on a large scale, contributing to the correct disposal of organic solid waste.

Keywords: composting; "respirometric" method; solid waste

1 Introduction

The environmental crisis in our contemporary, globalized world, is facing a paradigm: the society that now has the biggest technological development, also is the society that most destroys in the history. All the achievements of our civilization provide different negative factors, such as fast-paced population growth, the depletion of natural resources, the expansion of materials consumption and of the production systems that use polluting production processes and residue generators, which if untreated and / or properly designed will produce imbalances in the biosphere, changing vital ecosystems. (Barbieri, 2003).

On the looking for solutions for the destination of organic solid residues, we find that the composting process can be considered one of the most appropriate alternatives in the environmental point of view, promoting greater and more appropriate recycling in terms of material and energy when compared with other methods.

Composting is a biological process in which microorganisms transforms organic material in a material similar to the soil, which is called compound and can be used as fertilizer, but may occur through a group of techniques used to control the decomposition of organic materials, in order to obtain the shortest possible time, a stable material, rich in humus and mineral nutrients (Kiehl, 1998).

However, the use of the composting process in Brazil is still quite restricted compared to the method of the landfill, mainly because they require a bigger initial investment, and show more operational difficulty

operating the unit cost of treatment very superior to that method, besides the fact that negative experiences occurred in the past, by the high degree of empiricism used in the control and evaluation process, due to the lack of a further technical knowledge.

There are several attempts to reproduce in a laboratory scale the composting process, however, the reproduction on laboratory scale is not a very simple task, a lot of considerations and conditions must be considered (Petiot *et al.,* 2004).

The first factor is associated to the quality or composition of the residues, being the composition extremely varied of solid residues in the space and in time, one of the difficulties in obtaining and setting of certain design parameters.

Beyond the question of the qualitative aspect of the residue, several other parameters interfere in the composting process, moisture, oxygen, temperature, carbon/nitrogen ratio of particle size and pH. These aspects generate indexes that are used for the evaluation and monitoring of biological activity in the composting process (Herbets, 2005).

According to Akutsu (2009), using a technique that doesn't have criteria, parameters and consolidated indices, as regards the evaluation of their performance and operational control, presents uncertainties and lack of reliability, contributing for that doesn't exist a progress in your application, especially in large scale.

This work discusses an experimental project conducted at the Faculty of Engineering of the UNESP - Universidade Estadual Paulista, Bauru Campus since 2009, through a new methodology for evaluating, monitoring and operational control of the composting process, called "respirometric" method, where the approach in which parameters of biological degradation of waste is not measured in the solid phase, but in the gas phase. Through the analysis performed in the gaseous medium can be found numerous advantages such as greater accuracy, representativeness and reliability to constitute a homogeneous medium, and allow them to be performed in real time and continuously, which is essential for operational monitoring "on line" process (Akutsu, 2009).

This study monitored and analyzed by the "respirometric" method, the composting process of organic matter (crushed sugar cane, feed the foal, wheat germ and citrus pulp), seeking to increase the utilization and improvement the quality of the products generated, and reduced processing time, contributing to the existing literature on the subject and enabling disclosure and dissemination of results.

2 Bibliographic review

In the literature review, themes of interest to this research were approached, especially in regard to the correct destination of solid urban residues, and specifically the organic ones.

2.1 Solid waste

According to Albuquerque *et al.* (2007), the formation and development of cities, and even more with the Industrial Revolution as an important part of the rural population went in masse to the cities, resulting in a major urban growth and, on the other hand, when it began having a intensive use of the planet's resources, the problem of the residues management has worsened and Its bad domain began to give rise to the first serious environmental problems.

The concern about the destination of solid waste have reached levels increasing in all the sectors of society. This concern increased due to the growing garbage production in urban centers and the clear negligence resulting of the Government, Legislators, Administrators and, consequently, the poorest people who do not have the financial conditions, much less, an environmental education.

The National Solid Waste Policy, enacted in 2010, a compilation of principles, objectives, instruments and guidelines for the management of solid waste. The bill, which has handled more than 20 years in Congress until it was approved, the companies responsible for the collection of disposable products (reverse

logistics) and establishes the integration of cities in waste management and blame the whole society because of generating garbage.

