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COMPOSTING PROCESS AS AN ALTERNATIVE METHOD FOR THE DISPOSAL OF SEWAGE SLUDGE AND ORGANIC FRACTION OF MUNICIPAL SOLID WASTE

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This paper attempts to propose a method for the neutralization of municipal sewage sludge and organic fraction of municipal solid waste. Sewage sludge from municipal wastewater treatment plants, organic fraction of municipal solid waste (MSW), grass and sawdust as a bulking agent were used in this study. Four mixtures with variable additions of sewage sludge and grass were composted in lab-scale bioreactors during 30 days. The obtained reduction of the ratio C/N indicates that the composting process ran correctly, however, it didn't reach the optimal values for composts (in some samples the temperature was insufficient). This work showed that the co-composting of organic fraction of municipal solid waste and sewage sludge can be the ultimate way of converting these resources for environmental use. However, additional investigations are required in order to optimize the organic and nitrogen degradation of compounds via the co-composting process.

Keywords: compost, organic fertilizer, municipal waste, sewage sludge

1. INTRODUCTION

Sewage sludge and municipal solid waste management has became one of the largest environmental concerns in recent decades, with the problem of the ever-increasing quantity to be managed. Sewage sludge is produced in large quntities in Poland, about 563,1 tons of dry matter in 2009, from those almost 82 tons of dry matter were landfilled. Poland is obligated to adjust sewage sludge management due to the accession to the European Union. The EU regulations demand reducing of organic matter in landfill sites by 65% until 2016 in

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comparsion with the year 1995 [1], which is related to the reduction of sewage sludge and organic fraction of municipal solid waste landfilling. The European Community aims to ensure the member states to adopt a waste management hierarchy in which management systems are ranked based on their environmental impact [2]. The most preferable options include prevention, material recovery, and recycling [3,4].

Biological treatment seems to be an effective method for recycling organic wastes. Aerobic composting of organic materials is one of the organic treatment process. The final product of composting is a stable humus-like material known as compost [4]. Compost material can be used for improving soil structure, which can act as a soil conditioner or fertilizer [5]. Composting is proven method for the treatment of green waste and food waste [6,7]. Sewage sludge and organic fraction of municipal solid waste are also good substrates for composting and for agriculturae purpose due to high organic matter content (50÷70% of the total solids) [8]. However, sewage sludge cannot be composted alone due to high moisture content and it needs to be mixed with bulking agents. Another option is co-composting of sewage sludge with two or more types of organic wastes. Co-composting could include some benefits to the composting process, higher porosity, better C:N ratio, addition of active biomass, or simultaneous management of interesting wastes [9]. Sewage sludge from municipal wastewater treatment plant is biowaste, so is easily available for co-composting, although the presence of heavy metals could prevent its use because of the low metals concentration allowed in the final compost.

The aim of the present work was to study the co-composting process of different mixtures of sewage sludge, organic fraction of municipal solid waste, grass and sawdust as a bulking agent.

2. MATERIALS AND METHODS

Sewage sludge from municipal wastewater treatment plant "Warta" in Czestochowa and the organic fraction of municipal solid waste (MSW) separated at the landfill in Sobuczyna, sawdust and green waste in the form of grass were used as a substrate for composting experiments. The mixtures for co-composting process were prepared by adding different quantites by weight of co-substrates:

- Mixture I –30% MSW, 40% sewage sludge, 20% grass, 10% sawdust,
- Mixture II –30% MSW, 30% sewage sludge, 30% grass, 10% sawdust,
- Mixture III–30% MSW, 20% sewage sludge, 40% grass, 10% sawdust,
- Mixture IV–30% MSW, 10% sewage sludge, 50% grass, 10% sawdust.

Charakteristics of the above mixtures are detailed in Tables 1 and 2.

