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Impact of reduced straw content on the sewage sludge composting process

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Abstract: The main objective of presented research work was the assessment of the impact of reduced straw content, as organic carbon source, on the course of sewage sludge composting process. During the research work performed in industrial conditions, the composting process going in periodically overturned windrows differing in proportion of dehydrated sludge, straw and structural material being 4:1:1 and 8:1:2 respectively, was observed. The consequence of increase of sludge concentration with relation to straw was decrease of C:N ratio in the input material from 11.5 to 8.5. The following parameters were analyzed as indicators for the assessment of the composting process: contents of fulvic acids (FA), humic acids (HA), lignin, cellulose and hemicellulose as well as absorbance in UV/VIS (λ=280, 465 and 665 nm) range. The results obtained have indicated that the increase of sludge content extends the elevated temperature (T>50°C) period from 42 days to approximately 65 days. Our tests did not confirm that limitation of straw content added to sewage sludge had any adverse effect on the course of composting. PI index (HA/FA), which qualifies the compost as mature in the first case – No 1, exceeds limit value of 3.6 on the 83rd day whereas, in the second case No 2, on the 48th day.

Introduction

Due to high content of macroelements, mainly organic carbon, nitrogen and phosphorus, the mechanically dehydrated sludge makes a valuable material for the production of compost complying with the requirements set for soil improvers and materials substituting soil for crop production (Publications Office of the European Union 2001). Composting of sewage sludge from municipal wastewater treatment plants is practically a single method of biological treatment, which can provide a product that can be used in agriculture. Whereas application of methane fermentation considerably improves effectiveness of the entire sludge processing, the application of a post fermentation material composting module ultimately determines the quality of the final product, i.e. compost (Curtis and Claassen 2009, Carrizo et al. 2015). High concentration of total nitrogen in mechanically dehydrated sludge, generally falling within the 2÷7% dry mass range (Sidełko et al. 2010, Świerczek et al. 2018) and its high humidity amounting to 85÷75% (Kacprzak et al. 2017) necessitate the addition, at the compost mass formation stage, of supplementary material with high concentration of organic carbon and low concentration of nitrogen to the composted sewage sludge. According to various sources (Bernal et al. 2009, Sweeten and Auvermann 2008) the optimum C/N ratio value at the moment of composting commencement should be within the 20÷35 interval, whereas the value of this parameter only in the dehydrated sewage sludge itself generally does not exceed C/N=7 (Kacprzak et al. 2017). Therefore, a statement can be made that the composting of sewage sludge without addition of any material reducing concentration of nitrogen due to the risk of NH_3 formation (Hellebrand and Kalk 2001) is practically impossible. Furthermore, the addition of various supplements is a factor modifying the carbon to nitrogen proportion in a way assuring proper C/N ratio (Alvi et al. 2017, Sanchez et al. 2017, Doublet et al. 2010).

An important element of the analysis of the course of the composting process is the evaluation of the compost maturity. Immature compost may contain phytotoxic substances mostly in the form of short-chain organic acids, ammonia, sulphur hydrogen, phenol and other compounds, whose occurrence has adverse effect on plant germination and growth processes. To prevent the adverse effects caused by the application of immature compost, physico-chemical, microbiological and fertilizing criteria of its maturity are used. Such physical features as color, odor and temperature provide a general view of the composting process advancement level (Bernal et al. 2009). Chemical methods allow for the determination of physicochemical parameters values in compost samples and they are used to calculate the values of various indices describing speed of organic and mineral components transformation during composting. From agricultural point of view important information is not only the total carbon content, but also the form of its occurrence is of importance. Transformation of organic matter during compost maturing phase leads to the generation of large molecular compounds in the form of organic polymers. This process is called humification and the generated substances having exceptionally complex molecular form are called humus. The forerunner of humic compounds are mainly lignin, cellulose and hemicellulose from which various products originate such as, among others, amino acids and phenol, making a basic component of humic acids generated due to the occurrence of various enzymatic reactions (Yuan et al. 2017). During the preliminary phase of organic matter transformation, in the humification process dominate fulvic acids (FA), which are transformed, over time, into humic acids (HA). The change of organic carbon forms, occurring in the form of the so-called specific and non-specific humic compounds during composting process, makes a basis for the determination of indices allowing for assessment of the humification process progress defined as HA/FA and HA/TOC (Hsu and Lo 1999, Sanchez-Monedero et al. 1999, Bustamante et al. 2008). The first index described by the content of humic acids carbon (C_{HA}) to fulvic acids carbon (C_{FA}) ratio is expressed as PI (Polymerisation Index) abbreviation. The second index expresses the percentage of humic acids carbon content in total organic carbon (TOC); it is expressed as HI (Humification Index).

