RESEARCH OF THE POSSIBILITY OF USING THE HEAT GENERATED IN THE AEROBIC BIODEGRADATION PROCEDURE

Muvedet Šišić, Vehid Birdahić, Sanela Beganović, Mirnes Duraković
University of Zenica, Faculty of Mechanical Engineering
Zenica, B&H

Farzet Bikić
University of Zenica, Faculty of Metallurgy and Technology
Zenica, B&H

ABSTRACT
The paper describes the research methodology of the heat generated by the biological decomposition of a mixture of sludge from WTP (wastewater treatment plant) and biowaste and its use outside the system for a controlled biodegradation process. Earlier research in this area defined the optimal mixtures of sludge and biowaste that ensure quality management of the biological decomposition process. The research described in this paper aims to prove that the heat generated in the process of a biological enclosure can be taken outside the biodegradation system and used without violating the assumptions of optimal management of the process.

Keywords: sludge, biowaste, heat, bioreactor, heat exchanger

1. INTRODUCTION

In the process of biological decomposition of waste materials, in addition to the benefits related to the conversion of waste materials into a useful product - compost, certain heat is also produced, the potential of which needs to be investigated. In doing so, it is necessary to analyze the impact of individual solutions and designs of heat separators on the stability of the composting process, that is, to define the optimal process conditions that will provide heat separation in a way that does not endanger the process of aerobic biodegradation. The character of certain influential factors can be observed and evaluated through the parameters of the previously defined regression model with the addition of factors related to the design of the heated separator.

Earlier research in this area defined significant potentials of sludge and biowaste, as well as their optimal mixtures that ensure quality management of the composting process [1]. The research in this project, while respecting previous research and the need to establish a more stable process, included monitoring the input and output parameters of the composting process of organically saturated sludge from municipal wastewater treatment plants and biowaste created by the maintenance of urban green areas.

2. MATERIALS AND METHODS

Sludge for the purposes of the research was taken from the location of the municipal wastewater treatment plant in Srebrenik and Gradačac, since in earlier research these locations proved to be a source of sludge of optimal consistency and other characteristics important for the biodegradation process.

Before the final processing, the waste materials that are the subject of research need to be processed. The processing depends on the content of the mixture or the characteristics of

individual waste materials. The method of primary processing also depends on the method of final use [2].
It is necessary to foresee the following processing procedures: thickening, stabilization, and drying in the case of sludge and shredding in the case of biowaste. Sludge stabilization reduces the number of pathogenic microorganisms and unpleasant odors [1]. Stabilization and drying were carried out by leaving it for 15 days in natural conditions outside.
In order for sludge to be used for composting after stabilization, it must meet certain physical-chemical-biological criteria.
Samples of individual sludges were separated and the necessary analysis was performed. The results of the analysis of individual sludges are presented in Table 1. Where sample 1 represents sludge from the wastewater treatment plant in Gradačac and sample 2 represents sludge from the wastewater treatment plant in Srebrenik.

Table 1. Results of chemical analysis of individual sludges

Parameter	Sample 1	Sample 2
pH	8,5	7,3
Dry matter/moisture content [%]	63,02/36,98	67,88/12,12
Content ∑N [mg/kg]	48200	25900
Content ∑C [mg/kg]	305000	373800
Ratio C/N	6:1	14:1
Cd [mg/kg]	<0,1	<0,1
Cu [mg/kg]	100	50
Ni [mg/kg]	100	50
Co [mg/kg]	<1	<1
Pb [mg/kg]	<1	<1
Zn [mg/kg]	500	150
Cr [mg/kg]	<1	<1
As [mg/kg]	<1	<1
Hg [mg/kg]	<1	<1

By analyzing the values in Table 1, we can see that the concentrations of certain heavy metals are lower in sample 2. Also, the pH value and the C/N ratio are closer to the optimal values for the process of aerobic biodegradation in sample 2 [1]. For these reasons, it was decided to use the sludge designated as sample 2 in the research, sludge from the municipal wastewater treatment plant in Srebrenik.
After stabilization, the sludge was mixed with shredded biowaste, and compost mixtures were prepared as shown in Figure 1.

Figure 1. Biowaste preparation process and composting mixture

All components in the compost mixture also need to be analyzed in order to check the condition and content of the components determining the loss and successful management of the composting process. Earlier research in this area at the University of Zenica defined the optimal content of the mixture, i.e., the ratio of sludge to biowaste (in volume ratio sludge 30%, biowaste 70%) [1]. After defining the content, a chemical analysis of the compost mixture will be performed, which includes the parameters that determine the success of starting the composting process:

- mass fraction of dry matter,
- mass fraction of total organic carbon in dry matter,
- pH value of the mixture,
- mass fraction of total nitrogen in dry matter,
- mass fraction of total phosphorus in dry matter in.

