

DETERMINING THE EFFECTIVENESS IN VERMICOMPOSTING OF SEWAGE SLUDGES AND THE ATTEMPT TO INCREASE THE EFFECTIVENESS BY APPLYING BACTERIAL MICROORGANISMS

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Received: 2016.03.16
Accepted: 2016.06.01
Published: 2016.07.01

ABSTRACT

Applying vermicomposting process for sewage sludge treatment is a low-cost method which has been gaining a growing number of supporters around the world. In Poland it is still rather unpopular method. The following publication presents the results of 12 years (2004–2015) of research and experiments on the use of red Californian earthworm in Wastewater Treatment Plant in Zambrów. Among others, the results of analyzing vermicompost quality were shown concerning selected micro and macro elements, fertilizing value and sanitary condition. Cumulative content of the examined heavy metals was highest in 2004 and reached over 1200 mg⁻¹ kg s.m., whereas the lowest content of 520 mg⁻¹ kg s.m. was observed in 2012. The study results indicate that in the entire 12-year research period vermicompost met the standards for organic-mineral fertilizers, which means it contained over 20% of organic substance in reference to dry mass and over 1% of total nitrogen and 0.5% of phosphorous in reference to phosphorus pentoxide (P₂O₅). During the entire research period no living eggs of intestinal parasites *Ascaris sp.*, *Trichuris sp.*, *Toxocara sp.* and *Salmonella* bacteria were observed in the vermicompost. The research concerning red Californian earthworm proved substantial mineralization and humification of sludge. The application of EM formula considerably quickened the process and the achieved modifications in the vermicompost structure and content.

Keywords: vermicomposting, sewage sludge, Effective Microorganisms Bacteria

INTRODUCTION

Research on using earthworm in the compost process has been conducted, among others, in the USA, Canada [Mitchel et al. 1977], Iran [Alidadi et al. 2005], South Africa [Friedrich et al. 2013] and many other countries on all continents. Using earthworm for quickened sewage sludge composting in Poland dates back to the 1990's, while the first successful attempt at using earthworm to utilize sludge took place in a treatment plant in Pyrzyce. Applying a population of vermiculture on technical scale in Poland was successfully achieved for example in treatment plants in Kluczbork, Praszka, Wrocław, Gryfno, Zambrów and Brzesk.

It is increasingly common in Poland to apply low-cost methods for sewage sludge processing, such as composting, vermicomposting, cane fields, basket willow and solar driers. In the north-eastern region of Poland such methods have also been successfully applied by various facilities. The following factors have influence on such functioning:

- prevalence of small and medium wastewater treatment plants,
- agricultural and industrial specificity of the region,
- character of generated sludge,
- biomass in a form of straw, sawdust and wood chips available in this region,
- low soil class [Boruszko 2011].

All these factors justify the possibility of applying low-cost methods in these areas. Popularizing and spreading the use of these processing methods prior to environmental usage of sewage sludge is accordant with the contemporary legal regulations and formal requirements. Low input methods of sewage sludge processing are mainly characterized by simple construction and technology, as well as easy operating. These methods enable the use of technological devices to a small extent, thanks to which the electric energy consumption is usually insignificant. Taking advantage of natural processes occurring in the environment allows maintaining low exploitation costs [Kostecka 1995, Boruszko 2013].

Nowadays, an increasing interest of exploiters in these technologies can be observed within the country and abroad, which results in continuously rising number of created vermicomposting facilities for sewage sludge. Such tendencies are also visible in north-eastern Poland. One of the first treatment plants in Podlaskie Voivodship which for many years has been processing sewage sludge using low input methods is the treatment plant in Zambrów exploited by Zambrrowskie Ciepłownictwo i Wodociągi Sp. z o. o. [Boruszko 2012, Walkowiak 2007].

FIELD OF STUDY AND EXPERIMENTAL METHODS

Around 1 ton of dry mass of excessive raw sludge is generated in the municipal treatment plant in Zambrów per day. The solution for sludge management has been based on sludge and cane lagoons and, since 2003, plots with earthworm (vermiculture). With the exception of winter period, 70% of sludge is discharged directly onto a cane field which measures 3 times 3500 m². During the winter period, the sludge is transferred to sludge lagoons equipped with vertical drainage which ensures high effectiveness in dehydrating sludge while filling the lagoon. In the summer period it is transferred onto earthworm plots.