According to the Instituto de Pesquisas Tecnológicas (Institute for Technological Research) – IPT (2000), the provision of waste ground in the form of landfills untreated, results in high risks such as: contamination of underground aquifers, resulting in possible damage to public health, and other nuisances related to smell, fumes, visual impact, devaluation of land.

According Albuquerque *et al.* (2007), in the technical design waste, should be seen and analyzed from a biological perspective, and organic waste is all trash that has animal or vegetable origin, in other words, who recently was part of a living being. In more technical and modern language, we approach the solid waste, and its biological component of organic matter, but likewise from the living beings, animals and plants.

Even today this type of waste is considered polluting and where accumulated organic waste can often become highly rejected and smelly, usually due to decomposition of these products. Natural phenomena of decomposition occurs by the initial action of microorganisms, whose metabolic work has as a result the water, carbon dioxide and energy (heat).

2.2 Recycling

Recycling is a process that has gained considerable space and whose primary function is to promote the recovery of material taken as solid waste, transforming them into raw materials for use in processes for reprocessing.

The cycle disposal, recovery and secondary processing or reprocessing of recyclable material, also called "recycling." For Calderoni (*apud* Bautista, 2001), this end can be extended as a process by which any product or material which has served for the original purpose which it was designed, it can be regarded as a secondary raw material for producing new products and therefore able to be reintroduced separately from the waste and new production process in a same or similar to the former.

Regarding the level of recycling, Fialho (*apud* Baptista, 2001), considers that only purely economic aspects lead to solutions that are not optimal from an environmental standpoint. According to the author, the market alone cannot cause recycling to become an instrument of environmental management of solid waste. It is necessary a discipline of the whole process and it passes through the help of the brazilian legislature.

2.3 Composting

Composting is not a recent practice. One of the first records of the application of this technique in agriculture dates back to the Empire of Akkad in Mesopotamia, about 4500 years ago. Since then several civilizations, including Chinese, Egyptians, Greeks and Romans, piled in stacks of vegetable matter, manure, food scraps and other organic waste, and left them to decompose and stabilize until they are ready to be returned to the soil. However, after World War II, the increasing use of chemical fertilizers has increased and the traditional methods of fertilization have fallen into disuse (Almeida *et al., apud* Santos, 2007).

The definition of compost, is not universal being defined as the aerobic decomposition of organic material such as manure, leaves, paper and food scraps, promoted by microorganisms and being held in controlled conditions converting organic material into a product similar to the stable humus . Decrease (*apud* Santos, 2007) defines a composting process as controlled two oxidation heterogeneous biodegradable substrate resulting from the action of microorganisms (bacteria, fungi and actinomicetas) naturally associated with the substrate, during which there is a thermophilic stage, the temporary release of substances with the biomass and phytotoxic effect suffer profound changes (partial digestion and humification), and the major end product, designated compound, which must be uniform, resulting in heterogeneous two oxidation, biodegradable substrate which is sufficiently stable to be stored, cleaned and whose application to soil does not have adverse effects on the environment.

According Vallini (*apud* Santos, 2007) the composting process takes place in two phases: active and finishing (curing). The active phase of the composting is characterized by fast and intense aerobic biotransformation and high temperature, since the degradation reactions are very intense, affecting the release of energy in the form of heat, CO_2 and water vapor. The step of processing (curing), following the active phase is characterized as being a slow and gradual decrease in temperature.

The main factors influencing the composting process are those that affect, directly or indirectly to the metabolism of the microorganisms that are responsible for the decomposition of waste and its transformation into a stable product rich in humic substances - a compound (Santos, 2007).

In relation to the substrate, the factors influencing the composting process are: nature of the substrate as the origin is agriculture, forestry, urban, industrial particle size, the optimum size is 1-5 cm, since, as smaller size, easier to microbial attack and faster processing of the material composition, the amount of nutrients may be a factor which limits the growth and development of microorganisms involved in the composting process (Santos, 2007).