The composting process was conducted in insulated closed batch reactor with the volume of 45L (Fig.1). For insulation purpose, 5-cm-thick layers of glass wool were used by wrapping the sides of the reactor. The experimental work was conducted at room temperature. Atmospheric air was pumped into the reactor using a valve and a rotametr to control the airflow. The exhaust gas was cooled down to ambient temperature by passing through a condensation arrangement. The air outlet was analysed via gas analyser GA2000 analyzer (Geotechnical Instruments, UK), which enabled the measurements of O_2, CO_2 and NH_3 emission.

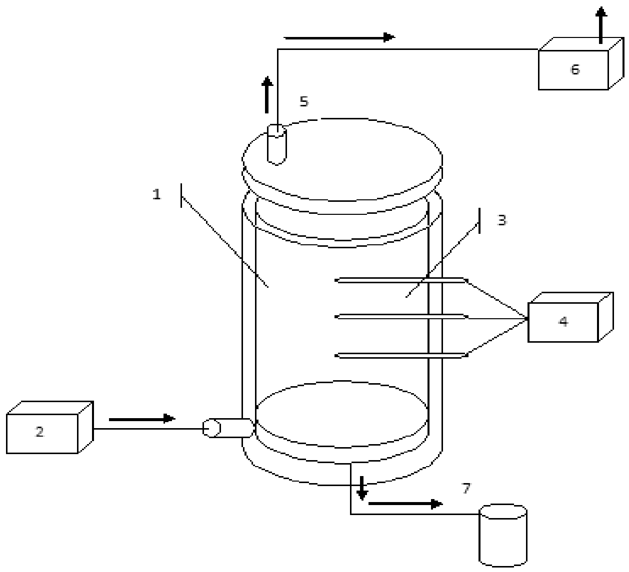

Fig. 1. Model of the bioreactor for composting and the associated monitoring and process control equipment: 1 –composting reactor, 2-aeration pump and regulating valve of the aeration intensity, 3 - temperature sensors, 4 – temperature control system, 5 – gas removal system, 6 – gas analyzer, 7 – leachate removal system

The pH was measured potentimetrically in the supernatant suspension of a 1:10 compost:water mixture. For moisture content determination, given samples were weighted into a crucible and put into an oven heated at a temperature of 105°C over night and reweighted. The difference in weight was expressed at the amount of water in the sample and was used to determine the moisture fraction of the material. The oven-dried sample was further mineralized at 550°C for 4 h for the determination of volatile solids (VS). Organic carbon in each samples was measured using TOC analyzer (Analytik Jena Multi N/C 2100). Total soluble N was extracted by the Kjeldahl digestion method using Büchi Distilation Unit K-335 equipment, followed by distillation and determination of NH_4-N using titrimetric procedures. Total P was determined by ammonium vanadate-molybdate method and concentration in the sample was read on spectrophotometer at 470nm. All compost digests were analysed for the total content of heavy metals by ICP-Mass Spectrometry (Optima 200 DV), after digesting samples with a mixture of conc. HNO_3 and HCl (1:3 v/v) in a microwave digester.

The population sizes of *E.coli* and *Salmonella* spp. were determined on selective media specific for each microbial group. The number of Helminth eggs were determined following Schwartzbrod (2003).

Data collected were analysed using Statistical Analyses Systems software. Results have been presented in averages and standard deviation.

3. RESULTS AND DISCUSSION

This experiment was carried out to verify the possibility of disposing of sewage sludge and organic fraction of municipal solid waste in the composting process. Figure 2 presents a graph of temperature changes during the composting process.