The prepared compost mixtures were placed in three plastic containers-bioreactors (Figure 2a). The biodegradation process and research were carried out at the "Kemal Kapetanović" Institute of the University of Zenica..

a) *b)*

Figure 2. Controlled biodegradation system: a) Sterns in series, b) Water circulation system

The tanks with compost mixtures are connected in a system that provides water circulation through heat exchangers including a common cold water tank as shown in Figure 2b). Three different types of heat exchangers are installed in three different tanks as shown in Figure 3.

a) *b)* *c)*

Figure 3. Different forms of heat exchangers, a) bioreactor 1, b) bioreactor 2, c) bioreactor 3

The temperature of the compost mixture and the temperature of the water before and after the exchanger was monitored with the help of sensors placed in all three systems with the possibility of electronic recording. The composting process is accelerated by blowing air with the help of a compressor. The general concept of the established bioreactor is represented by the scheme in the following figure.

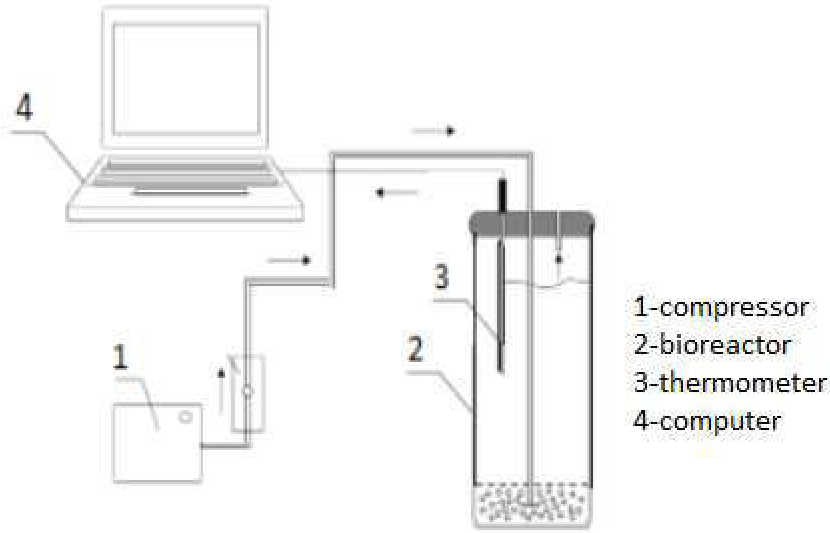

Figure 4. The general concept of the bioreactor

compost mixtures and the achieved process conditions, the temperature of the compost mixture in certain phases exceeds 70 °C [1]. In these situations, it is necessary to physically mix the mixture in order to reduce the temperature, which represents an unfavorable environment for the survival and development of bacteria that carry out the decomposition process.

In certain stages of the biodegradation process, i.e., after the end of the process, it is necessary to analyze the quality of the compost mixture, i.e., the finished compost, in order to determine the quality and justification of its use as a soil improver. Chemical analysis of compost includes the following parameters:

- pH reaction,
- total carbon,
- total nitrogen and C/N ratio,
- the concentration of easily accessible P_2O_5,
- the concentration of easily accessible K_2O,
- the concentration of total Ca and Mg [3].

The analysis of the content of heavy metals in the sludge was carried out using the Shimadzu Analytical Methods for Atomic Absorption Spectrometry method, and the preparation of samples for the chemical analysis required the application of standard methods of shredding the air-dried sample [4]. The pH value was measured using the method with a solution of 0.1M $CaCl_2$, 1M KCl, and H_2O in a ratio of 1:2.5 (m/v) for soil/compost and 1:5 (m/v) for waste sludge [5]. Determination of dry matter content and moisture content was performed using a standard gravimetric method [6]. The 4500-Norg B method was used to determine the total nitrogen content [7]. The total phosphorus content was determined using spectrometric methods with ammonium molybdate [8]. Determination of the concentration of readily available P_2O_5, K_2O, Ca, and Mg was performed using liquid ion chromatography methods [9].

The biodegradation process started properly immediately after placing the compost mixtures in the bioreactors. With the help of a compressor and an additional probe, the air was blown into the interior of the bioreactor every day. The liquid that was generated in the biodegradation process was returned back to the bioreactor.

3. RESULTS OF DISCUSSIONS

After 15 days from the start of the process, samples were taken from all three bioreactors, and an analysis of the necessary parameters was performed in order to evaluate the degree of biodegradation. The results of the analysis are presented in Table 2.

