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"EFFECTIVE MICROORGANISMS" (EM) IN REDUCING NOXIOUSNESS OF SELECTED ODORANT SOURCES

The article presents the changes in a chemical quality of air and in the olfactory noxiousness levels caused by the application of Effective Microorganisms (EM) contained in the EM-Farming™ preparation. The preparation was applied in selected facilities considered to be substantial sources of odorants. The research was conducted in a wastewater treatment plant, a composting plant, at a waste landfill and in a poultry house.

Within the framework of the project, basic indicators of the olfactory effect, namely ammonia and hydrogen sulphide, were examined along with carbon dioxide, the latter used as the indicator of the intensity of biochemical processes, including the odorigenic ones. Moreover, the sensory assessment method was employed to characterise the olfactory effect organoleptically.

The analysis of the results showed that the negative impact of the facilities on the surrounding area changed within a limited range of values. No clear upward/downward trends shown by the examined gases were observed. For each facility a different and unique pattern of the changes in the concentrations of NH_3, H_2S and CO_2 as well as in odour intensity was detected.

1. INTRODUCTION

A substantial progress in reducing the emissions of selected gaseous or dust pollutants into the atmosphere has been achieved in Poland in the past twenty years, but the emission of odorants continues to be a serious problem in certain industries, municipal service facilities and intensive animal breeding [4]. In the case of a wastewater treatment plant, a waste dumping site or a composting plant, an air-tight sealing or full separation of the facility from its surroundings may pose some technical and technological problems and additionally it can be economically unjustified [14]. However, in animal breeding facilities (poultry house, cow shed, pigsty or stable), the use of some methods reducing the impact of odorants, e.g. the masking of

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odours by chemical means, can be hazardous due to its potentially negative influence on the livestock.

According to data received from Central and Provincial Environmental Protection Inspection Offices, Sanitary and Epidemiological Stations and other organizations (e.g. local government bodies) in Poland the highest number of complaints concerning the animal breeding and husbandry relate to the operation of poultry keeping, swine and slaughter/milk cattle breeding facilities. And the complaints about the olfactory noxiousness of municipal service facilities focus predominantly on municipal wastewater treatment plants and waste dumping sites [4], [7]. Due to the fact that the number of composting plants have been growing continuously it can be expected that the number of complaints against them will grow, as well.

Because of the difficulties encountered in the process of controlling the olfactory noxiousness, it is necessary to look for effective solutions, as universal as possible, or at least most effective in the given groups of facilities. The research in the field has concentrated on various methods; biological methods are also explored, including those employing the so-called effective microorganisms (EM technology). A potentially positive influence of EM on minimisation of the olfactory noxiousness has been demonstrated, e.g. for leachates from organic waste composting processes [8] and a kitchen waste composting process [9].

2. GOAL AND SCOPE OF THE RESEARCH

The goal of the research was to establish the influence of the consortium of microorganisms (of the EM type) contained in the EM-Farming™ preparation on the level of the olfactory noxiousness of selected facilities.

The research was conducted in facilities involved in provision of municipal services, namely:

a) a wastewater treatment plant where a pile of screenings from the plant was examined;

b) a composting plant where piles of compost produced in Dano technology were examined;

c) a solid waste dumping site where a leachate catch pit and a ventilation well were examined as well as in a facility used for animal production purposes, namely a poultry house of about 1000 m^2, designed for 20,000 chickens.

The selected facilities can be numbered among those emitting especially disagreeable odours and being most complained about and it is extremely difficult to reduce their odorant emission levels effectively.

Time schedule for the research of each facility investigated was individual: for dumping site – 3 rounds of tests were carried out during 10 weeks, for wastewater treatment plant – 4 rounds in one month, and for composting plant as well as for poultry house – 5 rounds during 3–4 months. Air samples were taken in each facility prior to the introduction of the microorganisms to establish a point of reference or a research background to be used for interpretation of the examination results. Two similar compost piles were compared in the composting plant: the first one was treated with the EM preparation, whereas at the second one the composting processes were not modified. For methodological reasons the examination of this facility could show the real influence of the microorganisms on the change in the concentrations of the gases examined.