In relation to the composting process the important factors are: temperature, which varies depending on the microbial activity and pH, the optimum value is between 5 and 8; aeration, excess may cause the ventilation of the biomass and slow cooling the composting process, moisture content, during the decomposition, in which bacterial activity is prevalent, the biomass for composting shall have a moisture content of between 45 and 65%. For contents of moisture below 40%, microbial activity decreases and to greater than 65% water expels air most of the interstices between the particles of biomass, which hinders the diffusion of oxygen and can lead to conditions microaerophilic or anaerobic (Santos, 2007).

2.4 Applications respirometric method in the evaluation of composting process

The Stability is an important quality characteristic of the compound, but it is also difficult to measure an index. For Lasaridi *et al* (1998), a simple technique for evaluating the stability of the composting is respirometric method, which uses a dissolved oxygen probe to measure changes in oxygen concentration in an aqueous extract compound under conditions which ensure the activity microbial optimum and maximum reaction rates

The respirometric method or simply respirometry is a procedure in which the measurements of the speed or rate of oxygen consumption, or the rate of generation of gaseous by-products resulting from the respiration of active biomass when they perform biological degradation of a substrate organic, are performed in liquid or gaseous fuels (Akutsu, 2009).

In the case of composting processes, where there is a predominance of activity of aerobic bacteria in the degradation of waste, measures both the rate of oxygen consumption (O2) and temporal generation rate of carbon dioxide (CO2), in which case is the main by-product gas can be conducted in a controlled atmosphere, for example, the interior of a reactor (Akutsu, 2009).

According Akutsu (2009),

"The respirograma can extract various information and rates, also allowing the phases (lag, exponential and endogenous) process are identified. The lag phase is that associated with starting the process where there is usually the beginning of growth and adaptation of bacteria to the environment and waste. The exponential phase is characterized by intense bacterial activity in the conversion of residues, usually associated to the intense heat release which can have a predominance of thermophilic bacteria. The endogenous phase is characterized by the gradual extinction of food for bacteria, and they use up their own energy reserves to make the breath. In practice, it characterizes the initial end of the process herein referred to biostabilization, after which begins the stage of humus production of the compound. "

In the aspect of controlling production of the compound of quality, the degree of stability desired in a composting process determines various parameters and system design such as aeration rate and treatment time required for each type of organic waste, considering the various intrinsic qualitative aspects involved.

Gea *et al* (2004) examined the composting of various organic residues of different chemical compositions, using controlled conditions to study the suitability of different biological indices (oxygen uptake rate, respirometric index, and respiratory quotient) to monitor the biological activity of composting process. Among the tested rate, the rate of oxygen consumption (also referred to as dynamic content respirometric) gave more reliable values to evaluate the microbial activity in a composting environment.

Experiments performed by Tremier *et al* using respirometric method was created to study the kinetics of biological reactions involved in the treatment of organic waste, using waste to the composting process, the sludge mixed with pine bark. The rates of oxygen consumption of such mixture were monitored for 10-20 days using a 10 cell respiration maintained at constant temperature and humidity. The influence of temperature on the kinetics was tested. The results showed that this method respirometric is a useful tool for the characterization of biodegradability of the solid matter to organic and biological modeling the kinetics of the composting process.

3 Materials and methods

The experiments to evaluate the method "respirometric" were conducted on the premises of a composting pilot project at the premises of the laboratory of solid waste at the Faculty of Engineering, UNESP - Bauru, which has undergone reformulation, as the exchange of the rotary drum, and of maintenance that were required in other equipment, due to the long period that has been inactive.

Figure 1 identifies the general structure of the process equipment for experimental analysis of composting solid waste by the method "respirometric", which were used in this study.

Figure 1: Structure of the process of composting experiments basically formed by: tumbler, gas analyzer and data acquisition.

Equipment used were of a rotating drum, connected in a box with closed windows, to minimize the odor of the process, thus enabling the visualization of the same (figure 2), a gas analyzer (Figure 3) and a microcomputer data acquisition and control of the rotary drum (figure 4), each of these stages are interconnected and dependent.

Figure 2: Rotary drum.

Figure 3: Gas analyzer.

Figure 4: Acquisition of data.

The rotating drum, made of stainless steel, has a useful volume of 90.135 liters, has a tubular shaft which serves as a support for transferring the rotation and at the same time has inlet and outlet of the gases. It also has two sets of blowers (air pumps), one for feeding the reactor and another for the recirculation. Presents one of its walls, a removable window for handling the samples.

