Environment Protection Engineering

Vol. 37 2011 No. 3

MARIA GRABAS*, JANUSZ A. TOMASZEK*, EWA CZERWIENIEC*, JUSTYNA ZAMORSKA**
EWA KUKUŁA***, ADAM MASŁOŃ*, RENATA GRUCA-ROKOSZ**

NOXIOUSNESS OF ODOURS AND PROPERTIES OF WASTEWATER SLUDGE PROCESSING WITH BIOPREPARATION

The aim of the study was to verify the effectiveness of decrease of odour production during sludge stabilization with selected groups of microorganisms in conditions similar to those occurring on sludge storage pads. The experiments were carried out on a laboratory scale; the biopreparation EM-bio was used. It was found that in anaerobic conditions, biopreparation modified biochemical processes in a small degree and decreases the redox potential. Clear decrease of odour noxiousness of the wastewater sludge for samples with biopreparation was not observed. In the continuation of these studies sludge processing at higher redox potentials should be investigated.

1. INTRODUCTION

In wastewater treatment plants, odour problems occur as a result of odour emission from the utilization and storage of screenings, greet and sludge. The odours form during biochemical processes occurring in technological facilities, drying beds, storage pads and during sludge transport to the place of the final utilization. In the case of sludge treatment, considerable amounts of odour are produced during the stabilization processes and dewatering [1, 2]. In 1993, complaints pertaining to the noxiousness of odours represented 43% of all complaints [3].

The modification of the biochemical processes in wastewater sludge could lead to a significant limitation of noxious odour. During the decomposition of organic matter

*Faculty of Civil and Environmental Engineering, Department of Environmental and Chemistry Engineering, Rzeszów University of Technology, ul. Powstańców Warszawy 6, 35-959 Rzeszów, Poland. Corresponding author: M. Grabas, e-mail: grabas@prz.edu.pl

**Faculty of Civil and Environmental Engineering, Department of Water Purification and Protection, Rzeszów University of Technology, ul. Powstańców Warszawy 6, 35-959 Rzeszów, Poland.

***Faculty of Biology and Agriculture, Department of Environmental Biology, University of Rzeszów, ul. Pigonia 6, 35-959 Rzeszów, Poland.

by microorganisms both in the anaerobic and the aerobic cycles, intermediate products are generated which are extremely odour noxious to the environment. These are such by-products as sulfur compounds – hydrogen sulfide, mercaptans, sulfides, nitrogen compounds such as ammonia, and pyridine. Microorganisms added to wastewater sludge can change biochemical processes and significantly limit production of odorous gases [4, 5]. This leads to a new method with a possibility of sludge stabilization without odour production. The achievement of noxious odour limitation by this method is particularly rational when odour emission takes place over a large surface area, for example in sewage treatment plants where storage pads exist for the temporary disposal of sewage sludge.

The aim of the study was to verify the effectiveness of decrease of odour production during sludge stabilization with selected groups of microorganisms in conditions resembling those on sludge storage pads.

2. EXPERIMENTAL

The experiments were carried out on a laboratory scale. The biopreparation EM was used [6], activated in the molasses solution. This preparation, being a mixture of microorganisms such as acid milk bacteria, photosynthetic bacteria, yeast and actinomycetes, has been used in agriculture for soil improvement and in animal rising as a probiotic up to now. In order to check influence of actinomycetes, additional cultures obtained from composted sewage sludge were added. Isolates and cultures were run on the Pochon nutrient medium.

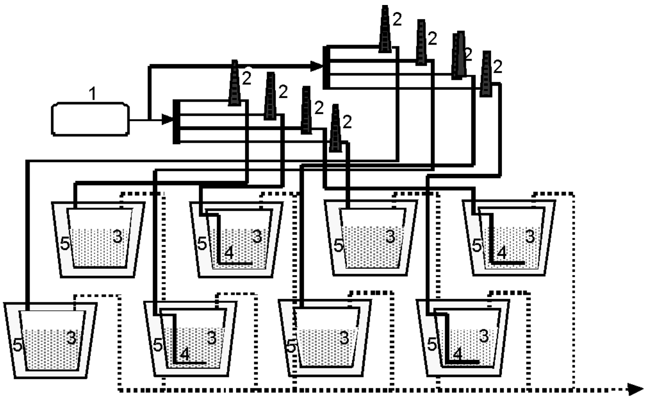

Fig. 1. Scheme of the research station: 1 – blower, 2 – rotameter, 3 – 30 dm^3 container, 4 – aeration system, 5 – thermal isolation of mineral wool