In the research process, the concentrations of ammonia, hydrogen sulphide and carbon dioxide in air were determined. These gases are the basic indicators of the impact of the facilities under examination on their immediate surroundings [5]. They were chosen in order to obtain information about the processes (generating, among other impacts, disagreeable odours) taking place in the facilities before and after applying of the microorganisms. An organoleptic profile of the olfactory impact has been developed by means of the sensory assessment method. Each time, in the process of taking the air samples, the air temperature and humidity and, in the case of the open-air facilities, the wind velocity and direction were measured.

3. METHODOLOGY

3.1. EM PREPARATION CHARACTERISTICS

The EM preparation is a consortium of a few dozen strains of various microorganisms, both aerobic and anaerobic ones, chosen by Teruo Higa, professor of horticulture [2]. The mixture of microorganisms includes, among others, photosynthetic bacteria (*Rhodopseudomonas palustris*, *Rhodobacter sphaeroides*), *Actinomycetes*, lactic acid bacteria and fungi (e.g. yeast). The microorganisms produce substances which enable them to survive in unfavourable environmental conditions; consequently, they can effectively compete with destructive and pathogenic microorganisms and to replace them. The EM preparation contains numerous enzymes which can decompose the organic matter in an environmentally-friendly manner and ensure the survival and growth of the microorganisms both in the soil and in other environmental media [1].

3.2. PREPARATION DOSING METHODOLOGY

The EM preparation was injected into the screenings and the compost piles, poured into the wells collecting leachate or gas from waste and applied in the form of mist (spraying) or by sprinkling within the buildings. In the screenings storage yard, the

EM preparation was for the first time applied on 8.10.2007 in the amount of 5 dm^3 per 1 m^3 of the screenings; for the second time the preparation was applied on 29.10.2007 in the amount of 2 dm^3 per 1 m^3. The compost pile was treated with the preparation for the first time on 8.10.07 (3 dm^3 per 1 Mg of the compost pile) and for the second one – on 26.11.07 (1.5 dm^3 per 1 Mg). 3 dm^3 of the preparation were poured both into the leachate catch pit and into the ventilation well on 28.11.07, on 3.12.07 in the amount of 15 dm^3, on 8.12.07 in the amount of 10 dm^3, and on 24.01.08 in the amount of 3 dm^3. In the poultry house, the preparation was applied in the form of mist or by sprinkling. The sprinkling took place on 24.10, 28.10 and 15.11.07 (0.05 dm^3 per 1 m^2 of the poultry house floor area), whereas the preparation mist was sprayed on 27.10, 29.10, 3.11, 6.11, 17.11 and 4.12.07 (0.0083 dm^3 per 1 m^3 of the poultry house cubature).

3.3. MEASURING DEVICES

An aspiration method was employed to determine the concentration of pollutants in the air. The method consists in passing a certain volume of air through a filter made up of the washers connected in series. The washers contained absorbing solutions adequately selected for each pollutant. A four-station AG-4 aspirator with the capacity of 60 dm^3/h was employed to collect certain amounts of the air containing the gases examined. Within the framework of the methodology adopted, some efforts were taken to minimise the influence of weather conditions, especially the wind, on the sample collection. In the case of the surface source of odorants at the open-air facilities, i.e. the screenings pile and the compost pile, the air samples were collected from under a special 60-dm^3 bowl put on the piles (figure 1). The method of sample collection from under the flux chamber used in the facilities directly affected by weather conditions made it possible to minimise the impact of determined substances potentially blown in by the wind and coming from other sources.

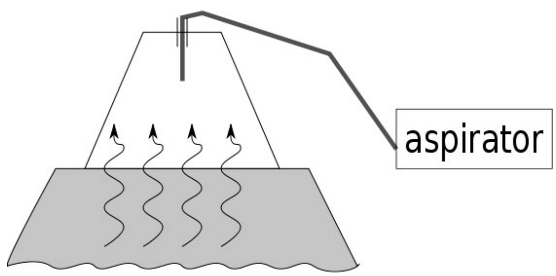

Fig. 1. Schematic diagram of the air sampling by flux chamber from a surface-based source

The washers were connected to the AG-4 aspirator and the air from the locations examined was fed to the washers via small hoses. In the catch pits, the hose ends were placed at the depth of 1.2 m. The pits were covered, therefore the influence of external factors was negligible. In the poultry house, the hoses were fixed on a tripod to take in the air on a constant level of 1.3 m above the ground.

The wind velocity was measured by means of A-1200 E anemometer. The air temperature and humidity were measured using the Assman psychrometer.

