

CHEMICAL COMPOSITION OF COMPOST FROM MUNICIPAL WASTE IN THE CONTEXT OF USE AS FERTILISER

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Abstract. The study addresses the problem of assessment of the chemical properties of compost produced on the basis of organic fraction of municipal waste, including the quantity and quality of organic matter. Six composts originating from central-eastern Poland were included in the research. The following analyses were performed: pH; salinity; content of C, N, P, K and heavy metals, fractional composition of organic matter (after decalcification, bitumens, fulvic acids, humic acids and post-extraction residue) and properties of humic acids (elemental composition and spectrophotometric properties). The analysed composts were characterised by a similar chemical nature. They were considered to be chemically and biologically silised. They were characterised by a significant potential for soil enrichment in soil humus and biogenic elements. The content of heavy metals in the tested composts did not constitute a barrier to their use as a fertiliser. The contribution of carbon of humic substances (separated by 0.1 M NaOH) ranged from 23.3 to 31.2%. Among humic substances the most humic acids prevailed, with the ratio of humic to fulvic carbon from 2.07 to 3.03. The elemental composition of humic acids of the tested composts was similar to those occurring in humus horizons of intensively used arable soils. Spectrophotometric parameters indicated a low degree of their humification.

Keywords: compost, humic substances, humic acids

INTRODUCTION

The primary cause of deterioration of the fertility of soils and their reduced resistance to degradation is a decrease in the content of soil humus. In the case of soils of arable lands in Poland, the causes of reduced levels of humus include primarily the specialisation of production and the dominant share of plants with a negative organic matter balance in the structure of sowings (mainly cereals grown in monoculture), insufficient organic fertilisation (mainly due to manure deficit) and climate change leading to an intensification of mineralisation of soil organic matter (Gonet and Markiewicz 2007, Becher *et al.* 2013). Also highly important are

the features of most of arable soils in Poland that are not conducive to a high level of humus accumulation. Those include primarily the particle size distribution (low content of clay fraction) and excessive acidification (leaching of alkaline components of low content of carbonates) (Karczewska 2012, Mocek 2015).

To ensure that soil performs possibly the best its production and environmental functions, one should aim at increasing the level of humus. In the context of improvement of the balance of soil organic matter, the importance of the so-called exogenic organic matter – formed outside of the soil environment but having a humus-forming potential – grows (Gonet and Markiewicz 2007, Maly and Siebielec 2015). In Poland, composts produced from the organic fraction of municipal waste are still an underestimated source of soil organic matter. As opposed to a majority of EU countries, such composts are used nearly exclusively in land reclamation and covering of waste dumps (Rosik-Dulewska 2015).

Minimisation of the amount of stored waste is a priority for modern waste management. In Poland, approximately 10.5 million tons of waste are produced per year, with a high (approx. 40%) content of organic substance (Rosik-Dulewska 2015), and a growing interest is noted in composting as a method of recovery of wastes. The organic fraction of wastes is a potentially good material for composting, and the compost produced in the process allows the recovery of organic matter and the utilisation of nutrients in the production of biomass (Kucharczyk *et al.* 2010, Rosik-Dulewska 2015). In the case of the use of compost produced from wastes in food production (in agriculture and horticulture) it is necessary to eliminate threats that could have a negative effect on the natural environment and on the quality of yields. In this context it is very important to conduct research and monitoring of the properties of produced composts. Municipal wastes, and thus also composts produced from them, are characterised by varied chemical composition (including the amount and quality of organic matter and the content of heavy metals) (Drozd *et al.* 2003 and 2009, Ciesielczuk and Kusza 2009, Gondek and Kopeć 2012).

The study presented here addresses the problem of estimation of the properties of compost produced on the base of the organic fraction of municipal waste. The objective of the study was the characterisation of the chemical properties, including the quantity and quality traits of organic matter, of six composts originating from central-eastern Poland.

MATERIAL AND METHOD

The research material consisted of samples collected from mature compost storage sites at selected companies situated in central-eastern Poland, dealing with the collection and utilisation of municipal wastes (Siedlce, Włodawa, Opoczno, Warszawa, Wołomin, Radom). The process of composting was conducted in prisms

in the open air, where the base of the composition of the composted mass were biodegradable municipal wastes (collected selectively and organic fractions from waste sorting facilities).

The following determinations were performed using samples of fresh material:

- measurement of pH value – with the potentiometric method, after sample flooding with 1M KCl (v/v = 1/2.5) (Hanna Instruments, pH 301);
- measurement of salinity – with the conductometric method, after sample flooding with H₂O (v/v = 1/2) (Hanna Instruments, HI 2300);
- dry matter content (after drying at temperature of 105°C).