The investigated sludge originated from a municipal sewage treatment plant. This was return sludge, thickened for 3 days in the gravity thickener, conditioned by polyelectrolyte and dewatered. Eight tests containing 30 kg of sludge were prepared. Sludge was thoroughly mixed by mechanical stirrer and placed in a closed, thermally insulated container in a heated room (Figs. 1, 2).

Fig. 2. Research station; volume of the container 30 dm^3

The temperature of the room was maintained between 18 and 21 °C. Sludge processing consisted in the following tests:

- control test 1without aeration,
- control test 2 with aeration,
- test 3 with biopreparation EM,
- test 4 with biopreparation EM and aeration,
- test 5 with biopreparation EM and additional actinomycetes,
- test 6 with biopreparation EM, additional actinomycetes and aeration,
- test 7 with biopreparation EM, exposed to light,
- test 8 with biopreparation, aeration and exposed to light.

During processing, air was flowing only above the surfaces of the sludge in tests 1, 3, 5 and 7 with the flow rate of 120 dm^3/h. The sludge in tests 2, 4, 6 and 8 was aerated from the bottom through the volume of the sludge at constant flow rates.

The experiment was carried out for 41 days, at 14 day intervals sludge and gas samples were taken. The samples of wastewater sludge were taken by means of a special sampler for soil sampling (Egner stick) disinfected previously. The samples were taken according to Polish Norm PN-R-04031:1997. The range of analyzed parameters included: temperature, reaction (PN-Z-15011-3:2001), redox potential (PN-ISO 11271:2007), mass and dry mass (PN-EN 12880:2004, using lyophilisation process), volatiles in dry weight (PN-Z-15011-3:2001), total nitrogen and organic carbon on the elemental analyzer Flash 1112 (ThermoQuest). Total organic carbon was determined following the removal of inorganic carbon by contact with the vapour of HCl in desiccators [10]. Analysis of nitrogen mineralization by soil microflora was based on the extraction of the sludge sample of 5 g in 50 ml of water. The probe was shaken for 30 min and then centrifuged, finally the following parameters were determined: ammonia nitrogen according to PN-ISO 5664, using UDK 132 Semiautomatic Distillation Unit, VELP, nitrate nitrogen (PN-C-04576-08:1982), nitrite nitrogen (PN-EN 26777:1999) and phosphate phosphorus (PN-EN ISO 6878:2005).

Odorimetric analysis of exhausted air was performed using the dynamic dilution method, by changing the flow rate of air. Estimation of the odour intensity was performed using *n*-butanol solutions [3].

Table 1

Results of wastewater sludge processing

Parameter	Day	1	2	3	4	5	6	7	8
pH	1	6.9	6.9	6.9	7.0	7.0	7.0	7.0	6.9
	13	7.0	7.1	7.2	7.7	7.4	7.1	7.1	7.2
	27	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.8
	41	8.0	8.0	8.0	8.0	7.9	8.0	7.9	7.8
Dry weight [%]	1	15.9	15.9	15.9	15.9	15.9	16.1	16.1	16.2
	13	16.2	16.6	16.0	15.6	15.7	15.7	15.7	16.0
	27	15.9	15.7	16.1	15.7	15.9	15.6	15.9	15.8
	41	15.5	15.2	15.9	15.3	15.1	15.3	15.3	15.3
Organic dry weight [%]	1	64.5	64.5	64.5	66.4	64.3	65	64.9	65.2
	13	65.4	65.9	65.4	63.9	64.8	64.4	64.0	65.0
	27	64.0	63.9	64.0	63.0	63.3	63.5	63.6	63.2
	41	63.1	62.9	64.1	62.2	62.4	62.6	62.8	62.4
Total nitrogen [% of d.w.]	1	5.7	5.5	5.6	5.5	5.3	5.5	5.6	5.5
	13	4.9	5.1	4.9	5.3	4.8	5.1	5.2	4.9
	27	4.5	4.9	4.8	5.0	4.6	5.0	4.8	4.8
	41	4.5	4.7	4.4	4.5	4.5	5.0	4.6	4.2
Organic carbon [% d.w.]	1	36.0	35.3	36.3	34.9	34.7	35.5	36.1	35.4
	13	30.7	31.8	32.5	32.9	31.2	30.2	33.6	31.6
	27	30.4	30.3	30.2	31.6	30.4	30.8	30.3	30.1
	41	29.1	30.2	29.9	30.0	29.8	30.6	29.6	29.6