3.4. METHODOLOGY APPLIED TO DETERMINE POLLUTANT CONCENTRATIONS IN THE AIR

The air samples were collected by passing the air through absorbing solutions. In the case of ammonia, the absorbing solution was 0.01 n sulphuric acid, 2% zinc acetate ($Zn(CH_3COO)_2$) was used as the absorbing solution for hydrogen sulphide, and the solution of 0.05 n barium hydroxide ($Ba(OH)_2$) – for carbon dioxide [6]. In most measurements, the time of air sample collection was 30 minutes. In order to adapt the sample size to the absorbing capacity of the absorbing solution, in some cases the collection time was shortened.

The ammonia concentration in the air was determined on the basis of the modified standard PN-Z-04041:1971 [6], [12], and the hydrogen sulphide concentration – on the basis of the modified standard PN-Z-04015-13:1996 [6], [13].

Carbon dioxide, being a gas of an acid character (carbonic acid anhydride), is absorbed by alkaline solutions. The relatively best absorbing agent of carbon dioxide contained in the air is the solution of $Ba(OH)_2$. As a result, barium carbonate is formed. The excess of barium hydroxide taken for absorption was determined by its titration with hydrochloric acid in the presence of phenolphthalein indicator [6].

In the poultry house, the air samples were taken simultaneously at 4 different measuring points. Due to a relatively homogeneous character of the entire poultry house the data used for the analysis were averaged. Similar conditions existed in the screenings storage yard and the compost piles; the only difference was that the samples were taken simultaneously at 2 points at each place.

3.5. ODORIMETRIC MEASUREMENTS

The olfactory influence of odorant sources was characterized organoleptically by means of a sensory assessment of odour intensity i, based on the Just scale expanded by one grade by KULIG (table 1) [3], [5]. The sensory assessment was carried out by a team of two people subject to an odour intensity perceptibility test [10].

Table 1

Odour intensity scale

Scale	Odour intensity *i*	Perceptibility range
0	No odour	Not perceptible to anyone
1	Barely perceptible odour	Perceptible to less than 50% of those examined
2	Very weak (threshold) odour	Perceptible to 50% of those examined
3	Weak odour	Perceptible to more than 50% of those examined and noxious to the minority of them
4	Strong odour	Perceptible to all and noxious to the majority
5	Very strong odour	Perceptible to all and noxious to all

The organoleptic sensory assessment of the olfactory impact of the compost and screenings piles was carried out at a distance of 1 m from the odorant source. In the poultry house, the assessment was made inside the room, and in the case of the leachate catch pit and the ventilation well the assessment was carried out at their outlets.

4. RESULTS AND DISCUSSION

The research was conducted in the period from October 2007 to February 2008. The results of meteorological measurements carried out in order to assess the odour impact are presented in table 2 and the changes of gaseous pollutant concentrations are shown in figures 2–7.

Table 2

Results of meteorological measurements and observations

Parameters	Screenings pile				Compost piles					Waste dump			Poultry house				
Sampling date	8.10. 2007	9.10. 2007	15.10. 2007	7.11. 2007	8.10. 2007	9.10. 2007	22.10. 2007	11.12. 2007	5.02. 2008	28.11. 2007	11.12. 2007	5.02. 2008	29.10. 2007	7.11. 2007	8.11. 2007	21.11. 2007	6.12. 2007
Temperature (°C)	10.2	7.3	9.4	4.6	11.3	10.4	5.6	6.2	7.2	0.1	6.1	5.8	29.5	25.4	26.2	26.4	209
Humidity (%)	92	89	58	81	83	80	77	97	76	89	97	88	63	66	72	75	83
Wind velocity (m/s)	1.1	1.3	1.4	3.2	2.1	1.7	1.8	1.2	1.2	3.7	1.6	2.6	–	–	–	–	–
Wind direction	SW	SW	S-SW	SW	SW	SW	E	ENE-ESE	W	WNW	NE	SW	–	–	–	–	–

The analysis of the results shows that the intensity of a negative impact of odorants on the surrounding area varies within a limited range of values. During the research no clear upward/downward trends in the concentrations of gases and odour intensity were observed. Each odorant source has its own unique pattern of changes.

