The Effect of a Biopreparation Intended for Improvement of Biowaste Processing Efficiency on the Quality of Obtained Stabilized Waste

Mateusz Malinowski[1(✉)], Katarzyna Wolny-Koładka[2], Maciej Gliniak[1], Stanisław Famielec[1], Kamil Malczewski[1], Karolina Malczewska[1], Iwona Paśmionka[2], and Volodymyr Sharabrin[2]

[1] Institute of Agricultural Engineering and Informatics, Faculty of Production and Power Engineering, University of Agriculture in Krakow, Balicka 116b, 30-149 Krakow, Poland
mateusz.malinowski@urk.edu.pl

[2] Department of Microbiology, Faculty of Agriculture and Economics, University of Agriculture in Krakow, Mickiewicza Ave 24/28, 30-059 Krakow, Poland

Abstract. The aim of the paper was an assessment of the effect of a commercial biopreparation, a liquid bacteria composite intended for improvement of biowaste processing efficiency, on the course of aerobic biostabilization process of the undersize fraction (waste separated from mixed municipal solid waste) mixed with municipal sewage sludge, as well as an assessment of the quality of initially obtained stabilized waste. Presented research comprised analyses of raw materials and mixtures used in the process and the waste obtained after 2 stage process (2 week intensive phase in a bioreactor and 6 week second phase - maturation in the compost pile). Moisture content, organic matter, C and N contents, C/N ratio and pH were analysed. Moreover, the number of parasites and microorganisms in waste was estimated. The process temperature was monitored. On the basis of conducted analyses it was stated that the biopreparation tested does not fulfil its basic role, so it should not be used in sewage sludge and municipal solid waste hygienization process. Physicochemical analysis indicated an insufficient progress in the properties of treatment waste. The number of all investigated microorganisms increased considerably after aerobic biostabilization process, despite the added biopreparation, which according to its manufacturer's declaration was supposed to reveal antimicrobial effect. Moreover, presence of a large number of live parasite eggs was found in all analysed samples, which makes environmental application of the tested biowaste impossible.

Keywords: Biowaste · Biopreparation · Aerobic biostabilization · Microbiocenotic composition · Parasites

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1 Introduction

The search for new methods which would enable shortening the duration of waste biological treatment and, at the same time, would ensure obtaining a final product of full value (e.g. compost) or waste meeting legal requirements (e.g. stabilized waste), has been currently one of the most important challenges of ecological engineering. Research conducted in this field focuses on decreasing the harmfulness of this process to the environment [5] and shortening biowaste processing time. Therefore, changes are made in construction of bioreactors [3] waste processing technologies, e.g. concerning lecheate recirculation [21], initial substrate transformation [10, 11, 30, 31], adding solid and liquid [9, 15, 17, 19, 20, 23] or gaseous substances [4]. Usefulness of these additives has been permanently discussed among experts and non-professionals [8].

Several works were published that studied both positive and negative effects on the course of the composting process and on the quality of the resulting compost [7]. Koivula et al. [12] studied the effect of bottom ash on the composting of source-separated catering waste and found that a 10% and 20% ash addition improved the temperature regime, mineralization and humification rates, and decreased loss of total nitrogen. Kollárová [13] experimented with two commercial additives for the composted waste. In this experiment, a positive effect was demonstrated on the reduced production of NH_3, CO_2, CH_4 and H_2S emissions. Out of three lime addition rates to sewage sludge (0.63%, 1%, and 1.63%) tested by Wong and Fang [29] the most efficient was 0.63%. This amount had a positive effect on composting by increasing temperature and CO_2 production without any negative effects on the microbial community. Bereza-Boruta et al. [2] investigated the effect of bacteria composite on odour emission and dynamics of bacterial microflora development.

Presented research analysed the efficiency of a liquid biopreparation (intended for sewage sludge composting plants and developed on the basis of various microorganisms mixture), whose main task is decreasing the odour nuisance of the process, shortening its duration owing to faster achievement of parameters for the final product and hygienization of the process waste (i.e. elimination of pathogenic microorganisms and parasites).

The aim of the paper was an assessment of the effect of a commercial liquid biopreparation on the course of aerobic biostabilization process of the undersize fraction separated from mixed municipal solid waste (MSW) and mixed with municipal sewage sludge. The paper also strived to investigate the initially stabilized waste generated in this process in view of their safe environmental application.

2 Materials and Methods

The waste (undersize fraction) was obtained from mechanical-biological installation (MBT) in Krakow (Poland), while sewage sludge came from the municipal sewage treatment plant in Bochnia (Poland). Analyses were conducted, in an insulated BKB100 bioreactor with 116 dm^3 working volume and 99 cm high. The bioreactor, insulated outside with a special thermal mat, inside had 9 sensors for the bed temperature measurement. Construction of the bioreactor makes collecting samples at various periods of the experiment possible. The functioning of the device was described in the papers by Baran et al. [1] and Malinowski [14].