The first plots for vermicomposting within the wastewater treatment plant in Zambrów were built in firm clay in 2003. The plots are equipped with drainage system, on which concrete blocks were laid nearby to ensure higher working comfort and to protect the earth worms from predators. The plots area is surrounded by half-meter concrete blocks. The bottom is cov-

ered with a layer of sawdust (around 15–20 cm) which regulates the C:N proportion. The sludge pumped from sludge lagoons is discharged on such prepared ground, divided by mounds of partially processed vermicompost from previous years. The mounds, which supply the population with oxygen during the filling process or during rainy periods, are raised above the level of filling [Alchimowicz 2005].

The transformed parts of mounds, abandoned by the earth worms, are extracted in spring. New mounds are created from the remaining material and new sludge is pumped. After the final vermiculture plots extension their basic technical and technological parameters are:

- Area of around 8500 m²;
- Average plot area – 190 nm²;
- Total number of plots – 47;
- Depth – 0.4 m;
- Total sludge volume on vermiculture plots - 8500 m² × 0.4 m = 3400 m³;
- Dry mass content in sludge – 12%;
- Sludge amount – 400 tons of dry mass on plots with vermiculture.

Since 2004 Effective Microorganisms in a form of a certified EM BIO formula manufactured by Greenland Company have been added to the technological process of sewage sludge treatment. On the grounds of several years' pilot research a singular dose of 5l of Greenland EM BIO formula has been accepted per 1 ton of sludge dry mass. A metering pump was used on pressure pipeline which pumped the excessive stabilized sludge onto cane lagoons. The content of dry mass in sludge is around 1% (10 g/l). The amount of sludge – around 2500 m³/month, that is 25 tons of dry mass per month. While using the maximum dose of 5l of EM BIO per ton of sewage dry mass in the first year, the dosage of formula for sludge before discharging it onto cane lagoon is 125 l of EM BIO per month.

Simultaneously, a dose of 1l of Em BIO per ton of sewage dry mass was used monthly to spray the plots containing vermiculture. A monthly dose of EM BIO formula for vermiculture is 400 l. Applying EM BIO to cane fields as well as vermiculture takes place during the vegetation period, which is from April until October. During the months (April – June) an additional dose of 500l of EM BIO is applied onto the sludge lagoon (on the sludge collected in the winter period before discharging onto vermicomposting beds) [Boruszko 2015].

The research in ready vermicompost was conducted between the years 2004 and 2015. The content of heavy metals (Pb, Hg, Cu, Cd, Ni, Zn, Cr), selected macroelements (Ca, Mg), fertilizing values (Nog., N – NH₄, Pog.), dry mass, organic substances and pH were determined in the vermicompost. Collecting samples and the methodology of analytical research were compliant with current Polish norms and regulations for municipal sewage sludge. The examinations were carried out in the Department of Technology In Engineering and Environmental Protection laboratory according to valid norms.

Sludge samples were treated with mineralization in HACH mineralizator with the use of sulphuric acid and hydrogen peroxide in mixture of nitric and hydrochloric acid in ratio 1:3. For further analysis mineralizators were filtered through MN 616 G paper filter. Determination of cadmium, nickel and total chromium content was done in samples of mineralizators with the use of atomic absorption spectrometr Perkin-Elmer 4100 ZL with transversely heated graphite cuvette and Zeeman-effect background correction. Determination of mercury content was done in samples of mineralizators by means of cold steam technique with the use of atomic absorption spectrometr Perkin-Elmer 4100 ZL equipped in add – on device FIAS-200. Determination of zinc,

lead and copper content was done in samples of mineralizators with the use of atomic absorption spectrometr Varian SpectrAA 20 Plus by means of flame atomization. Determination of potassium content was done in samples of mineralizators with the use of atomic absorption spectrometr Varian SpectrAA 20 Plus by means of atomic emission spectroscopy.

RESULTS AND DISCUSSION

The results of the research on the vermicompost produced over 12 years in treatment plant in Zambrów were presented below in tables and figures.

Table 1 and Figure 1 show the results of research concerning the content of heavy metals in vermicompost.