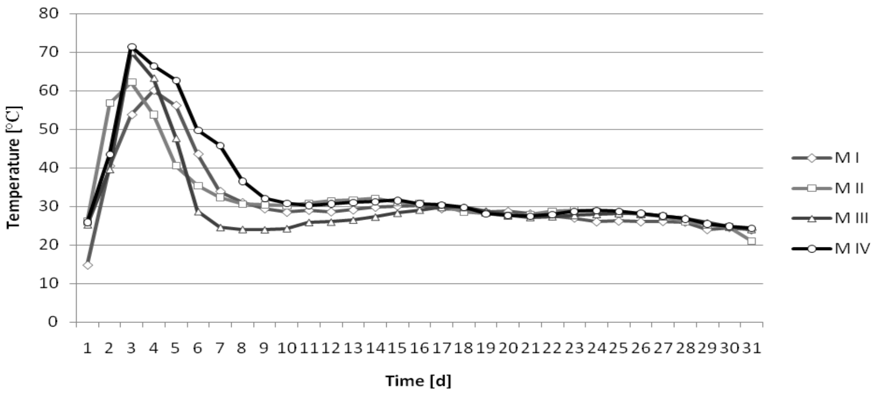

Fig. 2. Temperature during the composting process

The thermophilic phase (>50°C) was reached within two days and lasted for about three days for all composting experiments. Maximum temperature (71.4°C) was observed in the case of M IV, where the addition of organic waste was the highest. In the next period there was a clear drop in temperature whitch stabilized at the level 23°C. The duration of the termophilic phase was not sufficient to a fully hygienization of composts with 30% and 40% addition of sewage sludge.

Temperature, carbon dioxide production and oxygen consumption are very useful parameters for monitoring the composting process. The temperature must be positively correlated with CO_2 production and negatively with O_2. The negative correlation between O_2 and CO_2 has been observed for all mixtures. Oxygen concentration in the exhaust should be maintained between 10% and 18% (v/v) to optimize biological composting [11,12]. The period in which the consumption of oxygen decreased and then increased was corresponding to the period in which the temperature was high and the thermophilic conditions were observed, which are consistent with the results (Fig. 3).