The biopreparation is a liquid composite of yeast, mould, fungi and algae. The manufacturer states that the biopreparation application should result in a considerable water loss. After processing the waste should be more compact and drier.

The undersize fraction was mixed with municipal sewage sludge at 1:1; 2:1 and 3:1 ratios. The applied biopreparation dose was 1 ml per each kilogram of load wet weight. Two different concentrations of the biopreparation were applied in the analyses (it was solved in water at 1:5 and 1:10 ratios - according to the producer's recommendations). The waste and sewage sludge were mixed mechanically in a cement mixer prior to their putting in the bioreactor. The treatment of mixtures prepared in this way lasted for a total of 8 weeks (2 week intensive phase in the bioreactor and 6 week second phase – maturing in the compost pile). The non-mixed undersize fraction and municipal sewage sludge were also investigated.

Physicochemical analyses were conducted to determine the moisture content (MC), organic matter - loss on ignition (OM), C and N contents, C/N ratio and pH. Moreover, the number of parasites and microorganisms in the waste, sludge and in mixtures was estimated in order to assess the obtained material and its potential, e.g. environmental applications [26]. The process temperature was also monitored.

Microbiological analysis was conducted using serial dilutions method according to Koch. The following microorganism groups were determined: total vegetative bacteria and bacterial endospores, mould fungi, *Staphylococcus* spp., *Escherichia coli*, *Salmonella* spp., *Clostridium perfringens* [28]. Parasitological analysis of the samples containing sewage sludge and undersize fraction was conducted by means of reference method, which relies on determining the number of live eggs of intestinal parasites.

The number of live eggs of *Ascaris* sp., *Trichuris* sp. and *Toxocara* sp. intestinal parasites was determined by isolating live eggs from a representative sample of sludge and waste through shaking or mixing, washing using centrifugation and flotation, followed by a microscopic analysis. In compliance with the Regulation of the Minister of Natural Environment of 1 August 2002 on municipal sewage sludge, a total number of live eggs of *Ascaris* sp., *Trichuris* sp. and *Toxocara* sp. intestinal parasites should be determined per 1 kg of dry mass (ATT index). The research was conducted using modified flotation method with sodium nitrate. The method involves application of a saturated solution with a higher specific gravity that the eggs weight, which causes their flotation to the surface [6, 16, 22]. The substances free from these parasites' eggs may be used in agriculture, whereas the content of over 10 invasive eggs is regarded as contamination dangerous from epidemiological point of view and such substances cannot be applied in agriculture.

3 Results

Organic waste (21.2 ± 4.4%) and fine fraction (35.9 ± 5.7%), i.e. with grain size below 10 mm, dominate in the morphological composition of the undersize fraction used in the research. Inorganic inclusions (plastics and glass) constitute a total of 27.2%. Morphological composition of the undersize fraction falls within the range stated among others by: Baran et al. [1], Malinowski [14] and Stejskal et al. [24, 25]. Basic physicochemical properties of the analysed waste and mixtures were presented in Table 1. A sewage sludge additive (with the content of N = 6.6 ± 0.7% d.m) significantly affected the increase in MC, N concentration and loss on ignition in the analysed mixtures.

Table 1. Characteristics of physicochemical properties of waste and mixtures used in the biostabilization process with the biopreparation

Material*	MC	C	C/N	OM
	%	% d.m.	-	% d.m.
UF 100%	32.7	28.2	24.7	51.7
SS 100%	85.9	30.3	4.6	83.3
UF 50% + SS 50% (1:1)	63.3	43.7	13.3	78.8
UF 66% + SS 34% (2:1)	50.8	36.6	18.5	66.4
UF 75% + SS 25% (3:1)	46.1	34.3	20.2	61.7

* UF – undersize fraction, SS – sewage sludge

Sewage sludge used for the analyses contained a high content of intestinal parasite eggs (because it was not stabilized by e.g. calcined lime). ATT index was 995 ± 29. Moreover, the presence of spore forming bacteria, i.e. *C. perfringens* (4000 cfu g^{-1}) and pathogenic microorganisms, including *Samonell*a spp. (1105 cfu g^{-1}) and *E. coli* (33400 cfu g^{-1}) was identified in the analysed material, which suggest that only the temperature exceeding 100 °C might prove adequate for the samples hygienization.