In the scientific literature there are many examples of composting of sewage sludge mixtures within broad scope of C/N= 15÷28.9 ratio (Gonzalez et al. 2019, Zheng et al. 2018, Głąb et al. 2018, Li et al. 2017, Kulikowska and Sindrewicz 2018, Sidełko et al. 2010). The indicated interval of C/N values, i.e., 15÷28.9, comprises the values of this parameter indicated in the quoted papers. The differences originate, first and foremost, from the type and quantity of components used to form the compost batch. By observing the temperature increase and values during composting the authors have demonstrated that composting of sewage sludge may progress at various C/N values. As there is a risk of negative impact of ammonia (NH_3) generated at high concentration of total nitrogen in composted mass C/N values below 15 are not recommended.

Generally, straw being a supplementary source of organic carbon causes increase of C/N ratio value up to the level considered as optimal. However, straw is currently used more and more frequently in other sectors of economy, which means that it is in short supply on the market. Therefore, taking up any research work on the course of composting with reduced straw content, in relation to the amount originating from the balance of mass of carbon and nitrogen in the context of recommended C/N ratio, is justified.

The main objective of this research was the determination of impact of increased sewage sludge concentration mixed with straw on the course of humification of organic matter during composting. Our research comprised mostly an analysis of variation of humic substance content expressed by the occurrence of fulvic and humic acids. Additionally, the contents of such organic compounds as lignin, cellulose and hemicelullose, occurrence of which may have impact on the values of humification indices, were determined. The occurrence of lignin, which is a wood component, is associated with, among other things, chips added in the composting process. High cellulose and hemicellulose contents in compost making in total 75% DM of added straw originates directly from the application of this component.

Material and methods

Our field research was performed at the site of wastewater treatment plant in Goleniów (West Pomeranian Voivodeship, Poland) producing ca. 5500 Mg of mechanically dehydrated sewage sludge. Processing of the sludge generated in the municipal wastewater treatment process consists in its mechanical dehydration and then composting with the addition of straw, wood chips and mature compost inoculum. Composting proceeds in roofed windrows approximately 70 m long, with dimensions of trapezoid transversal cross-section being 3 m bottom base width and 1.5 m height. The windrows are mechanically overturned from time to time, twice a week during the first three weeks of composting, and, in subsequent weeks, once per week, on average. Composting takes 4–5 months depending on the external conditions. After this period, the compost is used for agricultural purposes.

The field research was performed in two series (S1 and S2). Each stage lasted 5 months. These stages consisted of two parallel compost tests consisting in monitoring the composting process carried out in windrows of approx. 50 m3 each. In the first series – S1, two windrows varying in the proportion of their particular components being respectively for windrow No 1 – 4:1:1 and windrow No 2 – 8:1:2 (sewage sludge: straw: chips and inoculum) were allocated. These proportions define the mass shares. In the second series – S2, which was performed after the completion of S1, the method of accomplishment of the field research, including the composition of the composted mixture, i.e., windrows No 3 – 4:1:1 and windrows No 4 – 8:1:2, was the same. During the tests, the changes of temperature in all windrows were monitored. The compost samples were collected from three places in each windrow and after mixing a representative sample of 1 kg was separated. Each representative sample was taken to determine the following indicators: dry mass (DM) after sample drying at 105°C, total organic carbon (TOC) in elemental analysis by application of VarioMAX CN according to PN-Z-15011-3 standard, and total nitrogen (N_{tot}) through elemental analysis having prepared samples in accordance with PN-R-04006 standard. During TOC determination using the VarioMAX CN analyzer, the analytical procedure for the determination of only organic carbon was employed. The procedure is based on a modification in the apparatus combustion system compared to the standard CN operating mode. This modification is compatible with DIN/ISO 10694 standard. During the tests the contents of organic substances, total phosphorus and selected heavy metals with definition of their chemical forms, where determined as well.