Connected to the recirculation line, the pilot assembly has a complete system of automated collection and analysis of gases O_2 and CO_2. The meter, a device model S710, manufactured by Sick Maihak, shows in its display and record the values of concentration of these gases in terms of percentage (% O_2 and% CO_2), with options to collect and record data at intervals of 1s the 600s. In the case of the experiment, the range of data collection instrument was set to 60s, in other words, 1 minute. In these terms, the device records a day a total of 1440 data. This equipment has a serial communication interface that sends the values measured consecutively in specific periods of time at a computer that receives an "on line", the information in the form of a sequence of alphanumeric characters (string), and its format is as follows:

#MS 07.02.12 15:41:08 4.381 Vol% CO2 16.227 Vol% O2

where:

a) # MS: indicator (header) analysis results of the S710 in operation;
b) 07/02/12: date of submission of data;
c) 15:41:08: time of data transmission;
d) 4.381 Vol% CO2: measure of CO_2 in Vol%;
e) 16.227 Vol% O2: measure of O_2 in Vol%;

After a detailed knowledge of the pattern of data generated by the gas analyzer, a software was developed by Prof. Dr. João E. M. Perea Martins, Department of Computer Science Faculty of UNESP Bauru, which continuously receives data from the analyzer, analyzes this data and separates the information concerning the levels of O_2 and CO_2. According to the percentage levels of gas concentrations, the software controls a hardware mechanism that allows the desired concentration and injecting a predetermined air flow rate into the reactor, for consumption of bacteria involved in the degradation of the waste. In this study we worked with O_2 levels between 5% and 20%.

The data structure has received a text format (TXT), which can be imported directly by other software such as word processors, spreadsheets, or mathematical processing software and hence the construction and analysis through charts.

3.1 Waste used for conducting experiments

Although the primary objective of the work is the evaluation of the method "respirometric", we sought to work with organic residues that are arranged in large quantities in the reality of Brazil. So, we choose to work as the main residue, bagasse from sugar cane (figure 5), found in abundance in the country due to the large scale production of ethanol and sugar, and which has as a primary disposal incineration, resulting in generation of electricity. This form of disposal is not suggested, because the soil is not suffering replenishment of organic compounds, requiring more remedial interventions.

Figure 5: Waste of cane sugar dropped in the courtyards of the processing industries brazilian ethanol and sugar - http://www.agricultura.gov.br.

It is observed in Figure 5, the high amount of waste sugar cane, found scattered all distilleries in the country, being intended for the most part, and the production of electricity through incineration.

Table 1 describes the materials that were used in an experimental procedure for composting and which can be observed in figure 6.

Table 1: Materials used.

Material	Mass (kg)
Bagasse sugar cane	1
Citrus pulp	1
Feed the foal	1
Wheat germ	1
Water	1,2
Total	**5,2**

Figure 6: Material used in the composting process, from left to right: I) Citrus pulp; II) Bagasse sugar cane; III) Feed the foal; IV) Wheat germ.

As illustrated in Figure 6, it can be noted that although the materials exhibit the same mass in kg, the volumes are not proportional as a function of their density, which verifies a much larger volume of crushed sugar cane compared with others.

3.2 Survey data "respirometric" - Measuring rates of O_2 and CO_2

The parameters measured in the gas phase essentially consisting in determining the time course of its O_2 consumption and CO_2 generation these gases are analyzed and recorded by the measuring device continuously, except collection periods materials for moisture analysis, in the process and represented here referred to as a cycle. When constructing a graph, by Matlab by plotting the values of the evolution of O_2 consumption and CO_2 to the respective generation cycle of the entire process, which in this trial achieved a total of 39 870 rows of data, there was obtained a diagram here called "respirograma" of the composting process.

4 Results

Are presented in Figure 7 a graph plotted by Matlab software, with the results obtained in the conduct of laboratory experiments using the method "respirometric" in this experiment between 01 to 29 December 2011, the period of 29 days. The "respirograma" of the composting process clearly presented the temporal evolution of sub-cycles of O_2 consumption and their CO_2 generation.