Microbiological determination, based on standard testing procedures, included: the total number of mesophilic bacteria (PN-EN ISO 6222:2004), total number of bacteria spores, MPN of I and II phases nitrifying bacteria, the number of *Clostridium perfringens* bacteria (PN-EN ISO 7937:2005), the number of coliforms (PN-75/C-04615/05, PN-77/C-04615/07), the presence of *Salmonella* (PN-Z-19000-1:2001).

3. RESULTS AND DISCUSSION

In the wastewater sludge before tests (test 1), the reaction medium was inert, the dry weight was low and equalled 15.9% but organic compounds – only 64.5% of the dry mass (Table 1). The sludge contained 5.7% of total nitrogen, medium amount of organic carbon – 36%; the ratio of organic carbon to total nitrogen was low however, and equalled approximately 6.32.

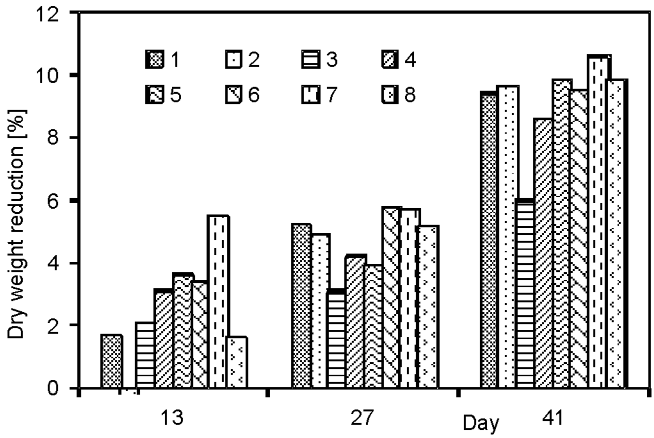

Fig. 3. Range of dry weight reduction during the experiment

During the experiments, the reaction medium was neutral but pH was slowly increasing, reaching after a month ca. 8 in all tests. The sludge mass, dry weight and organic dry weight decreased (Fig. 3). From the 13th to 41st day of the experiment a similar mass losses occurred in all aerated tests (2, 4, 6 and 8) and amounted to 2.5% of initial mass. The mass in other tests decreased marginally less but the most in the test 3 with biopreparation – 2.1%, and the least in the control test 1 – 1.9%. The largest degree of organic dry weight removal occurred in tests with biopreparation and ranged between 12.5% and 14.4%. In both control tests the value of this parameter was lower, in the test 1 it was equal 11.3% and in the test 2 – 11.8%.

After 41 days of the experiment, the content of organic carbon in all containers was very similar and ranged between 29.1% and 30.6% and the total nitrogen ranged between 4.2% and 5.0% (Table 1). The highest degree of organic carbon removal occurred in control test 1 and amounted to 26.8%, whereas in the test 3 with biopreparation it reached 22.6%. The maximum total nitrogen depletion equalled 28.6%, and occurred in control test 1, whereas in the test 3 with biopreparation a lower value equal 26.1% was obtained (Table 1). In the other aerated tests nitrogen and carbon losses were similar and a bit lower than in test 3.

