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EFFECTIVENESS OF SLUDGE PROCESSING WITH BIO-PREPARATION (EM-bio) AND STRUCTURAL MATERIAL

The tests on wastewater sludge processing with bio-preparation and structural material were carried out on a laboratory scale in three series. In each series, secondary sludge was used after aerobic stabilization and dewatering. Bio-preparation, called EM-bio, was applied. Wooden chips, sand and compost made of waste were used as a structural material. The aim of this study was to determine preliminary the effectiveness of bio-preparation (EM-bio), particularly to define the optimal conditions for applying the bio-preparation. The impact of structural material on sludge characteristics and stabilization was also discussed. The analysis of the results indicated that the bio-preparation slightly modified biochemical processes.

1. INTRODUCTION

Wastewater treatment plant exploitation is closely connected with the necessity of appropriate sludge management. Sludge needs to be processed and then properly utilized. The universally applied methods of sludge processing are as follows: thickening, stabilizing and drying. They allow mineralization of organic compounds, sludge volume reduction and hygienization. Nowadays, there is also another aim – to cut down or limit odour emission [1]–[4]. The application of bio-preparation to sludge processing can change the paths of biochemical processes in such a way that final substances are odourless [5], [6]. Sludge properties and process effectiveness can be changed as well.

Mixing sludge with structural material is a promising way of sludge management [7]. The aim of this study was to determine preliminary the effectiveness of bio-preparation (EM-bio) in limiting the odour nuisance of wastewater sludge, particu-

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larly to define the optimal conditions for applying the bio-preparation. The impact of structural material on sludge characteristics and stabilization is also discussed.

2. METHODS

The tests on wastewater sludge processing with bio-preparation and structural material were carried out on a laboratory scale in three series. In each series, secondary sludge was used after aerobic stabilization and dewatering.

Bio-preparation (EM-bio) containing a mixture of various coexisting microorganisms was applied [6]. EM is the standard abbreviation for "Effective Microorganisms". The constituent parts of anabiotic strains in EM include: yeast, lactic acid bacteria, phototrophic bacteria and fungi. A preparation containing actinomycetes was additionally introduced in the first and second series.

The study was carried out in three series. In the first and the second series, eight c.a. 20-kg samples were processed. In the third series, the mass of the samples approached 1.5 kg. Both in the first and the second series, a part of each sample was aerated by passing the air from the bottom of containers through the sludge. Exhaust gas above the sludge was carried away by an outlet system. The rest of the sample was only slightly aerated by supplying the air from above the sludge. The testing stations are shown in figures 1, 2 and 3, and the technology of sludge processing, in table 1.

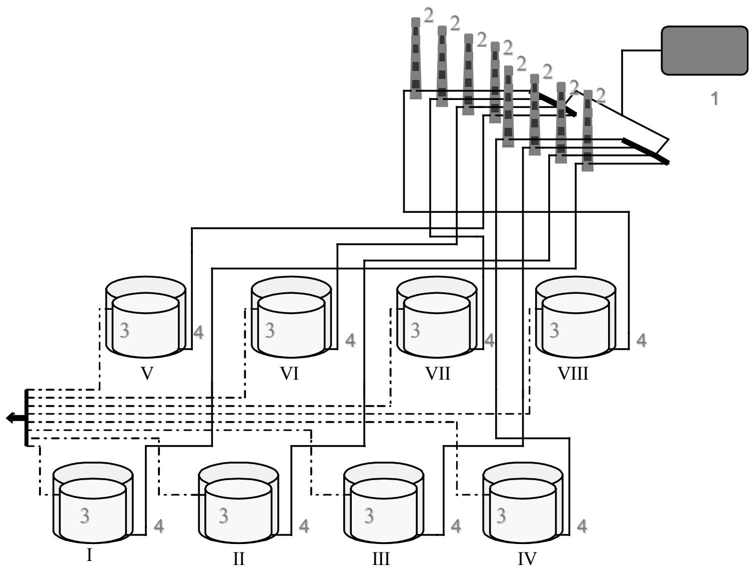

Fig. 1. Diagram of testing station; three series:
1 – blower, 2 – rotameter, 3 – 3-dm^3 container, 4 – aeration system