The contents of lignin, cellulose and hemicellulose were determined in composts using the filtration bags technique in Ankom A200. The content of neutral detergent fiber (NDF) was determined based on Van Soest method (Van Soest et al. 1991), the content of acid detergent fiber (ADF) and content of lignin (ADL) were determined too. The cellulose content was determined based on the difference between the cumulative lignin and cellulose (ADF) amount and the content of lignin itself

(ADL), whereas the content of hemicellulose was established based on the difference of NDF and ADF fraction shares.

The extraction of the sum of humic acids (HS=HA+FA) was performed using 0.5 M NaOH applying the modified IHSS method (Swift 1996). Carbon in alkaline extracts (C_{HS}) and (C_{HA}) was determined in VARIOMAX CN. Carbon in fulvic acids (C_{FA}) was determined as a difference between C_{HS} and C_{HA} carbon contents.

Absorbance in humus acids and humic acids contents was measured three times at the following wavelengths: λ= 280 nm (A2), λ= 465 nm (A4) and 665 nm (A6) (Sapek and Sapek 1986). Then, absorbance indicators defining the degree of humification A2/A4 and A4/A6 were calculated.

The results were worked out using Statistica 12 software from StatSoft. The analyzed physico-chemical parameters data were presented as mean arithmetic values of three subsamples received from representative samples. The data reduction procedure was performed through the primary components analysis (PCA) using XLSTAT software from Addinsoft.

Results and Discussion

Test results are shown in Table 1. The values of N_{tot}, TOC, HA, FA, lignin, cellulose, hemicellulose, A2/A4 and A4/A6 constitute a mean value of the assays taken in two runs. Case No 1 gives average values of the parameters in windrow No 1 and 3 with the same component content, i.e,. 4:1:1. Case No 2 gives average values of the parameters in windrow No 2 and 4 (8/1/2). The mean error of a single carbon and nitrogen assay calculated based on the elementary analysis using the VarioMAX analyzer was TOC ±0.11 and N_{tot} ±0.025. The detailed data, including those used for the validation of the methodology, have been presented in the report available from the site of the STEP project (Interreg South Baltic 2018), which did not comprise IR spectral tests, and lignin, cellulose and hemicellulose contents tests.

The test results analysis was performed based on changes in the determined indicators values constituting mean values of assays for two cases – No 1 and No 2. Figure 1 illustrates changes of the mean temperature values for the two above-defined cases.

Already on the third day of composting, the temperature in excess of 45°C (Fig. 1) was noted in both cases. Such high temperature indicates intensive decomposition of organic matter during composting of both windrows. However, the thermophilic phase period in windrows of different compositions was not the same. In case No 2 (Fig. 1) it was approx. 60 days, when the highest temperature was noted on approximately the 8th day of composting. In case No 1 (Fig. 1) the thermophilic phase lasted for about 40 days, and the highest temperature was noted on approximately the 11th day of composting. Such situation may have originated from higher content of the sewage sludge fraction in windrow No 2 and 4. Insignificantly higher values for total nitrogen noted in these cases indicate higher accessibility of nutrients for the development of thermophilic bacteria during composting. Increased concentration of total nitrogen in windrows with a higher content of sewage sludge posed the risk of ammonia formation. Ammonia as an inhibiting factor may inhibit the composting process, however, the presented studies have not confirmed these concerns.

The process of degradation of organic matter during composting was analyzed based on TOC variations, which gradually decreased for two cases. The process conditions in the thermophilic phase promoted intensification of mineralization, which resulted in 12% (case No 1) and almost 14% (case No 2) TOC reduction, by the end of composting of both windrows, with relation to its initial value. Hernandez et al. (2006) noted 8.45% and 15.3% reduction of organic substance respectively after 90 days of composting of sewage sludge with sawdust in 1:1 and 1:3 proportion. However, Ponsa et al. (2009), who composted sewage sludge with wood chips in 1:2 and 1:3 proportion, have noted the reduction of the organic substance at 10.55% and 15.3% level respectively. Higher intensity of organic matter biodegradation process in windrows No 2 and 4 was probably caused by a longer period of the thermophilic phase as well as higher composting temperature compared to windrows No 1 and 3. Such situation could contribute to intense decomposition of cellulose and hemicellulose in the composed matter (Meng et al. 2017).