The investigation of nitrogen mineralization by microflora showed that after two weeks of processing a large depletion of nitrates extracted from the sludge occurred (Fig. 4). Initial nitrate nitrogen values ranged between 119.3 mg N/kg d.w. and 192.7 mg N/kg d.w. and they decreased to the range of 7.6–18.8 mg N/kg d.w. The greatest decrement occurred in tests 3–5. In the control tests, the nitrate content decreased by up to 11%. After 13th day of experiment, the nitrate nitrogen contents extracted from all aerated tests were in the range 31–38 mg/kg d.w. and were higher than in the not aerated samples (23–25 mg/kg of d.w.). Simultaneously, the ammonia nitrogen amount increased considerably in the extracts. At the beginning of the experiment, the content of ammonia nitrogen extracted from the sludge amounted from 0.55 to 1.55 mg N/kg d.w. By the 41st research day it increased to the values of 7.4–9.3 mg N/kg d.w. The highest concentration occurred in the control test 1. In the other tests, the amount of ammonia was lower. The nitrite nitrogen content extracted from the sludge changed between 9.4 and 38.7 mg N/kg d.w. and did not depend on the method of sludge processing.

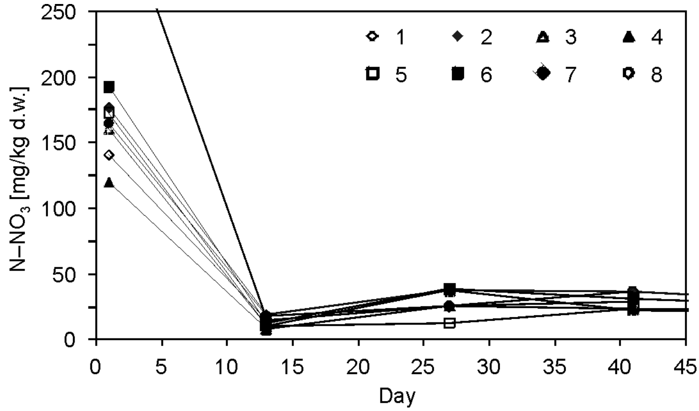

Fig. 4. Time dependence of nitrate nitrogen content extracted from the sludge

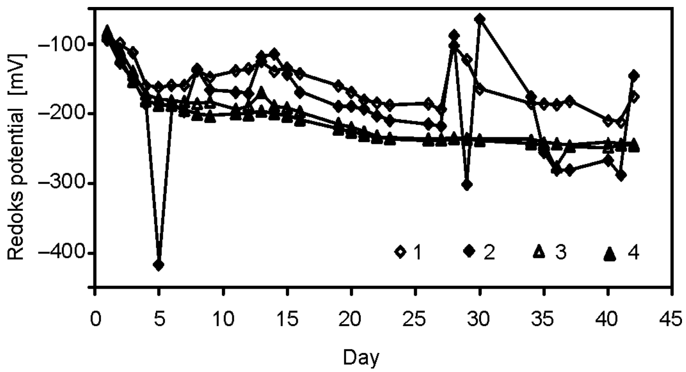

Fig. 5. The *in situ* redox potentials during the experiment at the depth of 14 cm

Concentration of phosphate phosphorus at the beginning of the tests was about 0.6 mg P/g d.w. After two weeks it increased to about 0.9–1.1 mg P/g d.w. At the end of tests its values were around 1.8 mg P/g d.w. There were no significant differences between tests.

The *in situ* redox potential in tests 1–4 at the depth of 14 cm gradually decreased (Fig. 5). After 40 days of the experiment it changed in the range from –210 to –270 mV. It was lower in the tests with biopreparation than in control test during large part of experiment.

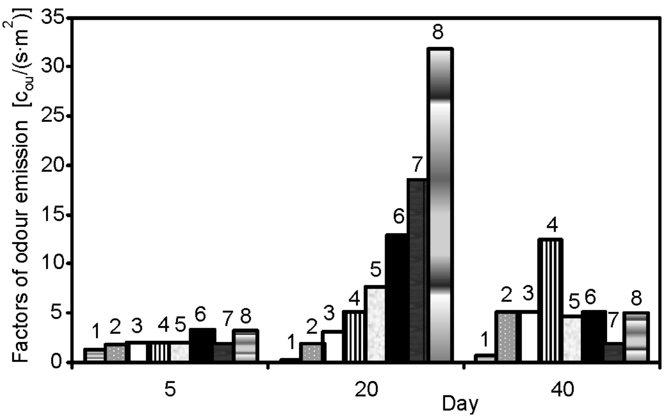

Fig. 6. Factors of odour emission during the experiment

Odour measurements (Fig. 6) showed that the number of odour units coming from aerated samples was greater than from the non-aerated samples. A progressive increase of the odour noxiousness occurred in all samples with biopreparation.