The conducted analysis shows that every year the content of all heavy metals in the examined vermicompost was below the current permissible values used in farming [regulations from 2002, 2010, 2015]. Also, the content of heavy metals was not exceeded in reference to permissible values of pollution in fertilizers or substances improving the growth of organic and mineral plants. [regulation from 2008]. Among the examined microelements in the vermicompost, the high-

Table 1. Contents of heavy metals in vermicompost in comparison to permissible values used in farming [mg⁻¹ kg d.m.]

Year	Pb	Hg	Cu	Cd	Ni	Zn	Cr
2004	48,3	1,09	148	2,31	15,7	983	22,5
2005	41,6	1,03	175	3,11	16,4	885	24,3
2006	42,5	0,97	164	2,98	14,3	845	21,2
2007	39,5	0,99	156	2,56	13,4	798	19,5
2008	35,1	0,87	132	2,45	13,2	805	20,3
2009	34,5	0,78	112	1,97	11,7	705	17,6
2010	33,0	0,86	130	1,1	12	689	11,8
2011	22,6	0,72	69,2	1,25	9,25	411	25,6
2012	15,0	0,36	60,0	1,30	6,50	425	11,3
2013	33,0	0,70	188,0	3,5	11,0	647	16,0
2014	21,9	0,52	115,0	1,47	15,3	613	21,0
2015	11,5	0,25	76	1,35	6,7	577	10,3
A	500	5	800	10	100	2500	500
B	750	16	1000	20	300	2500	500
C	140	2	-	5	60	-	100

A – Permissible values for sludge used in farming, based on regulations effective between 2002 and 2010.

B – Permissible values for sludge used in farming, based on regulations effective between 2010 and 2015.

C – Permissible values for organic fertilizers, based on regulations effective between 2008 and 2016.

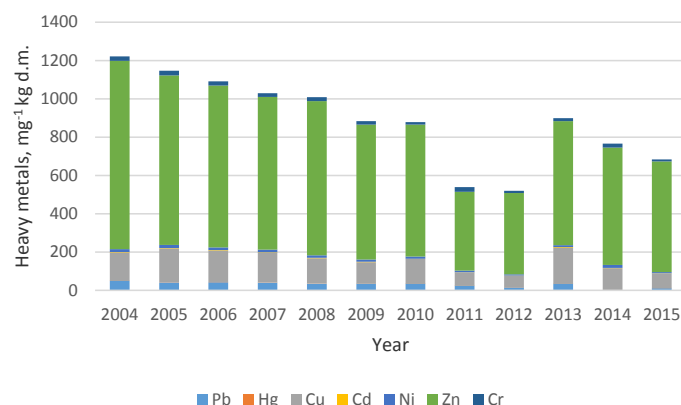


Figure 1. Contents of sum of heavy metals and individual heavy metals during experiments on vermicompost

est content was observed for zinc, which ranged from 411 mg⁻¹ kg to 983 mg⁻¹ kg of dry mass. It constituted respectively from 16.4% to 39.3% of permissible value in farming. The lowest values in vermicompost were observed for mercury, ranging from 0.25 mg⁻¹ kg to 1.09 mg⁻¹ kg of dry mass. It constituted respectively from 1.6% to 6.8% of permissible value in farming (according to the current regulations) and from 12.5% to 54.5% in reference to permissible values of pollution in fertilizers. The summative content of the analyzed heavy metals was the highest in 2004 and reached over 1200 mg⁻¹ kg of dry mass, whereas the lowest content was analyzed in 2012 at 520 mg⁻¹ kg of dry mass.

Table 2 and Figures 2, 3 and 4 present the research results for selected macroelements and fertilizing elements as well as vermicompost weight analysis in particular years.

Research results showed significant fluctuation in calcium content in vermicompost. The amount of this element oscillated between 12.05 g⁻¹ kg and 40.8 g⁻¹ kg of dry mass. The magnesium content was less variable and stayed between 1.0 g⁻¹ kg and 5.2 g⁻¹ kg of dry mass. Similarly, in case of fertilizing elements, high variability was observed for nitrogen: from 9.8 g⁻¹ kg to 31.1 g⁻¹ kg of dry mass, whereas phosphorous showed lower variability with its content in the vermicompost ranging between 2.6 g⁻¹ kg and 9.6 g⁻¹ kg of dry mass. The content of vermicompost's dry mass was between 41 % to 62,1%, while organic substances constituted from 21.3% to 48.3% of dry mass in the examined vermicompost.

