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CHEMICAL AND BIOLOGICAL PROPERTIES OF COMPOSTS PRODUCED FROM MUNICIPAL SEWAGE SLUDGE WITH SAWDUST SUPPLEMENT

CHEMICZNE I BIOLOGICZNE WŁAŚCIWOŚCI KOMPOSTÓW WYTWORZONYCH Z KOMUNALNYCH OSADÓW ŚCIEKOWYCH Z DODATKIEM TROCIN

Abstract: The paper presents results of investigations on composting municipal sewage sludge with an admixture of sawdust. The composting was conducted in the area of sewage treatment plant for 23 weeks by means of prism method. The prisms were formed and aerated using a loader and farmyard manure spreader. Four prisms were prepared, each composed of mixtures with various volumetric proportion of components. The control object was made up entirely of sewage sludge, whereas the other prisms were formed of the sewage sludge with a 10 %, 30 % and 50 % proportion of sawdust. In order to assess the quality of obtained composts their basic chemical parameters were determined and seed germination tests were conducted.

On the basis of conducted investigations it was established among others, that with growing sawdust share in the compost mass, in relation to the sewage sludge, organic C content was increasing visibly (217.0 g $\cdot$ kg^{-1} d.m. in the compost produced of sewage sludge and 250.1 g $\cdot$ kg^{-1} d.m. in the compost with a 50 % sawdust share), whereas the quantity of basic nutrients was decreasing in the final product. All produced composts revealed low heavy metal contents, concerning this type of material. Determined contents of Cd, Cr, Hg, Ni and Pb were visibly lower than permissible in organic and organic-mineral fertilizers. Composts with the highest share of sawdust proved the best substratum for the test plant germination. Out of the test seeds sown on it, 90 % germinated, whereas only 60 % germinated when the substratum was formed solely of sewage sludge.

Keywords: sewage sludge, sawdust, compost, heavy metals

In compliance with the law in force in Poland, municipal sewage sludge is counted among wastes which may be utilized in various ways. Currently one of quite frequently used methods is its application for fertilizer purposes [1, 2]. However, it should be remembered that the priority at such materials utilization is always their use in a way

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which will not cause any negative effect on people or the environment. Information gathered by GUS (Polish *Central Statistical Office*) [3] reveals that the amount of produced municipal sewage sludge has been increasing yearly by about 5 %, so sewage treatment plants produced 359.8 thousand Mg in 2000, 486.1 thousand Mg in 2005 and 567.3 thousand Mg d.m. of sludge in 2008. The tendency, according to the estimates of the Ministry of the Environment will persist in the subsequent years, which poses serious challenge of rational management of such huge mass of sludge.

Despite the possible occurrence of certain faults, posing a potential hazard to the environment, *ie* considerable amounts of heavy metals, toxic organic compounds or presence of pathogenic microorganisms [5–7], municipal sewage sludge is more and more often used in agriculture owing to its considerable quantities of organic matter and many nutrients [5, 7, 8]. In 2008 112.0 thousand Mg d.m. of sewage sludge was managed in this way, whereas 3 years previously only half of this amount was utilised in agriculture [3]. On of the basic requirements for environmental utilization of sewage sludge is its stabilization. Unfortunately, because no parameters which stabilized sewage sludge should reveal were stated in the legal regulations, very often sludge susceptible for putrefaction is supplied to the soil, which in result produces an arduous odour causing protest of the local residents against its use in this way. Therefore, in order to avoid the above-mentioned problems the sludge producer should make every effort to prepare the sludge in an appropriate way.

One of the methods enabling proper transformation of sewage sludge prior to their application to the soil is its composting, the main objective of which is obtaining material with the properties of organic fertilizer. Properly conducted composting process allows to stabilize the sludge, destroy pathogenic organisms and decrease its mass and volume [9]. Despite many analyses of composting, this issue still requires further research. A considerable non-uniformity of physicochemical parameters of sewage sludge and local specificity of each sewage treatment plant cause that it is impossible to develop a universal composting method for this type of materials. Therefore, aiming at correct mastering of composting technology, one should consider each treatment plant individually.

The research was conducted to determine the properties of composts manufactured from sewage sludge with a supplement of sawdust and an assessment of their phytotoxicity.

Materials and methods

The research was conducted at the central sewage treatment plant owned by Water Supply and Sewerage Company in Krzeszowice. Composts were produced from municipal sewage forming in the treatment plant area and sawdust. Decision about sawdust application was affected in the first place by financial and organizational reasons of possible future enterprise involving sewage processing for compost. After analysing local potential of obtaining various structure forming materials it turned out that in the closest neighbourhood of the treatment plant sawdust is the cheapest and best structure forming material available in large quantities.