A substantial decrease in carbon dioxide concentration was observed in the screenings storage yard: from the initial value of 36.4 g/m^3 recorded on 8.10.2007 prior to the application of EM to 7.2 g/m^3 the next day following a 24-hour-long exposure to the preparation; to 2.4 g/m^3 on 15.10.2007; to 1.4 g/m^3 recorded on the last day of the research (7.11.2007). Ammonia concentration followed the same pattern: its concentration decreased from 1 350 μg/m^3 to 283 μg/m^3; to 83 μg/m^3 and to zero at the end of the research (figures 2 and 3). The odour intensity decreased almost in the entire range covered by the research. The hydrogen sulphide concentrations were negligibly low (below the threshold value).

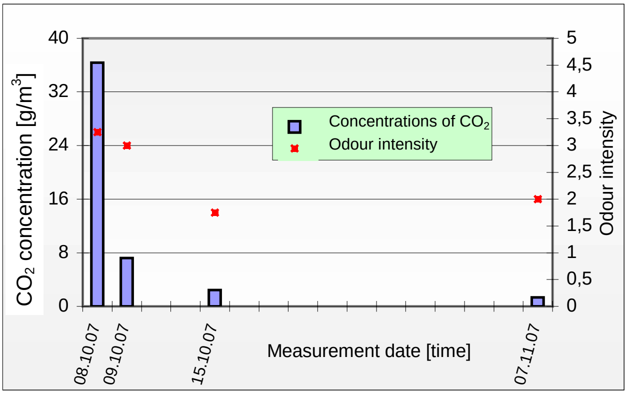

Fig. 2. Average concentration of CO_2 and odour intensity in the air above the surface of the screenings storage yard

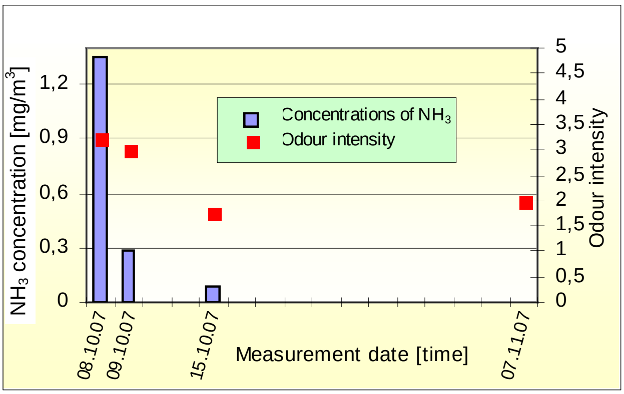

Fig. 3. Average concentration of NH_3 and odour intensity in the air above the surface of the screenings storage yard

The first three measurements at the wastewater treatment plant were carried out under quite similar weather conditions, as in October the air temperature ranged from 7.0 °C to 10.0 °C. Wind direction and velocity did not change much, either: the winds from south-western direction prevailed and their velocity varied from 1.1 to 1.4 m/s. The last measurement, on 7.11.2007, was taken under slightly different weather conditions: the air temperature dropped to 4.6 °C, the wind was stronger (3.2 m/s) but it blew from the south-west again (table 2).

It is not possible to determine unambiguously the influence of the effective microorganisms on the reduction of both the olfactory noxiousness and the concentrations of the gases due to a lack of an arbitrary reference point. However, a positive impact of EM on the quantitative reduction of the odorants emitted by the screenings storage yard cannot be excluded, especially at early stages where the application of the preparation was followed by almost fivefold decrease in the carbon dioxide and ammonia emissions.

The ammonia emissions decreased substantially at the compost pile treated with EM preparation as compared with the reference pile providing the background. Ammonia concentration decreased from an initial 423 $\mu g/m^3$ for the background and 358 $\mu g/m^3$ for the pile (prior to the application of EM) to respectively 158 and 8.5 $\mu g/m^3$ recorded in the last day of the research (5 February 2008). As in the case of the screenings storage yard, ammonia concentration decreased almost threefold following a 24-hour exposure to the EM preparation. A downward trend in ammonia concentration was also recorded in the reference pile, but this value dropped just twofold (figure 4). The increase in the ammonia concentration recorded in both piles on 11 December 2007 (as compared with the previous determinations made on 22.10.2007) was caused probably by a relatively high temperature in winter time (above 6.0 °C). In the research period, no hydrogen sulphide emissions were recorded at the piles.

There is another factor which makes this result supports the application of EM: the EM-treated pile is slightly younger (1 month at the maximum), therefore a higher ammonia concentration (compared with the research background) should hold longer.