For the remaining analyses the samples were dried at 40°C, ground in a ceramic mortar, and screened through a sieve (ø 2 mm). For the assay of chemical properties, a part of the dried material was ground in an agate mill (to particle size of < 0.25 mm). The results of analyses of the chemical properties were referenced to absolutely dry matter of the prepared sample (silised after drying at 105°C). The following laboratory analyses were performed (in 3 replicates):

- total content of carbon (TC) and nitrogen (TN) was assayed using a CHNS elemental analyser (Perkin Elmer, Series II 2400);
- content of P, K and heavy metals (Ni, Pb, Cd and Cr) was assayed using an ICP-AES atomic emission spectrometer (Perkin Elmer, Optima 3200 RL). Solutions for the assays were obtained after mineralisation in aqua regia;
- content of carbonates – with the Scheibler method.

Based on the amount of carbonates (mainly CaCO₃), the amount of carbon representing mineral compounds (IC) was determined. The content of carbon in organic compounds (TOC) was calculated as follows: TOC = TC – IC. The content of organic matter (OM) was calculated as: OM = TC · 1.724 (Bednarek *et al.* 2004);

Sequential fractionation of carbon compounds was performed (Dziadowiec and Gonet 1999, Becher 2013). The names and symbols of organic matter fractions and the method of their acquisition are presented in Table 1.

Preparations of humic acids were acquired with the use of alkaline extract (0.1 M NaOH). Gels of humic acids were acquired after acidification (5 M HCl, 24 h), centrifuging and decantation of solution of fulvic acids. The preparation of humic acids preparations was conducted following the Schnitzer procedure (Dziadowiec and Gonet 1999). After drying in a vacuum desiccator (temp. 30°C), the preparations were pulverised in an agate mortar and stored in an exsiccator (over concentrated H₂SO₄).

The following assays were performed for humic acids:

- elemental composition (C, H, N, O). The content C, H and N was assayed using an elemental auto-analyser with thermal conductivity detector (TCD) and acetanilide as standard material. The elemental composition was expressed in ash-free mass. Ash content was 0.97-1.31% (determined by

weighing, after roasting at 550°C). Oxygen content (in %) was calculated as: $O = 100 - (C+H+N)$. On the basis of the content of atoms of the elements, H/C, N/C, O/C and O/H ratios were calculated, as well as the degree of internal oxidation of molecules ($\omega = [(2O + 3N)-H]/C$) (Dębska 2004);

- spectrophotometric properties in VIS range, on a Lambda 25 spectrophotometer (Perkin Elmer), for 0.02% solutions of humic acids (in 0.05 M NaHCO₃) at wavelengths (nm) of: 400 (A400), 465 (A465), 600 (A600) and 665 (A665). The absorbance ratio A4/6 ($A4/6 = A465 / A665$) and the parameter $\Delta\log K$ ($\Delta\log K = \log A400 - \log A600$) were calculated (Chen *et al.* 1977, Kumada 1987).

The arithmetic mean values, minimum and maximum values, standard deviation (SD) and the coefficient of variation (CV) were calculated.

Table 1. Fractions of organic matter and methods of their acquisition

Fraction name and symbol	Method of acquisition
Fraction after decalcification C_{DEC}	Extraction 0.05M H ₂ SO ₄ ; extraction time 24 h; m/V = 1/25; centrifuging (g = 4000 rpm) and straining through cellulose filter. Carbon in solution assayed with oxidation-titration method (Kalembasa 1991)
Fraction of bitumens C_{BIT}	Extraction (ethanol + n-hexane, v/v = 1/1) in automatic solvent extraction apparatus Soxterm (Gerhard). Mass of bitumens determined by weighing. Carbon in preparations assayed in elemental analyser
Fraction of humic substances C_{HS}	Extraction 0.1 M NaOH; extraction time = 24 h; m/V = 1/25; centrifuging (g = 4000 rpm) and training through cellulose filter. Carbon in solution assayed with oxidation-titration method.
Fraction of fulvic acids C_{FA}	Acidification (2.5 M H ₂ SO ₄ , pH = 1,80) of measured part of extract 0.1M NaOH. After precipitation and sedimentation of humic acids (24 h), carbon content in fulvic acids solution was assayed with oxidation-titration method.
Fraction of humic acids C_{HA}	Calculation: $C_{HA} = C_{HS} - C_{FA}$
Residual fraction C_{RES}	Calculation: $C_{RES} = TC - (C_{DEC} + C_{BIT} + C_{HS})$

RESULTS AND DISCUSSION

Basic properties of the composts

The analysed composts were characterised by similar levels of dry matter content (average of 41.6%) (Tab. 2). This is higher than that of most natural fertilisers and waste materials used in fertilisation (spent mushroom substrate, sewage sludge, fermentation residues) (Kalembasa *et al.* 2012, Becher and Pakuła 2014).

Conductometric measurements in water solutions of the analysed composts (0.899-1.20 mS cm⁻¹) suggest low concentrations of soluble components (mainly ions), i.e. their low salinity.