Variations of HS concentration during composting were observed (Table 1). In case No 1 approx. 27% reduction of FA content with relation to this parameter value at the beginning of the composting process was noted. In case No 2 this decrease was more pronounced and was in excess 58%. In the process of organic matter humification fulvic acids characterized by high content of hydroxylic and carboxylic functional groups are transformed into more complex compounds such as humic acids (Sellami et al. 2008). Faster decrease of FA content in case No 2 indicates better achievement of the stability level by organic matter. Also, an increase of HA content in both cases indicated achievement of sufficient stability by the tested composts. However, in case No 2, the increase of HA was higher and appeared to be close to 12%. Such situation indicates more intense transformation of low-molecular substances into high-molecular ones and it may suggest, consequently, faster achievement of satisfactory level of maturity by compost with higher content of sewage sludge (Zhou et al. 2014). Humic acids could additionally be generated from other humic substances available in the compost, including fulvic acids (Kulikowska, 2016).

The windrow composting process was analyzed in terms of lignin, cellulose and hemicellulose contents. The research in the above scope was carried out only during the runs windrows No 1 and No 2. The contents of those substances in windrow No 1 decreased by 1.37%, 18.83%, 95.53%, and in windrow No 2, by 7.11%, 51.02%, 79.76% respectively. A significant reduction of the contents was noted only in the case of the two last parameters. Such situations confirm the fact that high process temperature favors decomposition of complex hydrocarbon structures, i.e., cellulose and hemicellulose. However, the occurrence of lignin hampered the organic matter decomposition processes. Its degradation proceeded mainly in acid environment and with participation of fungal enzymes. Higher temperature in windrow No 2 indicated higher activity of microorganisms in the thermophilic phase and contributed to effective degradation of the cellulose and hemicellulose fractions during composting.

PI and HI indices are extensively used for description of relative transformation of humic substance during composting. The first index reflects intensity of generation of complex humic acids molecules from less complex ones (Domeizel et