The achieved results show that during the whole 12-years research period the vermicompost met the standards for organic and mineral fertilizers, that is it contained less than 20% of

Table 2. Contents of: calcium, magnesium, nitrogen, phosphorus, dry mass, organic substances and pH in vermicompost

Year	Ca	Mg	N-total	N-ammonia	P-total	pH	Hydrating	Dry mass	Organic substances
	g ⁻¹ kg s.m	g ⁻¹ kg s.m	g ⁻¹ kg s.m	g ⁻¹ kg s.m	g ⁻¹ kg s.m	-	%	%	% dm
2004	40,8	4,3	31,1	0,02	9,6	7,02	53,0	47,0	48,3
2005	30,2	5,2	28,5	0,02	8,7	6,8	48,9	51,1	33,5
2006	27,2	4,7	21,3	0,01	8,5	6,6	58,9	41,1	40,3
2007	19,6	4,2	22,5	0,02	7,5	6,9	55,2	44,8	38,5
2008	21,5	3,9	17,8	0,02	6,4	6,9	49,7	50,3	30,5
2009	18,5	5,2	13,5	0,01	5,6	6,6	44,3	55,7	32,3
2010	14,9	4,6	12,1	0,01	4,2	6,5	43,3	56,7	28,7
2011	15,3	4,2	9,8	0,01	2,6	6,4	40,6	59,4	21,3
2012	17,4	4,8	10,2	0,01	3,2	6,1	37,9	62,1	31,0
2013	12,0	4,1	12,3	0,01	4,1	5,9	59,0	41,0	45,0
2014	15,9	1,0	12,2	0,01	4,0	5,9	52,4	47,6	30,6
2015	15,2	2,1	15,1	0,11	5,0	5,07	47,3	52,3	32,8

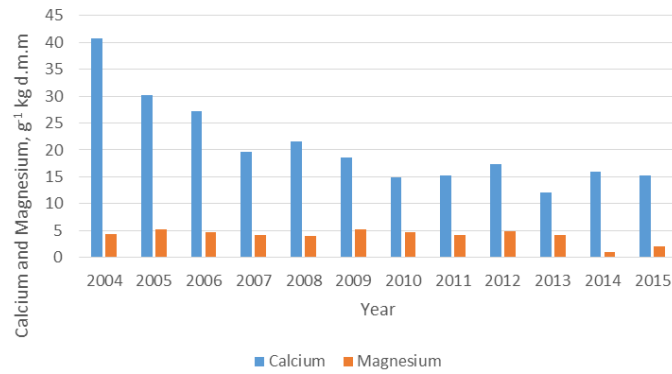


Figure 2. Contents of calcium and magnesium during experiments on vermicompost

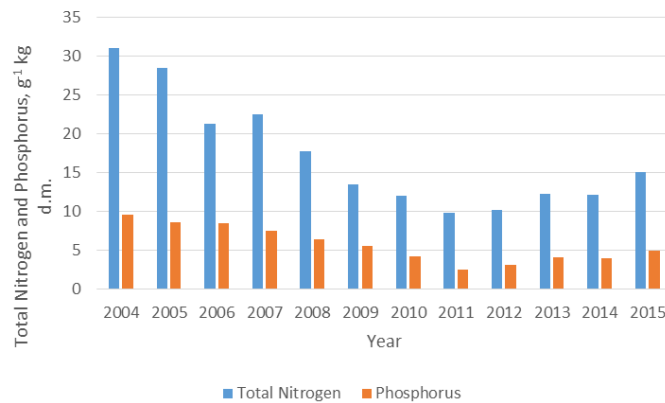


Figure 3. Contents of total nitrogen and phosphorus during experiments on vermicompost

