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ENERGETIC EFFICIENCY OF THE SEWAGE SLUDGE COMPOSTING PROCESS IN DEPENDENCE ON STRUCTURE OF THE ADDITIVES

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Abstract

Significant amount of the produced sewage sludge encourages to search for the most effective methods of its utilization. One of such methods is composting of the sewage sludge with various kinds of biological origin additives supporting the process. Temperature is one of most characteristic physical quantity which can describe the process course. The phase of the composting process can be defined on the basis of the temperature. The knowledge of the additives influence on the energetic efficiency of the process can help to optimize the course of composting and control it by delivering or receiving the energy surplus.

Introduction

The sewage sludge utilization is the issue arousing controversy in terms of the environmental protection and economic aspects. Sediments from municipal and rural wastewater, from agri-food industry are the rich source of nutrients for plants and have very effective soil-forming impact. The soil-forming properties of the sediments are mainly related to the presence of large amounts sediment organic matter, determining rich environment for microorganisms activities and the substances susceptible to the humus formation.

Composting of the sewage sludge as a method of its disposal has been known for a long time. Due to the physico-chemical composition of the sewage

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sludge which is not able to ensure the proper run of the composting process, it should be supplemented with additional missing substrates. Both the additives and aeration degree have an essential importance for the amount of generated thermal energy, which is one of the main indicators certifying the accuracy and intensity of the composting process (DACH et al. 2007, SOŁOWIEJ et al. 2010a, SOŁOWIEJ et al. 2010b).

The amount of energy produced in the first phase of composting process under defined conditions can be partially (with no influence on the process quality) used as a source of thermal energy (SOŁOWIEJ 2007). Linking the amount of emitted energy with the aeration intensity, CO_2 emission and applied additives allowed to reach better efficiency of the sewage sludge composting process. This efficiency concerned the reduction of composting period, selection of the appropriate proportions of the selected additives, and the control of the entire process by the aeration regulation and used percentage of the sewage sludge dry mass in the composition of the mixture.

Description of the experiment

The aim of the study was to compare the composting process course with a special regard of the amount of generated heat energy. The experiment was conducted in parallel on four identical positions and the particular bioreactors were filled with sewage sludge mixed with additives which compositions are presented in Table 1. The content of particular options was set on the basis of

Table 1

Variants compositions of the composted additives and selected properties of the components

Specification	Component	Dry mass [%]	Share [%]	Amount in d.m. [kg]	Mass [kg]
Variant K1 (75% of sewage sludge in dry mass of the mixture)	sewage sludge	16.7	75	6.00	35.93
	straw	86	5	0.44	0.51
	sawdust	87.9	20	1.60	1.82
	humidity [%]	78.99	100	8.04	38.3
Variant K2 (60% of sewage sludge in dry mass of the mixture)	sewage sludge	16.7	60	6.10	36.53
	straw	86	5	0.50	0.58
	sawdust	87.9	35	3.60	4.10
	humidity [%]	75.25	100	10.2	41.2
Variant K3 (45% of sewage sludge in dry mass of the mixture)	sewage sludge	16.7	45	6	35.93
	straw	86	5	0.6	0.70
	sawdust	87.9	50	6.7	7.57
	humidity [%]	70.02	100	13.25	44.2
Variant K4 (30% of sewage sludge in dry mass of the mixture)	sewage sludge	16.7	30	5.4	32.34
	straw	86	5	0.9	1.05
	sawdust	87.9	65	11.5	13.03
	humidity [%]	61.75	100	17.75	46.4

The research stand was equipped with a complete system measuring the bioreactor labour parameters (temperature, air flow, air humidity, control of collected condensates and effluents, concentration of selected output gases) indispensable for calculation of heat dynamics of composting process. The previous studies have proved that during the experiments the test stand ensures the course of the process similar as in the field conditions while composting with usage of tractor aerator and at the same time allows fully control the changes in the investigated material (CZEKAŁA et al. 2006, DACH et al. 2004).