Sewage sludge and sawdust were brought to a yard and used to prepare four compost prisms of the 2.5 m base and 1.5 m high each. Each of them was composed of mixtures with various volumetric share of the following components: sewage sludge 100 % without sawdust supplement (Compost 0 % – control), sewage sludge 90 % + sawdust 10 % (Compost 10 %), sewage sludge 70 % + sawdust 30 % (Compost 30 %) and sewage sludge 50 % + sawdust 50 % (Compost 50 %). Compost mass mixing and prism forming were done by means of farmyard manure spreader and loader. During composting, which was conducted for 23 weeks, the moisture and temperature of the prisms were controlled and on this basis eventual aeration of the compost mass was determined. All in all the prisms were forked six times.

After the experiment completion compost samples were collected and subjected to the following analyses: dry mass determination – by gravimetric method at 105 °C; organic carbon (C_{org}) using oxidation-titrating with potassium dichromate(VI) in acid environment; total nitrogen – with Kjeldahl's method at Kjeltec 2300 apparatus. In order to assess individual mineral components dried composts samples were incinerated in a muffle furnace at 450 ^{o}C for 12 hours. Subsequently the remains were digested in a mixture of concentrated nitric (HNO_3) and perchloric ($HClO_4$) acids (3:2, v/v). After total acid evaporation, 20 % HCl was added to the little steamer and the sample was heated on a water bath under cover for one hour. The whole was filtered into measuring flasks – 50 cm^3 in volume. In the filtrates prepared in this way the contents of Ca, K and Na were assessed by *flame emission* method and Mg by absorption method on *atomic absorption spectrophotometer* Solaar (Thermo) and P, Cd, Cr, Cu, Ni, Pb and Zn using ICP-AES method on JY 238 Ultrace apparatus (Jobin-Yvon). Hg concentrations in filtrates were determined by AAS using an automatic mercury analyser AMA 254.

Obtained composts were also subjected to germination ability test. This experiment was conducted in 3 replications in plastic containers, 18 cm in diameter filled with 1 kg of compost. 100 seeds of cress or mustard were sown to each container. After 7 days, during which constant moisture of the material was maintained, the number of germinated seeds was counted in all containers.

Results and discussion

The wastes used for the experiment were characterized by various chemical composition (Table 1).

Sewage sludge in comparison with sawdust, as a rule revealed a higher content of minerals in conversion to dry mass of materials. Macroelement contents in sewage sludge frequently exceeded their amounts in sawdust several times, whereas microelement contents were over 50-fold higher. The highest divergence was assessed for copper, whose concentration was as much as 45-fold higher in sewage sludge than in sawdust. On the other hand, C_{org} content in sawdust was definitely higher than in sewage sludge. It is also worth mentioning than heavy metal contents in the composted sewage sludge did not exceed their maximum permissible amounts stated in Polish legislation for this type of wastes used in agriculture [2].

Table 1

Chosen properties of sewage sludge and sawdust used in experiment

Property	Unit	Sludge	Sawdust
Reaction	pH	7.80	—
Dry matter	[g · kg^{-1}]	369.2	590.0
C_{org} N_{tot}	[g · kg^{-1} d.m.]	256.1 18.7	489.3 3.1
C : N	[-]	13.7	157.6
P K Ca Mg Na	[g · kg^{-1} d.m.]	7.4 1.6 29.1 2.7 0.5	0.9 1.4 2.7 0.8 0.6
Cd Cr Cu Hg Ni Pb Zn	[mg · kg^{-1} d.m.]	2.93 25.1 99.6 0.40 16.8 64.8 956.3	0.15 0.92 2.23 0.09 1.38 2.46 26.1

The differences in temperature in prisms between individual mixtures measured during the composting were relatively small (except the object with sewage sludge without sawdust, where the temperature was only slightly different from the ambient temperature). However, it is worth mentioning that most frequently the temperature of mixture with 50 % sawdust admixture was several degrees higher in comparison with the other mixtures, particularly at the initial stage of composting. At the initial stage of the experiment the temperature of prisms approximated 55 ^{o}C and then declined systematically with time reaching a value oscillating around 35 ^{o}C in the 23rd week.