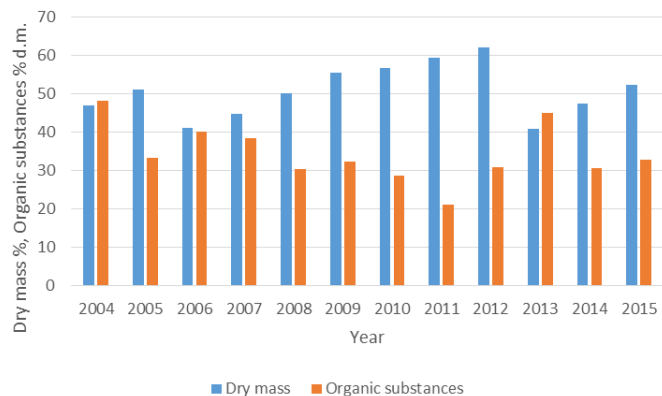


Figure 4. Contents of dry mass and organic substances during experiments on vermicompost

organic substance in dry mass and over 1% of total nitrogen and 0.5% of phosphorous in reference to phosphorus pentoxide (P_2O_5). The pH of produced vermicompost was gradually decreasing from 7.02 to 5.07 of pH value. During the entire research period no living eggs of intestinal parasites *Ascaris sp.*, *Trichuris sp.*, *Toxocara sp.* and *Salmonella* bacteria were observed in the vermicompost. Similar effectiveness of hygienization in the process of sewage sludge vermicomposting was achieved in the analysis [Brown et al. 1981].

The research on low-input processes of sewage sludge treatment resulted from an actual demand for high-quality compost produced on the basis of sewage sludge, as well as from legal regulations which require processing sewage sludge before recycling it [Riggle et al. 1994].

The conducted research is of high importance in terms of possibility of utilizing sludge generated in wastewater treatment plants in the north-eastern region of Poland.

When exposed to the vermicomposting process with the use of *Eisenia fetida* earthworm above all (it was a kind of the starting population), sewage sludge changes its characteristics. It enables obtaining valuable organic fertilizer with problematic sludge removed. The factor which determines the fertilizing value of vermicompost is the chemical content of sewage sludge used in its production. The type and quantity of the applied organic matter additive in a form of straw, sawdust, wastepaper or leaves has also a significant influence. Breeding concentrated populations of earthworm might play a substantial role in popularizing natural methods of avoiding soil degradation and recycling sewage sludge [Kacprzak 1994, Hatanaka 1983].

Breeding earthworm and subsequently applying it to the vermicomposting process has therefore become another alternative means of sewage sludge processing. Correctly maintained vermiculture transforms sewage sludge as waste matter into aerated fertilizer of lumpy structure, which is rich in nutrients [Kostecka et al. 1995 and 1996, Boruszko 2011].

EM application in low-cost methods of sewage sludge treatment has proven in several aspects the validity of continuing research in order to confirm EM's influence on the sludge quality and parameters of technological processes. The achieved research results have confirmed EM's observable effect on the change in the structure of dry mass in sludge processed into vermicompost. A slight, yet noticeable difference has been achieved in faster and more effective mineralization of organic substances present in sludge.

Low-cost methods of processing sewage sludge with the application of vermiculture might be an inexpensive and effective means of producing high-value fertilizers and soil enhancing substances [Baran et al. 1996, Kostecka et al. 1996, Wójcikowska- Kapusta 2001, Yadav et al. 2010].

CONCLUSIONS

The conducted research on low-input methods of sewage sludge treatment in the vermicomposting process with the application of Effective Microorganisms has resulted in the following achievements and practical conclusions:

1. The experience gained from applying Effective Microorganisms in low-input methods of sewage

sludge treatment point to great possibilities of intensifying these processes in reference to both the duration period and mineralizing difficulties (e.g. odor).

2. From the point of view of intensifying low-cost processes of sewage sludge treatment it is extremely important to determine and evaluate Effective Microorganisms' influence on the final character and physicochemical content of sludge or the produced vermicompost. Due to the fact that these processes often require a long time, it is necessary to continue the research in order to confirm the achieved effects.
3. The research concerning red Californian earthworm proved substantial mineralization and humification of sludge. The application of EM formula considerably quickened the process and the achieved modifications in the vermicompost structure and content.
4. Examined over the years, heavy metal values in the produced vermicompost are much lower in reference to those permitted by regulations concerning fertilizing and farming usage.

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