Table 2. Results of compost analysis after 15 days from the start of the process

Parameter	Sample 1*	Sample 2*	Sample 3*
pH	8,0	8,1	8,3
Dry matter/moisture content [%]	86,71/13,29	87,52/12,48	87,33/12,67
Content ∑N [mg/kg]	21700	21800	18600
Content ∑C [mg/kg]	370000	342500	367500
Ratio C/N	17:1	15:1	19:1
Ca [mg/kg]	139000	133000	118000
Mg [mg/kg]	4800	4800	4700
P_2O_5 [%]	0,595	0,595	0,527
K_2O [%]	0,73	0,87	0,82

**The sample number corresponds to the number of bioreactors*

The analysis of the same parameters was also carried out after 28 days after the start of the process. The results of the analysis are presented in Table 3.

Table 3. Results of compost analysis after 28 days from the start of the process

Parameter	Sample 1*	Sample 2	Sample 3
pH	6,4	6,2	6,3
Dry matter/moisture content [%]	88,04/11,96	87,84/12,16	86,98/13,02
Content ∑N [mg/kg]	33600	29800	29300
Content ∑C [mg/kg]	330300	371200	387700
Ratio C/N	10:1	12:1	13:1
Ca [mg/kg]	260430	251150	243050
Mg [mg/kg]	6437	6210	5718
P_2O_5 [%]	0,939	0,87	0,962
K_2O [%]	6,92	2,96	0,15

**The sample number corresponds to the number of bioreactors*

Process parameters were monitored for one month. The analysis of samples of individual compost mixtures presented in Tables 2 and 3 show the changes that characterize the course of the aerobic biodegradation process:

- reduction of the C/N ratio,
- increasing the concentration of nutrients.

The characteristics of the "product" obtained by the process that was the subject of research indicate the possibility of its application as a soil improver [1].
The temperature of the biodegradation process in all bioreactors was constantly monitored in the manner presented in Figures 5, 6, and 7.