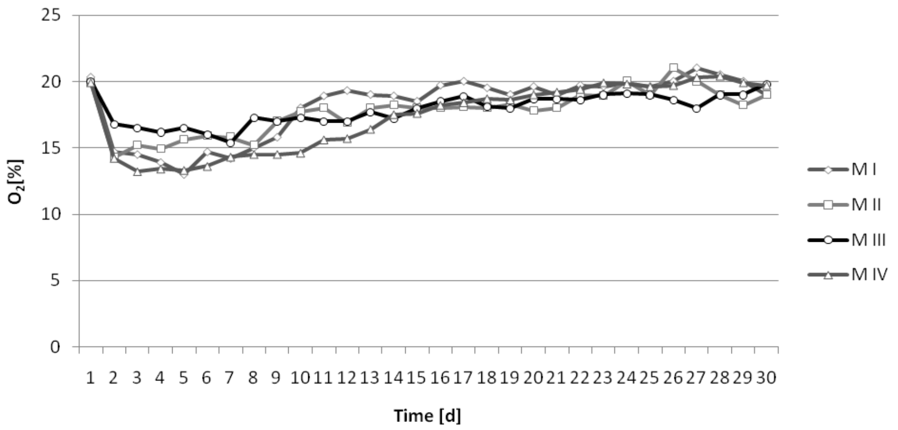

Fig. 3. Oxygen evaluation of waste mixtures during composting process

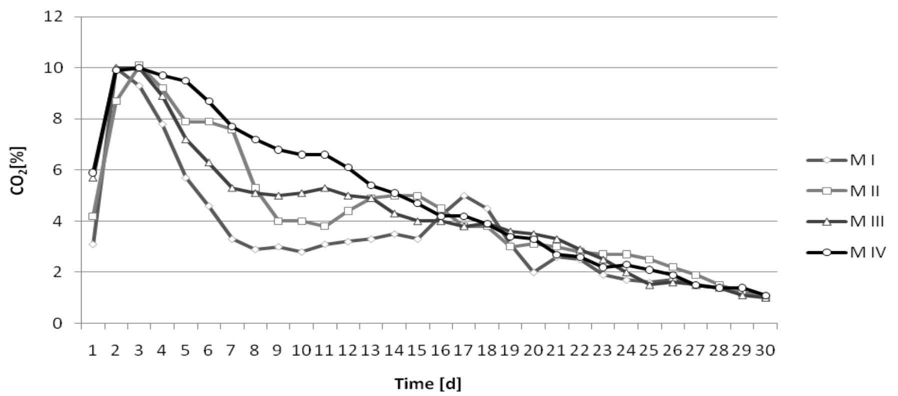

Figure 4. Carbon dioxyde evaluation of waste mixtures during composting process

Carbon dioxyde concentration for all mixtures showed a similar behaviour with temperature variations (Fig.4). During the process, the maximal carbon dioxyde production was noted within first a few days of incubation, probably due to easily biodegradable substrates. This phenomenon was strongly observed during composting of M IV, where grass represented 50% of mixture.

Carbon dioxyde concentration gradually decreased in all reactors and it became fairly constant after 27 days.

The moisture content slightly decreased in each of the compost at the end of the composting period. At the initial stage of experiment, the moisture content was about 71,5% and 69% for mixtures I and II, while for M III and IV was lower: 55,2% and 51,7% respectively. During the composting process the pH values varied in the range of 6.8-7.5. For composting process recommended pH values are within the range of 3-11 [23]. The C/N ratio of all samples generally decreased during composting. Values of the C/N ratio in initial mixtures ranged from 25,7 to 23,3. The optimal initiatory range of C/N ratio should be within the limits of 25:1-30:1. The C/N ratio was used by many authors as one of the indicators of compost maturity. However, it cannot be used as an absolute indicator of compost maturity due to its large variation, that is dependent on the starting materials. The obtained C/N ratio in this study was lower than recommended by authors [12,13]. Total nitrogen contents of M I-III increased after 30 days of composting due to the net loss of dry mass in terms of carbon dioxide, as well as the water loss by evaporation of organic matter[18]. In the sample M IV a decrease of total N was observed. However this decrease probably was caused by a short period of composting process. In the long term upward trend is observed. The decrease of total P content was observed at the end of the process, the loss of organic P is likely due to the mineralization of organic phosphorus and the consumption by microorganisms[14].

Table 1.Selected parameters in mixtures before the process and in the final product

Parameter	Mixture I		Mixture II		Mixture III		Mixture IV	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Organic matter [% d.m]	79,8	78,03	83,2	76,3	57,4	55,8	61,9	52
Dry matter [% d.m]	28,5	29,7	31,0	34,3	44,8	46,3	48,3	55,7
Moisture [% d.m]	71,5	70,3	69,0	65,7	55,2	53,7	51,7	44,3
C [%d.m]	30,3	29,5	34,5	30	27,3	25,7	29,3	23,4
N [%d.m]	1,3	1,34	1,34	1,4	1,2	1,24	1,26	1,12
P [% d.m]	3,45	3,32	2,5	2,1	3,1	2,23	3,03	2,14
pH	6,8	6,8	6,8	6,7	7,4	7,3	7,3	7,5
C/N	23,3	22,0	25,7	21,4	22,0	21,4	23,3	20,8

Concentration of heavy metals in the final product deserves consideration since they may enter the food chain when the digested products are applied on land. The final metal concentration compared with the maximum recommended values in the Polish regulations was shown in table 2 [21]. The results obtained during the experiment show that Cr exceeded the value in the case of compost

M I, the remaining amounts of heavy metals are within the scope of these limits[22].

Table 2. Heavy metal content in the composts

Metal	Limits imposed by Polish regulations	Mixture I	Mixture II	Mixture III	Mixture IV
		Final	Final	Final	Final
Cr mg/kg d.m.	100	105,0	94,9	76,7	49,7
Cd mg/kg d.m.	5	3,9	3,5	1,83	2,31
Ni mg/kg d.m.	60	60,0	50,5	51,7	36,2
Pb mg/kg d.m.	140	78,3	65,8	58,3	30,1
Hg mg/kg d.m.	2	0,3	0,2	0,2	0,1