Table 1. Evolution of some parameters and indexes during composting

Composting time day (no.)	Ntot g/kg DM	TOC g/kg DM.	HA g/kg DM	FA g/kg DM	Lignin g/kg DM	Celluloze g/kg DM	Hemicell. g/kg DM	PI	HI	A2/A4	A4/A6
case no. 1 (windrows no. 1 and 3) – 4:1:1 (sewage sludge/straw/wood cheaps and innoculum)											
3 (1/1)	30.48	413.43	153.74	58.17	18.28	9.37	15.21	2.64	37.19	5.66	16.74
10 (2/1)	27.36	397.08	148.51	47.22	30.25	10.83	11.14	3.15	37.40	4.37	14.03
16 (3/1)	28.68	389.93	148.00	42.51	29.48	14.40	7.55	3.48	38.09	3.69	14.13
24 (4/1)	29.07	378.05	149.46	48.52	34.26	11.56	12.87	3.08	39.54	4.53	14.06
29 (5/1)	33.25	378.48	161.60	78.47	22.94	10.56	8.57	1.90	42.70	3.11	16.35
48 (6/1)	35.05	365.30	163.01	46.12	29.41	11.54	10.31	3.50	44.62	2.58	14.20
62 (7/1)	35.79	367.28	156.00	71.46	24.90	8.12	9.63	2.28	42.48	2.76	14.71
83 (8/1)	34.51	379.68	160.78	44.05	27.61	10.11	3.56	3.54	42.35	1.77	13.78
111 (9/1)	34.41	358.55	163.92	42.02	30.83	11.94	2.49	3.83	45.72	1.79	13.74
133 (10/1)	35.53	362.18	165.51	55.03	29.87	10.41	0.68	2.98	45.70	1.82	13.04
case no. 2 (windrows no. 2 and 4) – 8:1:2 (sewage sludge/straw/wood cheaps and innoculum)											
3 (1/2)	40.74	390.78	146.84	74.77	25.18	11.76	5.75	1.96	37.58	4.99	15.76
10 (2/2)	27.35	386.85	158.45	46.96	27.29	11.23	9.49	3.37	40.96	5.08	13.93
16 (3/2)	27.84	378.00	142.11	43.75	30.61	13.86	10.56	3.25	37.59	4.08	14.76
24 (4/2)	28.63	371.23	142.57	53.69	27.68	11.53	9.43	2.66	38.40	4.20	14.65
29 (5/2)	35.59	358.35	143.01	46.20	26.45	13.53	16.43	3.10	39.91	3.42	14.23
48 (6/2)	31.22	362.80	152.76	28.50	31.83	10.81	4.38	5.36	42.11	2.19	13.83
62 (7/2)	33.93	358.03	157.28	36.63	32.30	8.50	5.54	4.29	43.93	2.36	13.00
83 (8/2)	34.75	363.43	154.75	44.49	26.96	6.10	4.14	3.48	42.58	2.45	12.63
111 (9/2)	36.73	358.08	152.54	28.10	26.96	5.40	2.27	5.43	42.60	2.59	12.12
133 (10/2)	35.53	337.05	163.68	45.50	26.31	5.76	2.58	3.60	48.56	2.65	11.71
sewage sludge	74.80	339.15	169.73	105.38	14.27	3.53	13.64	1.61	50.04	–	–
barley straw	7.00	457.00	67.32	34.68	21.71	45.89	29.27	–	–	–	–
wood cheaps	1.14	443.60	41.35	154.32	41.10	32.50	25.91	–	–	–	–