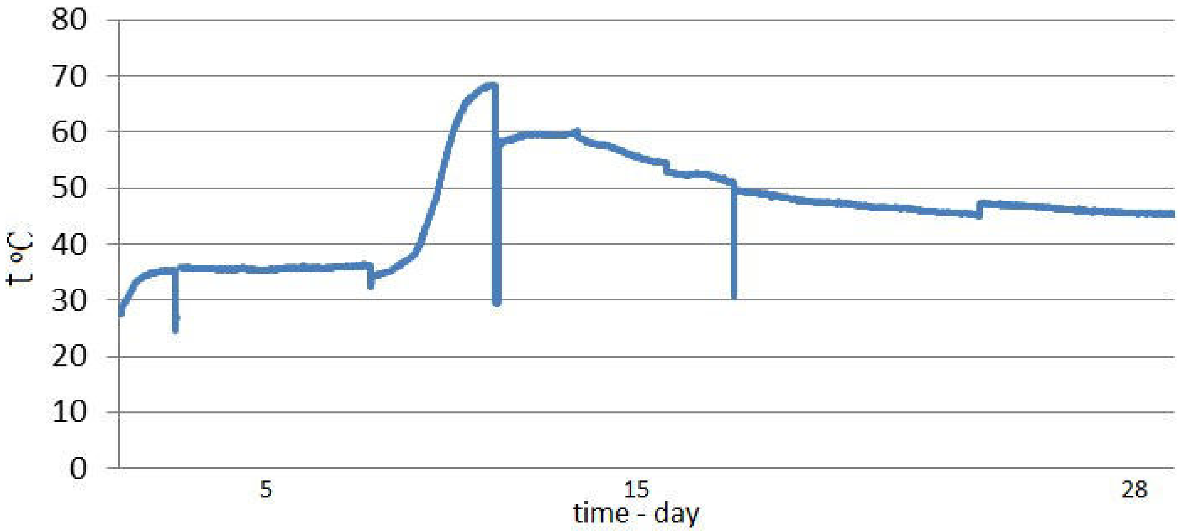

Figure 5. The temperature produced in the composting process – bioreactor 1

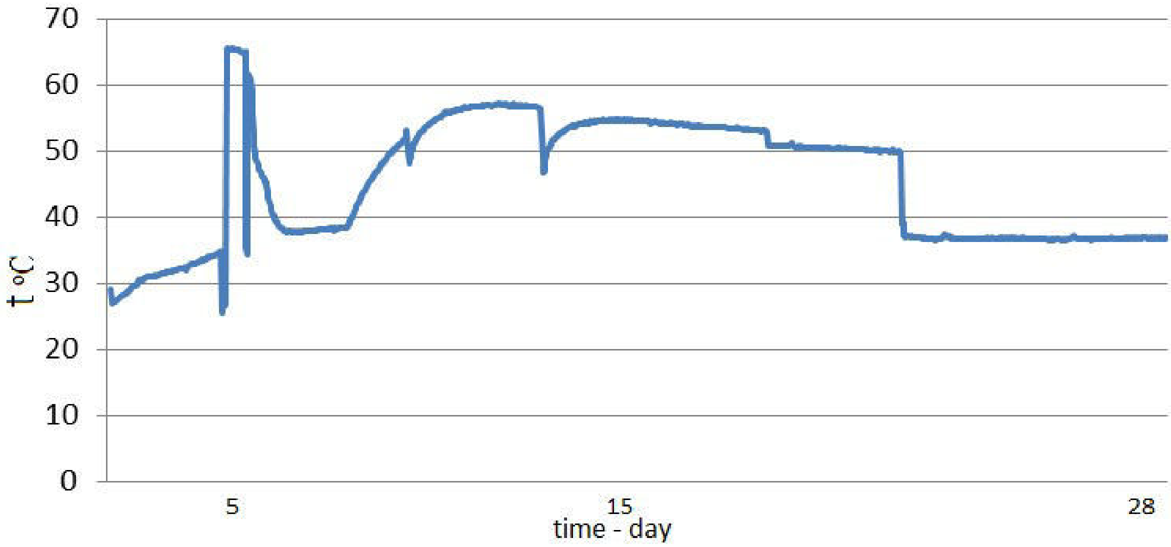

Figure 6. The temperature produced in the composting process – bioreactor 2

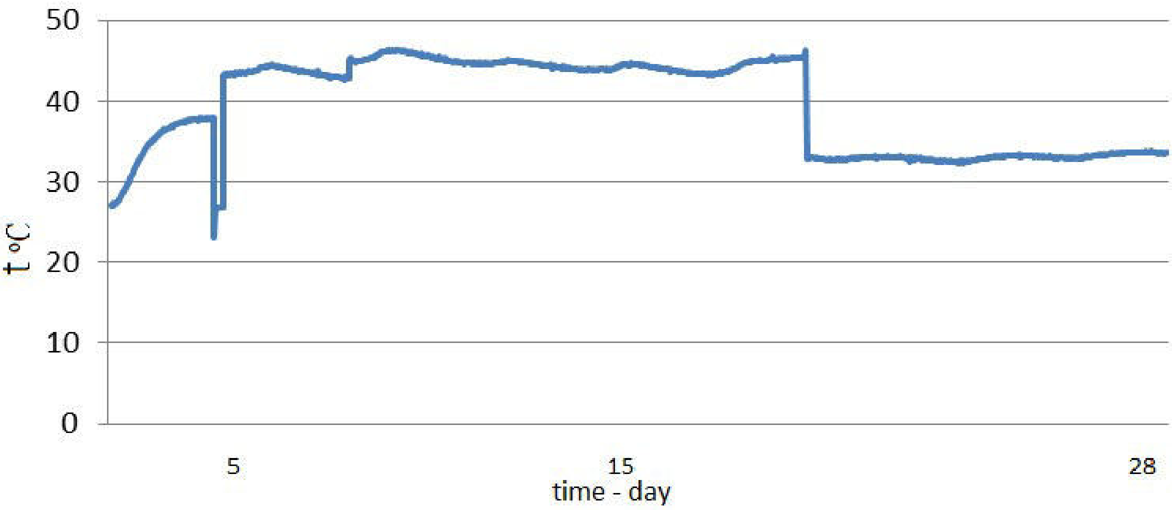

Figure 7. The temperature produced in the composting process – bioreactor 3

The bioreactor was alternately connected to the water circulation system, which extracted the produced heat from the bioreactor. By measuring the water temperature in the circulation system, it was determined that every 60 minutes the temperature increases by an average of 5 ºC. Extraction of the generated heat from the biodegradation system did not cause any disruption to the process

4. CONCLUSION

Taking into account the analysis of process parameters, it can be stated that compost as a product of aerobic biodegradation meets most of the criteria that determine the possibility of its use as a soil improver.

The current version of the Rulebook on determining the permitted amounts of harmful and dangerous substances in the soil and the methods of their testing ("Official Gazette of the Federation of Bosnia and Herzegovina", number: 96/22) [10] limits the possibility of using this compost in agriculture, but the possibility of using this compost as a soil improver certainly remains in the production of ornamental plants, maintenance of parks, etc.

In addition to the benefits of recycling sludge and biowaste as waste materials, this research proves the justification of using that is, transferring the generated bioheat with different technological solutions to other systems that can use it usefully. The research also proves that the release of this heat will not interfere with the process of aerobic biodegradation. In the phases where the excess generated heat has negative effects on the process of aerobic biodegradation, its extraction from the system is desirable [1,3].

5. REFERENCES

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