One of the problems posed by the direct use of composted sewage sludge and organic fraction of municipal solid waste in agriculture is the risk of plant and human contamination by pathogens. During the composting process, coliform, *Salmonella* and number of a live helminth eggs were determined in samples taken at the initial and final stage of composting process (Table 3). *Salmonella* is considered as the most specific and problematic microorganism from a hygienic point of view, since it is a universal bacteria with a high growth capacity. Although the presence of *Salmonella* was detected in the initial mixture I and II, where the content of sewege sludge was the highest, but it was not detected in the final product of all experiments. The obtained results show that all initial samples are infected with helminth eggs, but there is a large variation in the degree of infection for the different sludge samples (216 to 311 eggs/kg d.m.). The inactivation of the helminth eggs in the compost can be accomplished, if the temperature inside the reactor is sufficient as in the case of M IV.

Escherichia coli are the most representative microorganisms. Most coliforms died when they are exposed to a temperature of 55ºC for 1h or 60ºC for 15-20 min. The concentration of this pathogens was considerably reduced during the composting process. In all mixtures the obtained temperature and duration of thermophilic phase is maintained seems enough to reduce this pathogen in the resulting composts. The Polish regulations require no presence of *Salmonella* and a live Helminth eggs to allow the use of composts in agriculture.

Table 3. Microbiological and parasitological survey in mixtures

Parameter	Mixture I		Mixture II		Mixture III		Mixture IV	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Coliform count	10^{-3}	10^{-4}	10^{-3}	10^{-4}	10^{-2}	not detected	not detected	not detected
Salmonella	detected	detected	detected	detected	not detected	not detected	not detected	not detected
Live Helminth eggs/kg d.m.	302	128	311	197	216	84	not detected	not detected

4. CONCLUSIONS

Four experiments were conducted in a small laboratory scale bioreactor with different feedstock quantities: OFMSW, sewage sludge, grass and sawdust as a bulking agent. Decrease in the C/N ratios indicates that the composting process ran correctly however it didn't reach low enough values. There was significant impact of the high temperature on the rate of the process and of the extent of the hygienisation. The final compost IV was well sanitized as a result of the high temperature achieved due to higher grass addition in these mixture. However the composts II and III can be used in agriculture after hygienisation. Conclusively, the co-composting of organic fraction of municipal solid waste and sewage sludge can be the ultimate way of converting these resources for environmental use. Additional researches are required in order to optimize the better organic and nitrogen compounds degradation during co-composting process.

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UNIESZKODLIWIANIE KOMUNALNYCH OSADÓW ŚCIEKOWYCH I ORGANICZNEJ FRAKCJI ODPADÓW KOMUNALNYCH JAKO ALTERNATYWNA METODA ICH ZAGOSPODAROWANIA

Streszczenie

W pracy podjęto próbę unieszkodliwiania komunalnych osadów ściekowych oraz organicznej frakcji odpadów komunalnych. Do przeprowadzonych badań zostały użyte osady ściekowe z oczyszczalni ścieków „Warta" w Częstochowie oraz organiczną frakcję odpadów komunalnych (OFOK) wydzieloną w Zakładzie Zagospodarowania Odpadów w Sobuczynie k/Częstochowy. Sporządzono cztery mieszanki, w których zastosowano stały udział wagowy OFOK i materiału strukturotwórczego (trociny). Natomiast zmiennymi były udziały trawy i osadów ściekowych. Doświadczenie prowadzono przez 30 dni w izolowanym bioreaktorze symulującym warunki pryzmowe. Zawężenie stosunku C/N wskazuje na poprawność prowadzenia procesu chociaż nie osiągnął on wartości optymalnej dla kompostów ze względu na krótki czas prowadzenia procesu. Stwierdzono, że uzyskana temperatura i czas jej trwania nie był wystarczający dla pełnej higienizacji kompostów M I-III. Współkompostowanie organicznej frakcji odpadów komunalnych i osadów ściekowych może być metodą ostatecznego zagospodarowania tych surowców na potrzeby przyrodnicze. Wymagane jest jednak prowadzenie dalszych badań w celu optymalizacji procesu.