It should be noted that the "x" axis of the graph represents the period of 29 days in which occurred the composting process and the "y" axis the percentage of gases inside the rotating drum.

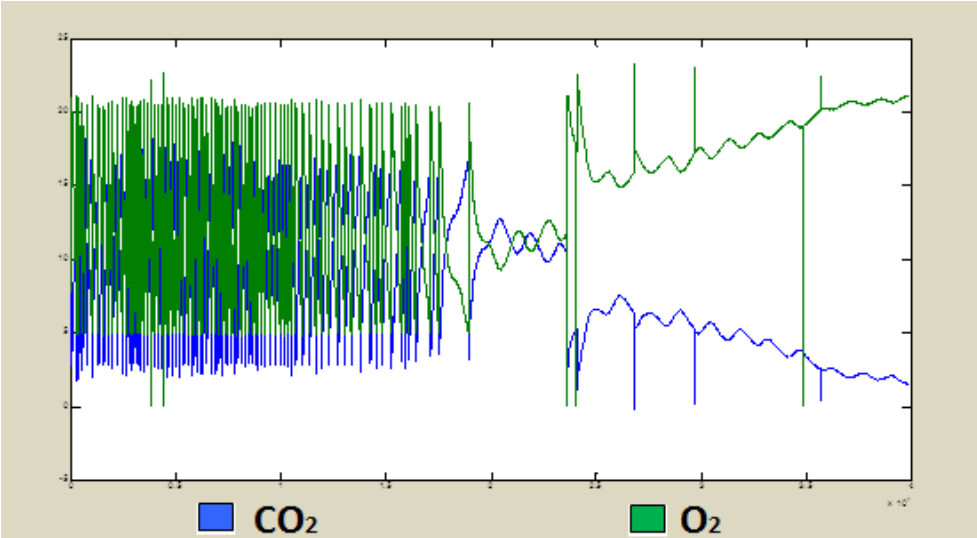

Figure 7: "Respirograma" process, analyzed over a period of 29 days.

By means of Figure 7, sees that the degradation process starts at around day 2, from which the stresses occurring high O_2 consumption and CO_2 production high. Halfway through the process, around the 15th day, there was sharp fall in the rate of O_2 consumption by raising the percentage of this gas in the reactor. In the same period is noted the same proportion, the decrease of CO_2 production, indicating that this residue was already stabilized. There are some points on the graph where the points are within the ceiling or the minimum percentage, are moments in which there were momentary interruptions systems, or by collecting samples for analysis of moisture and pH or lack of electricity.

Can be visualized by means of Figure 8, the physical result obtained by the process, noting that the mass of the compound was reduced to 2.230 kg, with a greater compression and an intense odor. Although the composting process have stabilized, there is waste of sugar cane is not decomposed, probably due to the presence of lignin, phenolic polymer, which provides protection, rigidity and impermeability to the cell wall, being difficult to bacterial decomposition.

Figure 8: Compound stabilized, obtained at the end of the decomposition of organic material.

5 Conclusions

We can highlight the following conclusions:

a) The method "respirometric" through the pilot project Akutsu (2009), proved to be an extremely useful and reliable with respect to the responses that can provide the operational monitoring and evaluating the progress of the progressive degradation solid waste;
b) The measurements of parameters in the gas phase, through the evolution of O2 consumption and their CO2 generation, proved far superior in terms of representativeness, precision and reliability when compared to the traditional method that performs the evaluation of the degradation process the second analysis of the solid phase;
c) The "respirometric" method for presenting real-time responses "on line" in reduced time intervals, allows an operation much more tailored and efficient, including the possibility of interventions in a timely manner to correct certain errors or failures that may eventually occur during the process.
d) The parameters obtained by the method "respirometric" allow their use as design parameters, operation and control of the composting process, the process to be used in full scale.
e) The results demonstrate the feasibility and potential projects, focused on the development of technological tools for use in process automation for disposal of solid organic waste by composting

These findings demonstrate the feasibility and potential projects for the development of technological tools applied in process automation, not only in the disposal of organic solid wastes by composting, but in all areas of environmental management.

It should be remarked that the search is in a second phase of experiments, with the use of other organic waste, sewage sludge.

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