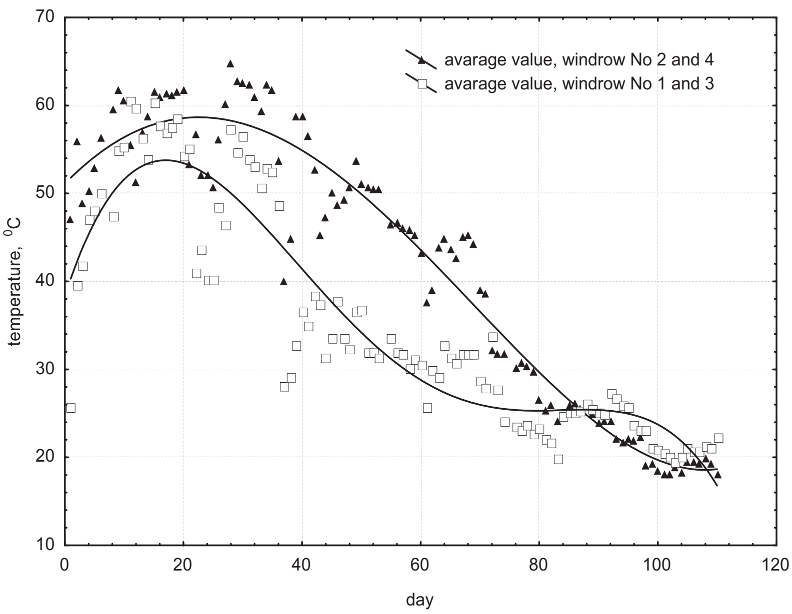

Fig. 1. Variations of average temperature values in both cases during composting

al. 2004, Czekała 2008). HI index describes the intensity of transformation of organic carbon attributable to the so-called non-specific humic substance into specific humic compounds – humus (Baffi et al. 2007). The values of both humification indices for the tested windrows increased, but not in the same way. PI index for case No 1 increased almost by 14%, and for case No 2 – by 83%. However, mean initial values of this index were similar for both windrows and were: for case No 1 – PI=2.64 and for case No 2 – PI=1.96 respectively. These values tell us that at the preliminary composting phase, low-molecular fractions of fulvic acids dominated in both windrows over the high-molecular fraction of humic acids. According to Zhou et al. (2014), HA/FA ratio within the interval of 3.6÷6.2 indicates the generation of mature compost. The very moment in which windrows with lower sludge content (windrows No 1 and 3) reached the stable value of 3.6 occurred on the 83rd day of the process counting from the date of composting commencement, whereas in windrows No 2 and 4 it was the 48th day. At the same time, the humification process in case No 2 proceeded in a more stable way, which was indicated by the dynamics of PI index value change. PI value for both cases was maintained above 3.6 until the end of the composting process. The significant impact on the humification process has the timing of the thermophilic phase, particularly its final stage. The thermophilic phase period was definitely longer for case No 2 and allowed for the generation of fully mature compost on the 40th day. HI index values for both cases already at the beginning of the composting process, were higher than those indicated by Bernal et al. (2009) (HI≥3.5). For case No 2, compared to case No 1, a higher increase of that index, by nearly 15%, was noted.

At the next stage of tests A2/A4 and A4/A6 the indices were determined; they were calculated from absorbance of humic acids in UV-VIS range. The first index indicates the content of organic substance at the preliminary decomposition stage (Sapek and Sapek 1986). At the preliminary phase of composting, this index clearly decreased in both compost windrows, which was associated with intensely proceeding processes of depolymerization associated with microbiological decomposition of complex organic structures, mainly hemicellulose and cellulose. The said non-humic compounds usually absorb energy of radiation near UV (λ=280 nm) (Zbytniewski and Buszewski 2005a, 2005b). After the 48th day of composting, the value of A2/A4 index for case No 2 started to slightly increase until the end of the process. This can be explained by an decrease of intensity of organic matter decomposition process and, at the same time, it can be supposed that there occurred an increase in the humic substances structure of phenol and benzenecarboxylic groups containing compounds (Veeken et al. 2000). The value of this index for case No 1 decreased until the 83rd day of the process. During composting, the organic material transformed gradually into structures of highly aromatic degree and high-molecular mass (Lv et al. 2013, Zhang et al. 2015). Such situation was confirmed by the decrease of A4/A6 index for both windrows. During 133 days of composting, A4/A6 index decreased for case No 1 by approximately 22%, and for case No 2 by approximately 26%. Such difference was probably caused by more intense decomposition of the organic matter in case No 2, which had a favorable effect on the process of humification of composted materials (Yuan et al. 2016). The above results indicate that compost with lower straw content may not only get to the intended stability, but may also mature faster.

Comparison of the composting process proceeding in cases No 1 and No 2 was performed based on PCA multidimensional analysis using all the parameters being determined during the tests (Fig. 2÷5). Figures 2 and 3 show subsequent location of grouping variables with relation to F1 and F2 components, as well as the impact of active variables on the above primary components. The analysis was performed based on the correlation matrix. The number of primary components was defined using Kaiser's criterion according to which only factors with their own values exceeding 1 should be retained. According to PCA performed for case No 1, F1 and F2 components explained 47.77% and 28.13% of total variance respectively.

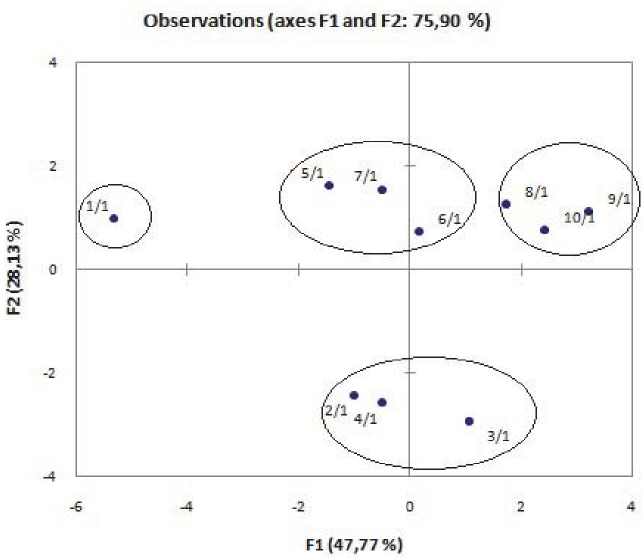

Fig. 2. Observations graph. Projection of case No 1 compost samples onto the space defined by the primary F1 (PI, TOC, hemicellulose, FA, A2/A4 and A4/A6) and F2 (HA, HS, HI) components