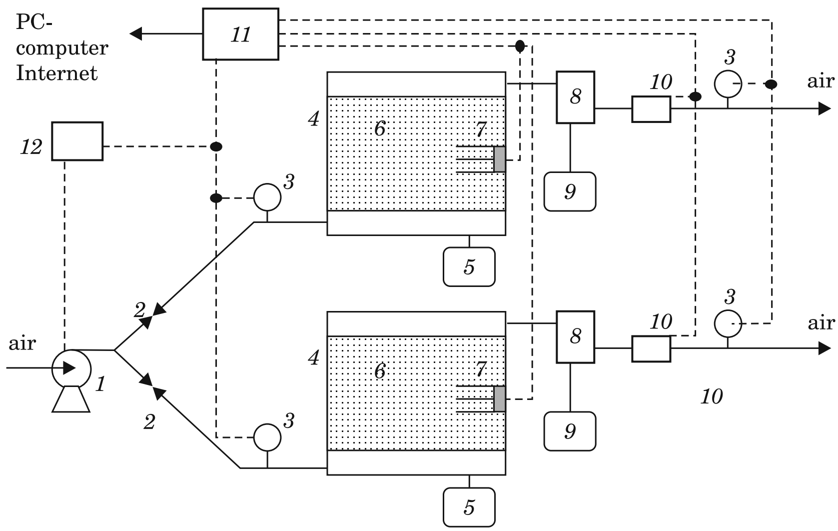

Fig. 1. Bioreactor scheme: *1* – pomp, *2* – flow controller, *3* – flow meter, *4* – insulated chamber, *5* – effluent tank, *6* – composted mass, *7* – set of temperature sensors, *8* – air cooler, *9* – condensate tank, *10* – set of gaseous sensors, *11* – recorder, *12* – pomp steering system

Methods and Results

The dynamics of the energy changes of bioreactor can be described with the overall heat balance equation:

$$\frac{dQ}{dt} = \frac{dQ_{\mathrm{bio}}}{dt} + \frac{dQ_{\mathrm{intake}}}{dt} - \frac{dQ_{\mathrm{exhaust}}}{dt} - \frac{dQ_{\mathrm{lost}}}{dt} \tag{1}$$

where:

Q – heat contents of the bioreactor [kJ],

Q_{bio} – heat of bioreaction in composting process [kJ],

Q_{intake} – heat contained in the inlet air [kJ],
Q_{lost} – heat losses via surface of the bioreactor [kJ],
$Q_{exhaust}$ – heat contained in the exhaust air [kJ].

In order to compare the quantity of energy produced in the composting process of the individual variants Q_{WK} was calculated as a sum of the energy in exhaust air ($Q_{exhaust}$) and the energy lost by walls of the bioreactor (Q_{lost}), reduced by the energy provided with intake air (Q_{intake}).

$$Q_{WK} = Q_{exhaust} + Q_{strat} - Q_{intake} \tag{2}$$

$$Q_{exhaust} = h_{exhaust} \cdot V_{exhaust} \tag{3}$$

$$Q_{intake} = h_{intake} \cdot V_{intake} \tag{4}$$

$$Q_{lost} = u \cdot t \cdot a(T_w - T_z) \tag{5}$$

where:
$h_{exhaust}$, h_{intake} – enthalphy air streams: exhaust and intake [kJ/m^3],
$V_{exhaust}$, V_{intake} – air volume: exhaust and intake [m^3],
u – overall heat transfer coefficient [W/m^2 K],
a – area of walls of the bioreactor [m^2],
t – time (s),
T_w – indoor temperature of the bioreactor [°C],
T_z – ambient temperature [°C].

In order to determine the value of enthalpy for the inlet and outlet air of the bioreactor the Kaiser method has been applied (KAISER 1996).

Using the above mentioned equation it was possible to determine the amount of energy emitted during the composting process in particular bioreactors.

The temperature is the main parameter characterizing the composting process. Figure 2 shows the temperature distribution in every variant.

The amount of carbon dioxide present in the outlet air of the bioreactor proves the activity of thermophilic organisms using oxygen in their metabolism in composting process. As it is shown in Figure 3 the amount of CO_2 leaving the bioreactor has fall down in three variants to zero in the 17th day of composting and maintained at a low level only in case of K4 variant. This certifies the end of thermophilic phase of the process.