Due to disadvantageous physical and chemical properties of sewage sludge, a supplement of other organic wastes is usually added to them to ensure the optimal conditions of composting. This measure ensures among others a suitable aeration of compost mass or C : N ratio (20–30 recommended at the initial phase) [10], which is crucial in the process of organic matter decomposition and enzymatic activity [11]. Recommended initial C : N quantitative ratio was maintained only in case of two mixtures with the highest proportion of sawdust. Initially its value in the prepared compost materials was as follows: compost – 0 % sawdust 13.7; compost – 10 % sawdust 16.1; compost – 30 % sawdust 21.0 and compost – 50 % sawdust 23.2. However, beside the composting conditions, compost fertilizer value is mainly affected by the kind of applied wastes and their share in individual mixtures [12].

Properties of products obtained in result of six month composting of sewage sludge and its mixtures with sawdust were presented in Table 2. Their pH was neutral, pH value of three composts with sawdust admixture was on an approximate level, oscillating around pH = 7.5, whereas in case of sewage sludge composts was higher by almost a unit.

Changeability of organic carbon content between analyzed composts was considerable and ranged from 198.1 g · kg^{-1} d.m. to 250.1 g · kg^{-1} d.m. A comparison of the obtained results with the amount of C_{org} in the initial components (Tables 1 and 2) shows an obvious diminishing of its content in result of composting. Also other authors reported carbon loss during composting [13, 14]. This element content in composts was strictly positively correlated with its amount in the initial material. However, it is worth mentioning that the lowest contents of C_{org} were assessed in compost with a 10 % sawdust supplement. It may be explained by the fact that a relatively small admixture of sawdust to sludge on one hand caused an increase in C in the compost mass, on the other, through loosening the structure it contributed to activating organic matter breakdown process leading to greater carbon losses. In the other composts with 30 and 50 % sawdust supplements, the amounts of C_{org} introduced to the compost mass were big enough, so that despite less intensive breakdown of organic matter, C_{org} content was bigger in comparison with the compost manufactured solely of sewage sludge (Table 2).

Table 2

Selected properties of composts produced from municipal sewage sludge with sawdust supplement (23 weeks of composting)

Property	Unit	Compost 0 %*	Compost 10 %	Compost 30 %	Compost 50 %
Reaction	pH	8.36	7.51	7.50	7.42
Dry matter	[$g \cdot kg^{-1}$]	395.6	521.3	510.6	462.3
C_{org}	[$g \cdot kg^{-1}$ d.m.]	217.0	198.1	232.3	250.1
N_{tot}	[$g \cdot kg^{-1}$ d.m.]	16.7	15.5	15.6	15.1
C : N	[-]	13.0	12.8	14.9	16.5
P	[$g \cdot kg^{-1}$ d.m.]	6.9	6.6	6.5	6.7
K	[$g \cdot kg^{-1}$ d.m.]	1.6	1.8	1.8	1.6
Ca	[$g \cdot kg^{-1}$ d.m.]	28.2	28.0	27.2	26.5
Mg	[$g \cdot kg^{-1}$ d.m.]	2.6	2.7	2.6	2.5
Na	[$g \cdot kg^{-1}$ d.m.]	0.6	0.7	0.9	0.8
Cd	[$mg \cdot kg^{-1}$ d.m.]	2.91	2.93	2.87	2.71
Cr	[$mg \cdot kg^{-1}$ d.m.]	26.0	25.6	24.4	22.4
Cu	[$mg \cdot kg^{-1}$ d.m.]	99.6	93.2	86.8	81.9
Hg	[$mg \cdot kg^{-1}$ d.m.]	0.42	0.40	0.40	0.38
Ni	[$mg \cdot kg^{-1}$ d.m.]	19.6	18.2	16.4	16.4
Pb	[$mg \cdot kg^{-1}$ d.m.]	76.4	79.2	82.4	79.3
Zn	[$mg \cdot kg^{-1}$ d.m.]	1149.5	962.2	913.9	852.7

* Sawdust share in compost mixture (v/v).

Because of definitely lower content of nitrogen in sawdust in relation to its amount in sewage sludge, the highest content of this element was assessed in compost produced of sewage sludge without supplement, whereas the lowest in a mixture with the highest share of sawdust (Table 2). Also nitrogen transformations occurring during composting led to diminishing of its content in all obtained products. This element content in compost of sewage sludge was lower by *ca* 11 % in comparison with the initial material (Tables 1 and 2).

The outcome of diversified contents of carbon and nitrogen in the analysed composts was the value of C : N ratio. Its value 10–15 is treated as an indicator of compost maturity [15]. A comparison of previously stated values of this index, assessed in freshly prepared compost mixtures with the results obtained after composting completion (Table 2) reveals that the higher its value at the beginning of the process the higher was its decline. Relatively high values of C : N ratio in composts with 30 % and 50 % share of sawdust may testify their not full maturity.