Pathogenic microorganisms i.e. *Staphylococcus* spp. (135100 cfu g^{-1}), *E. coli* (48000 cfu g^{-1}), *Salmonella* spp. (240 cfu g^{-1}) and *C. perfringens* (80 cfu g^{-1}) were the most numerous in the undersize fraction. The total content of intestinal parasite eggs was 857 ± 42 and, like in case of sewage sludge, *Ascaris* sp. eggs were the most numerous group.

As a result of aerobic biostabilization of the undersize fraction, sewage sludge and their mixtures with the biopreparation additive, ATT index decreased on average by 124 ± 36. A very high abundance of *Staphylococcus* spp., especially following the aerobic stabilization process and *Salmonella* spp. are also particularly noteworthy. Comparing the results of bacterial counts from the subsequent waste samples subjected to aerobic biostabilization, it should be stated that the applied process parameters, and also the preparation and sewage sludge additive contributed to the increase in microorganism number. The numbers of individual microorganism groups grew significantly, while in case of pathogenic microorganisms, i.e. *E. coli* and *Staphylococcus* spp., reached the values 624000 cfu g^{-1} (fraction:sludge 2:1) and 294000 cfu g^{-1} (fraction:sludge 1:1), respectively. Therefore a counterproductive effect was achieved, which suggests, that the parameters of aerobic stabilization process were favorable for the development of determined microorganisms. In the research conducted by Wolny-Koładka et al. [27] the content of some microorganisms was also increasing during processing of undersize fraction (100%).

Table 2 shows the effect of applied biopreparation on the maximum temperatures reached during the process, but also on the duration of the intensive (thermophilic) phase, during which the temperature exceeds 45 °C. The processing temperature exceed 60 °C in case of stabilization of the undersize fraction and undersize fraction mixed with sewage sludge at 1:1 and 2:1 ratios, whereas slightly higher temperatures were achieved with the biopreparation addition in 1:10 concentration.

Table 2. Maximum temperatures during waste biostabilization and duration of intensive (thermophilic) phase

Mixture*	Applied biopreparation	Maximum temperature	Duration of the thermophilic phase
	-	[^{o}C]	[days]
UF 100%	1:10	62.4	3
UF 100%	1:5	60.2	4
SS 100%	1:10	42.2	1
SS 100%	1:5	49.8	4
UF 50% + SS 50% (1:1)	1:10	70.4	4
UF 50% + SS 50% (1:1)	1:5	66.7	5
UF 66% + SS 34% (2:1)	1:10	64.2	4
UF 66% + SS 34% (2:1)	1:5	63.8	2.5
UF 75% + SS 25% (3:1)	1:10	56.7	4
UF 75% + SS 25% (3:1)	1:5	54.3	4

* UF – undersize fraction, SS – sewage sludge

Table 3. Final parameters of the stabilized waste

Mixture*	MC	C	OM	pH
	%	% d.m.	% d.m.	
UF 100%	33.4	24.7	36.2	8.5
UF 100%	31.8	25.6	33.1	8.4
SS 100%	77.3	39.3	72.2	7.1
SS 100%	71.3	36.9	69.7	7.4
UF 50% + SS 50% (1:1)	33.3	26.4	42.2	7.9
UF 50% + SS 50% (1:1)	32.6	24.1	36.9	7.8
UF 66% + SS 34% (2:1)	28.9	26.1	41.1	8.3
UF 66% + SS 34% (2:1)	29.5	24.2	38.7	8.5
UF 75% + SS 25% (3:1)	28.6	19.6	28.7	8.6
UF 75% + SS 25% (3:1)	27.9	22.3	35.4	8.9

* UF – undersize fraction, SS – sewage sludge

Final values characterizing physicochemical properties of waste after the process were presented in Table 3. As a result of the conducted process, water content in the sludge and in the analysed mixtures decreased significantly. The content of C declined in each of the analysed variants, but only in one fell below the reference value (20%). Also, only in two cases among all analysed ones, the values of loss on ignition below 35% d.m. were reached. The applied biopreparation did not allow for shortening the process duration, because it should last for at last several weeks more. Hlisnikovsky [8] and Razvi i Kramer [18], reached similar conclusions while testing the preparations based on microorganisms. They tested seven compost additives and demonstrated that the additives were no more efficient than mature compost without admixtures.

4 Conclusions

On the basis of conducted analyses it was found that the number of all analysed microorganisms increased significantly following the aerobic biostabilization process, despite the addition of the biopreparation, which according to its manufacturer was supposed to reveal antimicrobial activity. A physicochemical analysis indicated an insufficient progress concerning the obtained quality parameters of the treatment waste, thus it cannot be considered safe for agriculture use or depositing on a landfill site. The waste should be further processed to lower, among others, its C concentrations and organic matter content. Therefore, it should be said that the analysed preparation does not fulfil its basic function, so it should not be used in the process of the undersize fraction or sewage sludge hygienization.

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