Due to the fact that we compare only the heat energy of the process, we have taken under the consideration first 17 days of composting. In the further

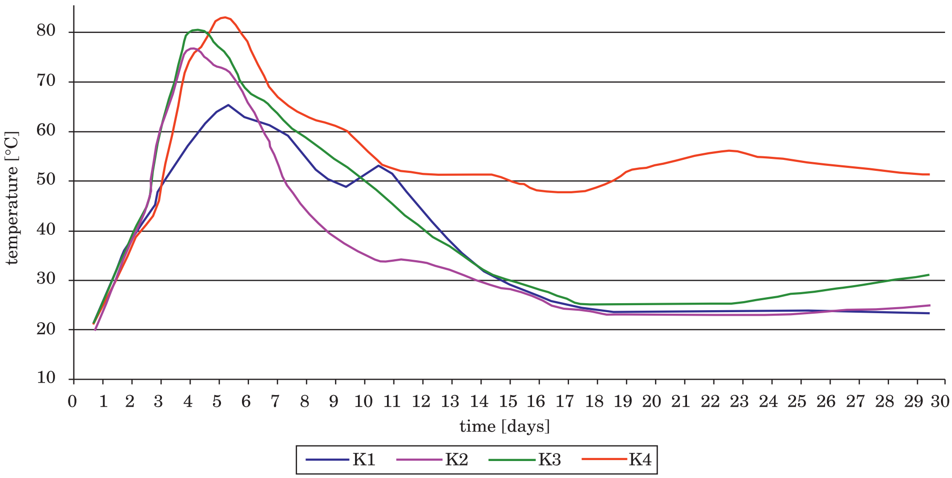

Fig. 2. Temperature distribution in particular variants

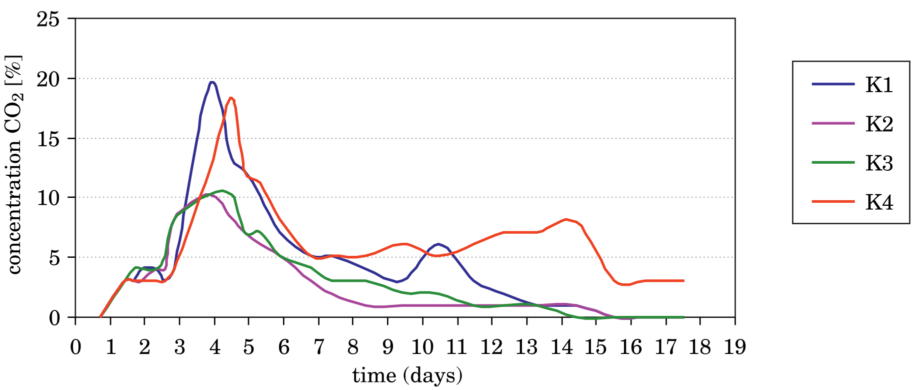

Fig. 3. Distribution of CO_2 concentration in outlet air

mesophilic part of the process apart from the heat energy also the methane is produced. Its energetic value should be taken into account in the energy balance, however it was not the subject of the research.

In consequence of conducted research the obtained data allowed to calculate the amount of energy that was emitted in composting process in particular variants (Tab. 2, Fig. 4).

Table 2

Amount of the heat emitted in particular variants in kJ for 1 kg of prepared mixture

Variant	K1	K2	K3	K4
Heat amount [kJ/kg]	1631	1342	1329	1535

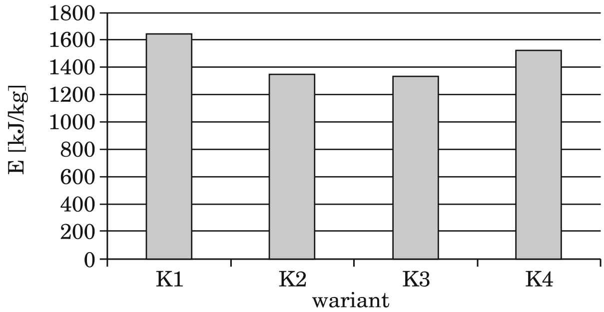

Fig. 4. Amount of the heat emitted in particular variants

Summary and the conclusions

On the basis of conducted research it has been stated that the highest temperature of composting process in the thermophilic phase is in case of K4 mixture (82°C) and slightly lower in K2 and K3 (respectively 80 and 76°C). Considerably lower temperature was noted in K1 mixture (65°C). However calculation of the amount of generated heat through the respective mixtures showed that the highest amount was during composting of K1 mixture (1631 kJ/kg). The confirmation of these calculations correctness is that in K1 variant it has been stated the highest amount of produced CO_2, which proves the highest metabolic activity of thermophilic microorganisms.

Slightly lower CO_2 emission was noted in case of K4 variant and calculated energy amounted 1535 kJ/kg, the lowest were for K2 and K3, which resulted in decreased amount of produced heat – respectively 1342 kJ/kg and 1329 kJ/kg. Lower temperature – in comparison with the rest of the mixtures – noted in K1 option was caused by its higher humidity and thus allows more heat to evaporate water.

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