Differences in the content of the other macroelements (P, K, Ca, Mg, Na) between individual composts were relatively small (Table 2). Very often quantities of these elements in the final products were decreasing with increasing sawdust share in the compost mass. Phosphorus content in the composts on the level of *ca* 7 $gP \cdot kg^{-1}$ d.m. was rather average considering the compost produced of sewage sludge, but clearly bigger than the minimum amount (2 $gP_2O_5 \cdot kg^{-1}$ d.m.) as required by the Regulation of the *Ministry of Agriculture and Rural Development* (MARD) of 18 June 2008 [16] for solid organic fertilizers in which phosphorus content is declared. As results from other authors' investigations [8, 15], sewage sludge generally contains small amounts of potassium. The fact was confirmed in the presented investigations because potassium quantities assessed in the composts were only between 1.6 and 1.8 $gK \cdot kg^{-1}$ d.m.

One of crucial parameters of compost fertilizer value is heavy metal content. Analysis of heavy metal contents in the obtained composts showed their highest amounts in the compost obtained of sewage sludge, whereas the lowest in compost with the highest sawdust supplement (Table 2). Obtained results are on one hand the outcome of increasing mineral content in result of organic compound mineralisation occurring during composting process [14], and on the other are due to dilution obtained through an addition of sawdust containing small amounts of metals. All heavy metal contents (Cd, Cr, Hg, Ni and Pb) in the analysed materials (Table 2), as required by the MARD Regulation [16], were visibly smaller than the values permissible in organic and organic-mineral fertilizers.

Germination tests of cress (*Lepidium sativum* L.) and mustard (*Sinapis alba* L.) were conducted to determine phytotoxicity of the composts. The tests revealed that the best substratum was compost produced of sewage sludge with a 50 % sawdust supplement. On this substratum 86 and 92 out of 100 seeds respectively of cress and mustard germinated (Table 3).

Table 3

Results of germination test of cress and mustard seeds on composts produced from municipal sewage sludge with sawdust admixture

Material	Number of sown seeds	Number of germinated seeds	
		crees	mustard
Compost 0 %*	100	56	57
Compost 10 %	100	78	80
Compost 30 %	100	90	78
Compost 50 %	100	86	92
Control	100	89	94

* Sawdust share in compost mixture (v/v).

The plants germinated slightly more weakly on the compost with 30 % sawdust addition. The compost obtained from the sewage sludge without any admixture proved the most toxic because only about 60 % of the seeds of both plants sown on it germinated.

Conclusions

1. Composts produced of municipal sewage sludge and sawdust may be a valuable organic fertilizer because in view of its chemical composition it meets all the requirements posed for the fertilizers of this type. It is abundant in essential fertilizer components (organic matter, N and P) and does not contain excessive amounts of heavy metals.

2. Sawdust supplement to sewage sludge in the amount higher than 30 % of sewage volume contributed to increase in the content of organic carbon and decrease in heavy metal concentrations in the composts obtained from mixtures of this type.

3. Composts originating from sewage sludge and sawdust were characterised by a higher biological value in comparison with the composts produced solely from sewage sludge.

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Abstrakt: W pracy przedstawiono wyniki badań dotyczące kompostowania komunalnych osadów ściekowych z dodatkiem trocin. Kompostowanie prowadzono na terenie oczyszczalni ścieków, metodą pryzmową przez 23 tygodnie. Do formowania oraz napowietrzania pryzm użyto ładowarkę i rozrzutnik obornika. Przygotowano 4 pryzmy, a każda z nich składała się z mieszanin o różnym udziale objętościowym komponentów. Obiekt kontrolny składał się wyłącznie z osadu ściekowego, natomiast pozostałe pryzmy formowano z osadu ściekowego z 10 %, 30 % oraz 50 % udziałem trocin.

W celu oceny jakości otrzymanych kompostów badano ich podstawowe parametry chemiczne oraz przeprowadzono testy kiełkowania nasion. Na podstawie przeprowadzonych badań stwierdzono m.in., że wraz ze wzrostem udziału trocin w masie kompostowej, w stosunku do osadów ściekowych, wyraźnie zwiększała się zawartość węgla organicznego, natomiast zmniejszała się ilość podstawowych składników pokarmowych w produkcie końcowym. Wszystkie wytworzone komposty charakteryzowały się niską, jak na tego typu materiał, zawartością metali ciężkich. Komposty z największym udziałem trocin okazały się najlepszym podłożem do kiełkowania roślin testowych.

Słowa kluczowe: osad ściekowy, trociny, kompost, metale ciężkie