The results of bacteriological analyses demonstrated a lack of significant differences in the microflora of tests (Table 2). The wastewater sludge was characterized by a high number of vegetative bacteria. In every test after the period of transformation the number of these bacteria decreased. However, reduction in their number was smaller than during the mesophillic or thermophillic fermentation process [7]. In all samples of sewage sludge, the quantity of bacteria spores increased. In samples without aeration the proportional participation of bacteria spores was higher.

The investigated sludge contained a large number of *coli* and of *Salmonella* bacteria [6]. The sanitary effect was not observed taking into account the presence of *Salmonella*. After 41 days of the experiment these bacteria were present in all samples. Especially large number of *coli* including *E. coli* O157 indicated a potential health risk. According to obligatory rules in countries of the European Union, the majority of organisms from sewage sludge are listed in the second group of risk with exception of *Salmonella* and *E. coli* O157 and of several mycobacteria which are listed in the third group of risk [8, 9]. The titre of *E. coli* in investigated sewage sludge increased almost imperceptibly, which proved about a minimal reduction in the number of these bacteria.

The number of *Clostridium perfringens* increased in all investigated samples when the number of nitrifying bacteria decreased. It indicated poor oxygen conditions in samples. The lower number of nitrifying bacteria might also be a cause of the lack in the odour noxiousness limitation of the studied wastewater sludge.

Table 2

Results of bacteriological analyses

Parameter	Day	1	2	3	4	5	6	7	8
Total number of bacteria [cfu/g d.w.]	13	$3.2\cdot10^8$	$3.4\cdot10^8$	$4.1\cdot10^8$	$4.9\cdot10^8$	$3.7\cdot10^8$	$3.9\cdot10^8$	$3.5\cdot10^8$	$3.0\cdot10^8$
	27	$5.4\cdot10^8$	$4.8\cdot10^8$	$3.5\cdot10^8$	$9.5\cdot10^8$	$3.0\cdot10^8$	$3.5\cdot10^8$	$6.1\cdot10^7$	$3.6\cdot10^8$
	41	$1.8\cdot10^8$	$1.2\cdot10^8$	$6.1\cdot10^7$	$2.4\cdot10^8$	$6.9\cdot10^7$	$1.60\cdot10^8$	$1.4\cdot10^8$	$1.5\cdot10^8$
Ratio of total number of bacteria to total number of bacteria spores [%]	13	0.55	0.58	0.29	0.31	0.72	0.47	0.46	0.59
	27	1.07	0.52	2.39	0.23	2.02	0.93	7.41	1.60
	41	1.07	0.74	2.01	0.57	1.60	0.52	1.27	0.71
Number of *Clostridium perfringens* [cfu/g d.w.]	13	$1.0\cdot10^5$	$9.2\cdot10^4$	$8.7\cdot10^4$	$1.2\cdot10^5$	$1.4\cdot10^5$	$1.2\cdot10^5$	$1.1\cdot10^5$	$1.1\cdot10^5$
	27	$1.2\cdot10^5$	$1.6\cdot10^5$	$1.0\cdot10^5$	$1.1\cdot10^5$	$1.7\cdot10^5$	$1.5\cdot10^5$	$2.0\cdot10^5$	$2.0\cdot10^5$
	41	$1.1\cdot10^5$	$1.6\cdot10^5$	$2.2\cdot10^5$	$1.7\cdot10^5$	$1.8\cdot10^5$	$2.3\cdot10^5$	$2.1\cdot10^5$	$1.3\cdot10^5$
Titre of *Coli*	13	$2\cdot10^{-7}$	$2\cdot10^{-7}$	$2\cdot10^{-7}$	$2\cdot10^{-7}$	$2\cdot10^{-7}$	$2\cdot10^{-7}$	$2\cdot10^{-7}$	$2\cdot10^{-7}$
	27	$7\cdot10^{-6}$	$4\cdot10^{-6}$	$5\cdot10^{-6}$	$4\cdot10^{-6}$	$2\cdot10^{-6}$	$4\cdot10^{-6}$	$2\cdot10^{-6}$	$8\cdot10^{-6}$
	41	$7\cdot10^{-6}$	$4\cdot10^{-6}$	$4\cdot10^{-6}$	$4\cdot10^{-6}$	$4\cdot10^{-6}$	$4\cdot10^{-6}$	$4\cdot10^{-6}$	$2\cdot10^{-6}$
Titre of II phase nitrifying bacteria [1 g d.w.]	13	$4\cdot10^7$	$4\cdot10^7$	$5\cdot10^7$	$5\cdot10^7$	$4\cdot10^7$	$4\cdot10^7$	$5\cdot10^7$	$4\cdot10^7$
	27	$4\cdot10^6$	$4\cdot10^6$	$4\cdot10^6$	$5\cdot10^5$	$10\cdot10^5$	$4\cdot10^6$	$5\cdot10^6$	$4\cdot10^6$
Presence of Salmonella sp. [100 g of sludge]	13	pres.	pres.	pres.	pres.	pres.	pres.	pres.	pres.
	41	pres.	pres.	pres.	pres.	pres.	pres.	pres.	pres.