However, the sensory odorimetric examination did not revealed any differences between the piles. The intensity of odour emitted by both piles decreased gradually from an initial $i = 3 \div 3.5$ prior to the application of EM, through $i = 2.5 \div 3$ recorded on 9.10.2007, $i = 2$ recorded on 22.10.2007; $i = 0 \div 2$ recorded on 11.12.2007 to $i = 0 \div 1$ in the last day of the research (5.02.2008). The differences in odour intensity recorded in particular days depend on the place in the pile where organoleptic sensory assessment is made.

Some positive changes in the concentrations of the gases of interest were also observed in the leachate catch pit and the ventilation well of the waste dumping site. Both in pit and well, the odour intensity decreased although it was still on quite a high level. Also the concentration of hydrogen sulphide decreased from the initial reference value of 23.3 mg/m^3 (recorded on 28 November 2007) to 20 mg/m^3 on 11 December

2007 and 6 mg/m^3 on 5 February 2008 at the leachate catch pit, and from the initial reference value of 1.7 mg/m^3 to 0.8 mg/m^3 and zero concentration of hydrogen sulfide recorded in the last day of the research at the ventilation well (figures 5 and 6). Moreover, the leachate catch pit showed reduced concentration of carbon dioxide: from 15.5 g/m^3 to 13.9 g/m^3 and 10.1 g/m^3 (figure 5).

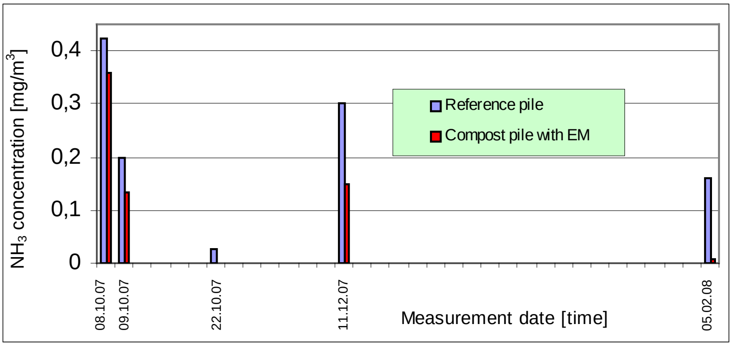

Fig. 4. Average concentration of NH_3 in the air above the surface of the compost piles

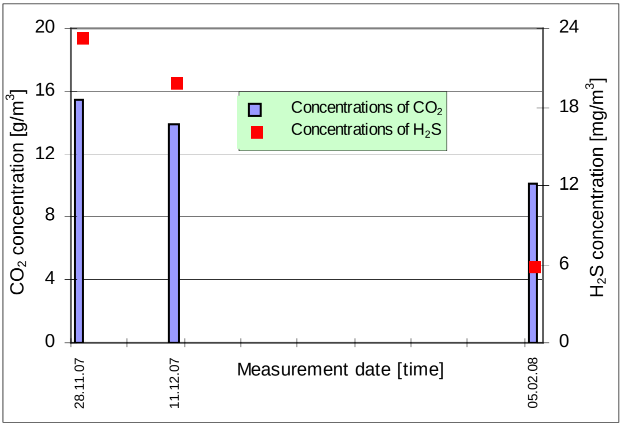

Fig. 5. Concentration of CO_2 and H_2S in the leachate catch pit at the waste dumping site

The research was conducted in autumn and winter, hence relatively low ambient temperature, especially at the moment of collecting the first samples from pit and well (0.1 °C on 28 November 2007), could affect biochemical processes [11]. However, the leachate catch pit and the ventilation well are built into the waste dumping site a dozen or so metres deep. The conditions (e.g. thermal ones) inside them hardly change with time (especially in a two-month period) and depend on the processes taking place, with a similar intensity, inside and in the lower part of the waste pile. It can be assumed that such a significant change in the concentration was not only a result of natural processes taking place in the waste dumping site, but it also depended on the microorganisms introduced that changed both concentration and odour intensity.