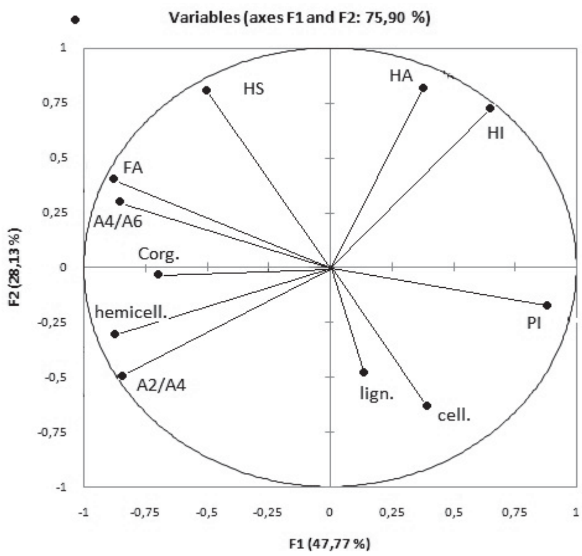

Fig. 3. Variables graph (values of specific parameters and indices). Projection of weights onto the space defined by the primary F1 and F2 components (case No 1)

The greatest impact in creation of F1 factor (r≥0.7) had positively correlated PI variable and oppositely correlated the variables, i.e., TOC, hemicellulose, FA, A2/A4 and A4/A6 (Fig. 3). On the other hand, for F2 factor, the most significant were positively correlated variables HA, HS and HI. The classification based on PCA method using selected chemical parameters and indices of maturity allowed for the determination of four compost groups.

The variables correlated negatively with relation to F1 component (TOC, hemicellulose, FA, A2/A4 and A4/A6) characterize the initial composting phase. Mineralization processes that dominated in this period caused intense decomposition of hemicellulose and stimulated generation of fulvic acids in 2/1 and 4/1 composts (Fig. 2). As described in Table 1, the abbreviations 2/1 and 4/1 denote compost made of a mixture of the components used in the tests in the proportion 4/1/1. The values of physicochemical parameters corresponding to these cases are average values obtained from compost samples taken from windrow No 1 and 3 after 10 and 24 days of composting, respectively. Partial inhibition of the composted matter biodegradation was noted for compost 3/1. This was caused by a momentary decrease of windrow temperature during the thermophilic phase. During further composting (5/1, 7/1) total quantity of humic substances increased. This originated from formation of humic acids structures. This was confirmed also by high values of A4/A6 index. Both humic acids content results as well as HI and PI indices values indicated commencement of the compost maturing phase already at the 48th day (6/1). However, the processes associated with the generation of condensed humid acids structures slowed down. Such situation may indicate too intense course of the maturing process, which led, consequently, to repeated remineralization and upsetting of dynamic balance between various forms of humic substances (Domeizel et al. 2004). From the 83rd day of composting, the process temperature decreased down to 25°C and renewed increase of HI and PI index values indicated intense course of the humification processes in case No 1.

The PCA analysis results for case No 2 (Fig. 4÷5) indicated two main F1 and F2 components, which explained 85.19% of total variability.

The first component explained 64.3%, and those variables that were best correlated with it are FA, cellulose, hemicellulose, TOC, A4/A6, A2/A4, Ha, PI, and HI respectively (Fig. 5). The second component explained 20.89% of variability and was best correlated with HS and lignin. In Figure 4 the analyzed compost samples were divided into four different groups, according to their properties. Composts 1/2 and 2/2, whose mean composts were made of a mixture of sewage sludge, straw, wood chips and innoculum in the proportion of 8/1/2 respectively (Table 1), characterize the beginning of the composting phase during which the intense mineralization of organic matter proceeded. High temperatures noted between the 16th and 48th day of composting, contributed to intense decomposition of hemicellulose and hardly decomposable lignin (3/2, 4/2, 5/2). The result of this process was a fast increase of the generation of humic acids as of the 48th day of composting. From this moment onwards also swift increase of PI and HI maturity indices in subsequent samples (6/2, 7/2, /8/2, 9/2, 10/2) was noted. Such situation leads to a statement that composting process of sewage sludge was more intense in this windrow, in which the quantity of straw with relation to sewage sludge was twice as low.