4. CONCLUSIONS

- The analysis of initial results indicated that the biopreparation in a small degree modified biochemical processes and caused redox potential to decrease.
- The clear decrease of odour noxiousness of the wastewater sludge for samples with biopreparation was not observed in applied conditions. The aeration process caused an increase of the number of odour units released to the environment during sludge processing.
- A sanitary effect was not achieved in the experimental conditions.
- Very small air space in the containers with wastewater sludge caused almost anaerobic conditions. The intensity of aeration, applied in the experiment improved aerobic conditions to a small degree. Also the composition of bacterial microflora indicated that the availability of oxygen was limited.

• The faintly alkaline reaction of the sludge proved that the growth of lactic acid bacteria was limited.

• It is supposed that low redox potential was a reason of a weak growth the micro-organisms from biopreparation.

• In the continuation of these studies conditions for the tests should be changed. The course of processes of wastewater sludge processing at higher redox potential should be investigated.

ACKNOWLEDGEMENT

The study was financially supported from the science funds for the years 2007–2010 by of the Polish Ministry of Science and Higher Education, as a state project No. PBZ-MEiN-5/2/2006.

REFERENCES

[1] KIM H., MURTHY S., MCCONELL L.L., PEAT C., RAMIREZ M., STRAWN M., Water Sci. Technol., 2002, 46 (10), 9.
[2] SERCOMBE D.C.W., Water Sci. Technol., 1995, 31 (7), 283.
[3] KOŚMIDER J., MAZUR-CHRZANOWSKA B., WYSZYŃSKI B., *Odours*, PWN, Warsaw, 2002 (in Polish).
[4] HIROSHI E., J. Biosci. Bioeng., 2001, 91 (6), 607.
[5] SUN Y.H., LUO Y.M., WU L.H., LI Z.G., SONG J., CHRISTIE P., Environ. Geochem. Health, 2006, 28, 97.
[6] HIGA T., *Microbiological Method for Disposing of Organic Waste Materials*, United States Patent No. 5 707 856, 1998.
[7] SHABAN A.M., Water Sci. Technol., 1999, 7, 165.
[8] CARRINGTON E.G., *Evaluation of sludge treatments for pathogen reduction*, [In:] Report No. CO 5026/1, European Communities, 2001, Luxembourg.
[9] SAHLSTRÖM L., ASPAN A., BAGGE E., DANIELSSON-THAM M., ALBIHN A., Water Res., 2004, 38, 1989.
[10] ZIMMERMANN C.F., KEEFE C.W., BASHE J., Method 440.0. NER Laboratory, USEPA, 1997, Cinciniati, Ohio, http://www.epa.gov/nerlcwww/m440_0.pdf. Date of last access: 20.02.2011.