Fig. 2. Testing station – containers with samples; series I and II

Fig. 3. Testing station – containers with samples; series III

Table 1

Technology of sludge processing

	Sample No.	1	2	3	4	5	6	7	8
Series I	EM-bio	–	–	+	+	+	+	+	+
	Aerating	–	+	–	+	–	+	–	+
	Actinomycetes	–	–	–	–	+	+	–	–
	Light	–	–	–	–	–	–	+	+
Series II	EM-bio	–	–	–	–	+	+	+	+
	Actinomycetes	–	+	–	–	–	+	–	–
	Aerating	–	+	–	–	–	+	–	–
	Mixing	–	–	+	+	–	–	+	+
	Wooden chips	–	–	–	19%	–	–	–	19%
Series III	EM-bio + actinomycetes	–	–	–	+	+	+	+	+
	Aerating	+	+	+	+	+	+	+	+
	Mixing	+	+	+	+	+	+	+	+
	Dry weight	53%÷66%	40%÷56%	82%÷87%	82%÷89%	55%÷68%	40%÷57%	55%÷70%	44%÷58%
	Compost	43%	23%	0%	0%	43%	23%	33%	17%
	Sand	10%	10%	100%	100%	10%	10%	21%	22%
	Sludge	47%	67%	0%	0%	47%	67%	56%	61%

At 14-day intervals, sludge samples were taken and gas analyses were carried out. The samples of wastewater sludge were collected by means of a special sampler for soil, previously disinfected by a denaturant. The samples were taken from all depths of the container. The range of the parameters under analysis included: temperature, reaction (according to Polish Standard PN-Z-15011-3), redox potential (PN-ISO 11271:2007), mass and dry mass (using the lyophilization process), volatiles in dry weight (PN-Z-15011-3), and total nitrogen and organic carbon with the Flash 1112 analyzer (ThermoQuest). Nitrogen mineralization by microflora was based on the extraction of 5-g sludge sample in 50 cm^3 of water. Such a sample was shaken for 30 min and then swirled. Finally, the following parameters were determined: ammonia nitrogen according to PN-ISO 5664, using UDK 132 Semiautomatic Distillation Unit (VELP), nitrate nitrogen (PN-82/C-04576.08), nitrite nitrogen (PN-EN 26777) and phosphate phosphorus (PN-EN 1189).

Respiration activity in wastewater sludge and the volume of the gases released, i.e. oxygen, carbon dioxide and methane, were determined according to the standards: PN-ISO 16072, PN-ISO 14240-1, PN-ISO 17155, respectively. Odorimetric analysis of the sludge consisted in testing the odour noxiousness of exhausted air using the dynamic dilution method and an estimation of the aroma intensity using *n*-butanol solutions. The aroma intensity was tested by four or more persons. The results of gas analysis will be published elsewhere.

3. RESULTS

Some technological parameters are shown in table 2, and the results in figures 4–6. In the sludge, before processing and without structural material, the reaction was inert, the dry weight was low and varied from 15.9% to 16.5% in all the series, volatiles in dry weight reached 64–71% of the dry mass (table 2). The sludge contained a high amount of total nitrogen (5.5–6.5%) and a medium amount of organic carbon (32–41%). The total nitrogen to organic carbon ratio (C/N) was low and equalled approximately 6.2.

Table 2

Some technological parameters

Parameter	Series I	Series II	Series III
Duration of series [d]	69	59	56
Initial dry weight [%]	15.9÷16.2	13.8÷24.1	35÷84
Initial volatiles in dry weight [% of d.w.]	64.3÷66.4	71.0÷85.5	6.5÷28.3
Initial organic carbon [% of d.w.]	34.7÷36.3	33.1÷40.8	4.7÷21.4
Initial total nitrogen [%]	5.3÷5.7	3.4÷6.7	0.6÷4.7
Initial C/N [–]	6.3÷6.6	5.7÷10.6	4.0÷10.15
Porosity [%]	–	–	41÷65
Temperature inside samples [^oC]	17.2÷20.2	17.0÷24.5	12.0÷26.0
Redox potential [mV]	–300÷–80	–260÷300	–36÷650
Aerating [l/kg of d.w. h]	13÷27	36÷307	50÷525

In the second series, a small amount of wooden chips was added to samples 4 and 8, so that some initial parameters were higher compared with the remaining samples: dry weight was 23.9% and organic compounds reached 85% of the dry mass. Initial total nitrogen concentration was lower and equal to 3.5%, so C/N was higher – 10.7. In the third series, sand and compost made of waste were used. Initial parameters of the mixtures differed considerably. The initial dry weight varied from 31% to 54%, but in the sand (samples 3 and 4), it was as high as 84%. Organic compounds content reached 16–34% of the dry weight, but in samples 3 and 4, it was about 7% of d.w. The samples contained 5.5–6.5% of total nitrogen and a medium amount, i.e. 32–41%, of organic carbon. The ratio of total nitrogen to organic carbon (C/N) was low and approached 6.2.