Also the issue of transformation of heavy metals, the quantity of which increases with increased share of sewage sludge in the composted mass, is important. The issue of transformation of heavy metals compounds during composting, that was documented in numerous research works (Janowska et al. 2017, Robledo-Mahon et al, 2019, Liu et al. 2019), is extremely important in the context of evaluation of the real hazard, particularly in the case of use of the sewage sludge based compost in agriculture. My own research of this matter is continued.

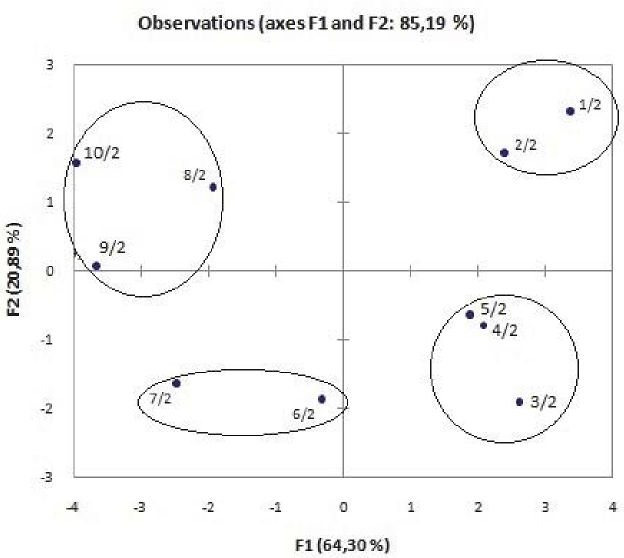

Fig. 4. Observations graph. Projection of case No 2 compost samples onto the space defined by the primary F1 (PI, TOC, hemicellulose, FA, A2/A4 and A4/A6) and F2 (HA, HS, HI) components

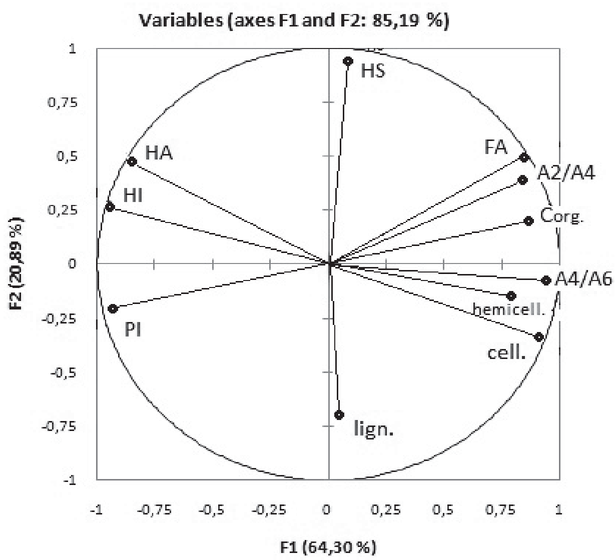

Fig. 5. Variables graph (values of specific parameters and indices). Projection of weights onto the space defined by the primary F1 and F2 components (case No 2)

Conclusions

The quality of compost produced in industrial conditions depends on, among others, a share of structural material such as barley straw. Unfortunately, this material is currently in short supply, therefore, costly. The tests we performed revealed that the reduction of barley straw share in sewage sludge composting process may be, to some extent, favorable for the process. Such situation creates better conditions for the microorganism being a component of sewage sludge. Their occurrence may have favorable impact on decomposition and transformation of organic matter. Reducing barley straw content in the sewage sludge composting process, one can intensify the biodegradation process thus extending the termophilic phase and, at the same time, increasing the degree of humification of the final product. The test results obtained confirmed the possibility of reducing the share of straw in the mixture with sewage sludge prepared for composting. It is planned to continue research towards determining the optimal composition of mixtures of sewage sludge with various components determining the optimal C/N ratio.

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