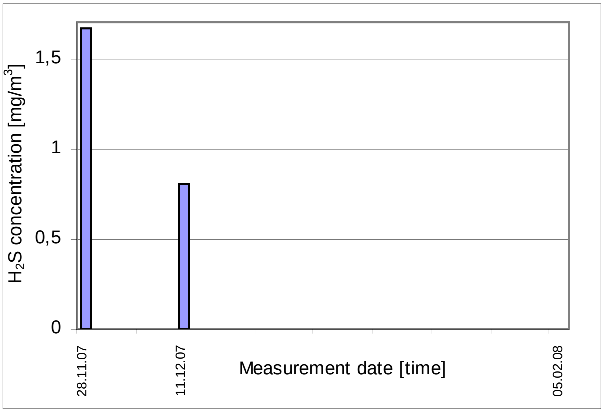

Fig. 6. Concentration of H_2S in the ventilation well at the waste dumping site

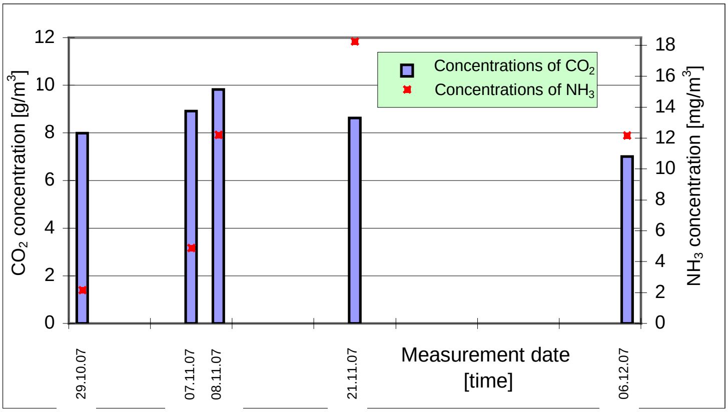

Fig. 7. Average concentration of CO_2 and NH_3 in the air in the poultry house

In the poultry house, the effect of the preparation was limited mainly to the compensation of the effects connected with an increased pollutant emission caused by the gain in the total chicken mass and an increase in their droppings. An increase in the chicken mass and in the amount of droppings results in a growing concentration of the gases in the entire period of the poultry keeping cycle. After an initial systematic increase in the ammonia concentrations from 2.2 mg/m^3 recorded on 29.10.2007, 4.9 mg/m^3 recorded on 7.11.2007 and 12.2 mg/m^3 recorded on 8.11.2007 up to the maximum of 18.2 mg/m^3

recorded on 21.11.2007, a decrease in its concentration to 12.2 mg/m^3 was observed in the last day of the research (6.12.2007). A similar upward trend followed by a decrease in the concentration was shown by carbon dioxide, but the difference was that its concentration started to fall as early as on 21.11.2007 from the maximum of 9.8 g/m^3 (recorded on 8.11.2007) to 8.6 mg/m^3 (figure 7). As chicken grew the room was aired more frequently and the air temperature decreased from the initial value of 29.5 °C recorded in the first day of the research to about 21 °C recorded in the last day. Hence, the downward trend showed by the concentration could have resulted from the action of EM or been caused by an intensified ventilation of the room.

The processes of organic matter degradation taking place in the screenings storage yard or compost piles were extremely intense, especially in the first phase, and could go on even at low temperatures. Nevertheless, the end of our research coincided with the phases of less intense transformations and the period of relatively low temperatures which could have resulted in a diminished activity of the microorganisms and a slowdown in the biochemical processes. It is also important to point out that in the poultry house, in order to ensure an adequate growth of the poultry, the temperature did not fall below 20 °C; therefore it can be assumed that in this case any external factors had no significant influence on the development and activity of the effective microorganisms. Taking account of the above it can be concluded that in the majority of places examined, microbiological processes were effective, although less intensivee than in summer time.

5. CONCLUSIONS

The research made it possible to determine the changes in the olfactory noxiousness in the places of interest due to the activity of the consortium of microorganisms (of the EM type) contained in the EM-Farming™ preparation. It can be presumed that consortia of microorganisms are capable of reducing odorant emissions but their activity is specific, depending on individual place. The methodology employed made it possible to obtain only partially unambiguous, repeatable in the future results. The preliminary research was conducted over the least favourable seasons, i.e. in autumn and winter (in the period from October 2007 to February 2008). In the winter period, the decomposition processes are much less intense than in summer. In spite of an exothermic character of the majority of processes which produce, among other compounds, ammonia, hydrogen sulphide and carbon dioxide, low temperatures effectively slow down or even prevent the activity of some organisms, e.g. those which produce hydrogen sulphide. Low temperatures limit substantially the intensity of biochemical transformations and, probably, affect EM, as well. The research should be continued with a stricter control of operating conditions, e.g. room ventilation operations, and paying close attention to the technological work which has an effect on the odorant emission levels.

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