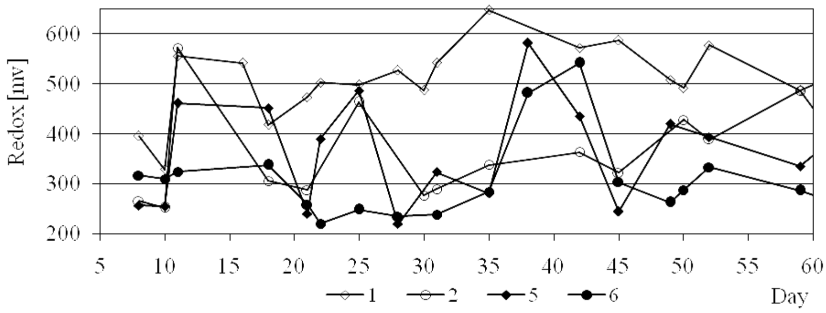

Fig. 4. Changes of redox potential during series III

In all the series, redox potential was measured in situ to the depths of 4 and 14 cm. In the first series, all the results were always negative. In the second series, in samples 1 and 5, redox potential (ORP) was decreasing during the experiment. Aerating and mixing had no substantial influence on ORP. An average value of this parameter was –148 mV for the samples without EM-bio (No. 1–3) and –170 mV for the samples with EM-bio (No. 5–7). The samples with wooden chips displayed increasing value of ORP, hence at the end of the series, after 43 days of processing, it ranged from ca. 200 to ca. 300 mV. In the third series, in all the samples and during the whole time, redox potential was high, with an average value of 345 mV (figure 4). In all the series, ORP in the samples with the EM-bio was slightly smaller.

In the first series, dry weight slightly decreased, but less than 1%. In the second series, this parameter was changing in a different way: in sample 1 it declined by about 1%, in samples 2, 3 and 7, it increased by about 1%, and in the rest of the samples it increased by about 2%. The third series was characterised by a considerably greater increase in dry weight, so water was added to each sample regularly to keep dry weight at the established (88% for samples 3, 4, 60% for samples 1, 5, 7 and 50% for 2, 6, 8) which prevents the samples from drying.

In the first series, the content of organic compounds slightly decreased and ranged from 66% to 62% of the dry weight. The biggest drop of this parameter, equal to about 5%, appeared in sample 4. In the second series, a decrease in organic compounds was similar, but in samples 4 and 8 this decrease was equal to 9% and 11.3%, respectively. However, the content of organic compounds in samples 4 and 8 at the end of the experiment was still higher than in the rest of the samples. In the third series, the content of final organic compounds constituted 15–30% of the dry weight, but in samples 3 and 4 it was about 6% of d.w.

Total nitrogen content gradually decreased to about 1% in all the samples of the first series, when organic carbon decreased to about 5–6%. The content of total nitrogen in the second series slightly increased by about 1–1.5%, while organic carbon concentration dropped in the range from 0.5% to 6.6% in the first month. It is important to stress that in all the samples with EM-bio, a decrease in organic carbon was found to be smaller than in the samples without it. In the third series, the same interdependence was found for total nitrogen.

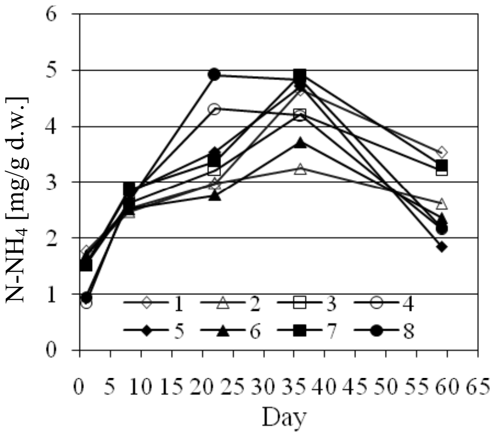

Fig. 5. Changes in ammonia nitrogen concentration in series II

As a result of nitrogen mineralization in the first series, the concentration of ammonia nitrogen was gradually rising from an average value of 0.9 mg $N\text{-}NH_4$/g d.w. to 8.2 mg $N\text{-}NH_4$/g d.w., while the concentration of nitrate nitrogen was reduced from 0.18 mg $N\text{-}NO_3$/g d.w. to 0.02 mg $N\text{-}NO_3$/g d.w. In the second series, the increase of ammonia nitrogen concentration was considerably lower, with an average value of 1.4 to 4.3 mg $N\text{-}NH_4$/g d.w. after 36 days of processing (figure 5). The average concentration of nitrate nitrogen was decreasing from 0.011 to 0.008 mg $N\text{-}NO_3$/g d.w. The highest concentration of this compound was measured in the samples with the structural material, where it fluctuated between 0.010 and 0.024 mg $N\text{-}NO_3$/g d.w. There were no differences between the samples with EM-bio or without it. Other changes in nitrogen mineralization were observed during the third series. The average concentration of ammonia nitrogen was 0.3 mg $N\text{-}NH_4$/g d.w. at the beginning of the experiment, and it decreased to about 0.1 mg $N\text{-}NH_4$/g d.w. at its end. Average nitrate nitrogen content was increasing from 0.007 to 0.190 mg $N\text{-}NO_3$/g d.w (figure 6). In sample 5, the concentration of nitrate nitrogen at the end of experiment reached the highest value of 0.41 mg $N\text{-}NO_3$/g d.w. Lower values observed in samples 3, 4, and 8 and were equal to 0.007, 0.005 and 0.002 mg $N\text{-}NO_3$/g d.w., respectively.

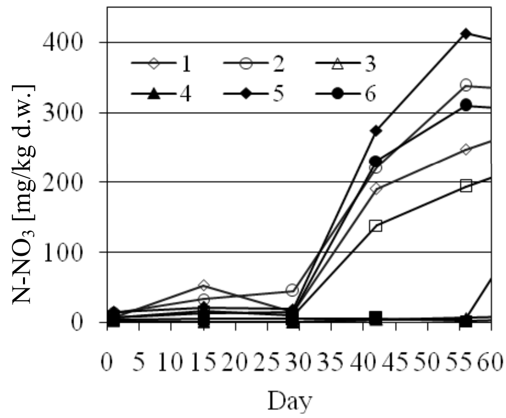

Fig. 6. Changes in nitrate nitrogen concentration in series III

Concentration of phosphate phosphorus in the first series was gradually rising from an average value of about 0.6 mg P/g d.w. to 1.8 mg P/g d.w. The same upward trend was observed in the second series, where its average concentration was increasing from 0.4 to 2.5 mg P/g d.w. In the third series, we did not observe any regularity in the changes of phosphate phosphorus concentration which fluctuated between 0.0 and 0.26 mg P/g d.w. with an average value of 0.4 mg P/g d.w. There was no visible impact of EM-bio on this parameter in any series.

In the first series, sludge was not porous, thus the contact area between sludge and air was small. At a low intensity of aeration, it created almost anaerobic conditions for sludge processing. In this series, mixing was not an efficient method of improving the conditions of sludge processing.

Aeration intensity was not the reason for a better sludge stabilisation in the third series compared with the second, because this parameter was similar in both series (table 2). Higher dry weight and porous structure of sludge made its stabilisation better.

4. SUMMARY AND CONCLUSIONS

1. The analysis of the results prove that the bio-preparation slightly modify biochemical processes. In the samples with EM-bio, the redox potential was lower and a decrease of volatiles in dry weight was slightly smaller than that in the samples without it.

2. The amount of structural material for processing the sludge with EM-bio should be calculated to achieve initial dry weight in the range of 40–55%.

3. The addition of wooden chips made both initial and final sludge dry weight greater and created its porous structure. 19% addition of wooden chips whose dry weight approached 24% was too small to assure good conditions for the processing of dewatered sludge with EM-bio.

4. Compost allowed the sludge to create porous structure and to achieve a dry mass as high as 30–55%. It also ensured a high redox potential and nitrate nitrogen production, but was responsible for low C/N ratio and low organic carbon concentration.

5. Due to its specific structure compost makes the sludge loose, thus improves the exchange of gases and creates favourable conditions for aerobic zones.

6. The impact of EM-bio on phosphorus concentration was not visible in any series.

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EFEKTYWNOŚĆ PRZETWARZANIA OSADÓW WTÓRNYCH Z DODATKIEM ŚRODKÓW STRUKTUROTWÓRCZYCH I BIOPREPARATU EM

Proces przetwarzania osadów ściekowych z biopreparatem i materiałami strukturotwórczymi był badany w skali laboratoryjnej w trzech seriach. We wszystkich seriach wykorzystano osad wtórny po tlenowej stabilizacji i odwadnianiu. Zastosowano biopreparat EM-bio. Trociny, piasek i kompost z odpadów wykorzystano jako materiał strukturalny. Celem badań było określenie skuteczności biopreparatu EM-bio w ograniczaniu uciążliwości zapachowej osadów ściekowych, a w szczególności określenie optymalnych warunków stosowania biopreparatu. Omówiono także wpływ materiałów strukturotwórczych na charakterystykę osadu i jego stabilizację. Analiza wyników badań wykazała, że biopreparat EM-bio modyfikował procesy biochemiczne zachodzące w osadzie.