Table 2. Values of descriptive statistics of selected properties of tested composts

Parameter	Unit	Mean	Range	Standard deviation	Coefficient of variation (%)
pHKCl		–	7.20-7.67	–	–
Dry matter	%	41.6	38.1-45.5	2.58	6.11
Salinity	mS cm ⁻¹	1.04	0.899-1.20	0.11	10.4
CaCO ₃	g kg ⁻¹ d.m.	35.4	19.3-41.8	8.31	23.5
TC	g kg ⁻¹ d.m.	168	142-193	23.4	13.9
IC	g kg ⁻¹ d.m.	4.24	2.32-5.02	1.00	23.5

TC – Total carbon; IC – Inorganic carbon

In the analysed composts a significant amount of carbonates was noted, favourable in the context of their fertiliser use, with an average level of 35.4 g kg⁻¹ (Tab. 2). In the case of the arable soils of Poland, apart from the need for humus reproduction, a fundamental task in activities aimed at improving soil fertility is the neutralisation of acidification (Karczewska 2012, Mocek 2015).

The observed high values of pH in 1M KCl (7.20-7.67) allow the analysed materials to be classified as slightly alkaline. Generally, the results of laboratory analyses and the values of standard deviations calculated for the results suggest a similarity among the analysed composts that originated from various sources.

The calculated values of organic matter content, amounting to 240.9-325.5 g kg⁻¹, do not allow to classify all of the analysed composts as organic fertilisers (Tab. 3).

Table 3. Content of organic matter and selected biogenic elements

Compost No.	OM	TOC	TN	P	K	TOC/TN	TOC/P
	g kg ⁻¹ d.m.						
1	303.5	176.1	13.5	2.23	5.65	13.1	79.0
2	240.9	139.8	9.63	3.07	2.40	14.5	45.6
3	325.5	188.8	15.0	2.48	6.77	12.6	76.2
4	247.6	143.6	11.4	2.08	5.37	12.6	68.9
5	252.9	146.7	10.1	1.54	3.76	14.5	95.0
6	322.4	187.0	15.8	2.43	7.10	11.8	77.1
Mean	282.1	163.7	12.6	2.30	5.18	13.2	73.6
Standard deviation	39.3	22.8	2.58	0.50	1.80	1.11	16.2
Coefficient of variation (%)	13.9	13.9	20.6	21.8	34.8	8.40	22.0

In conformance with the quality requirements given in the Regulation of the Minister of Agriculture and Rural Development of 18th June 2008 (J. of Laws No. 119, item 765) to the Act in Fertilisers and Fertilisation (J. of Laws No. 147, item 1033), organic fertilisers should contain a minimum of 30% of organic substance, as converted to dry matter. At the same time, the observed levels of nitrogen, phosphorus and potassium are considerably higher than the limit values for organic fertilisers specified in the abovementioned Regulation (J. of Laws No. 119, item 765).

The content of the analysed biogenic elements in the composts under study was characterised by a fairly high variation – the highest in the case of potassium. The results indicate that the analysed composts should be considered as a significant source of biogenic elements.

The calculated values of C/N ratio (mean of 13.2) and C/P ratio (mean of 73.6) suggest a high degree of transformation of organic substance and stabilisation of the process of its degradation (Tab. 3). Generally, the values of those ratios indicate “maturity” of the analysed composts (Drozd *et al.* 2003 and 2009). In addition, the discussed quantitative ratios of C to N and C to P are similar to those found in the arable horizon of soils under intensive agricultural use and biologically active (Kalembasa and Becher 2009, Becher *et al.* 2013, Mocek 2015). The potential fertiliser use of compost will have no significant effect on a change in the quantitative relations of carbon, nitrogen and potassium in soil. One should, therefore, suppose that there will be no significant shift in the balance of transformations of those elements in the soil environment, in the direction of synthesis or mineralisation (Paul and Clark 1996, Kalembasa and Kalembasa 2015 and 2016). Similar quantitative ratios of carbon to nitrogen and phosphorus are noted in spent mushroom substrate (Kalembasa *et al.* 2012, Becher and Pakuła 2014).

The analysed composts were characterised by a varied content of heavy metals (Tab. 4).

Table 4. Content of heavy metals in the tested composts

Compost No.	Zn	Cu	Pb	Cr	Ni	Cd
	mg kg ⁻¹ d.m.					
1	103.9	16.6	9.20	6.48	3.65	0.071
2	199.1	44.6	15.3	12.3	8.58	0.719
3	67.76	10.8	5.68	4.07	3.53	0.048
4	98.94	17.3	6.68	4.85	3.83	0.063
5	117.8	14.2	10.6	5.00	3.69	0.074
6	153.3	25.0	10.1	6.94	5.23	0.103
Mean	123.5	21.4	9.60	6.60	4.75	0.179
Standard deviation	46.3	12.3	3.39	2.98	1.98	0.265
Coefficient of variation (%)	37.5	57.4	35.3	45.2	41.7	147

The assayed amounts of chromium, cadmium, nickel and lead are notably lower (by more than an order of magnitude) than those allowed by Polish law for fertilisers or plant cultivation augmenting agents that can be used as fertilisers in agriculture – those limit contents are (mg kg^{-1} d.m.): Pb – 140; Cr – 100; Ni – 60; Cd – 5 (J. of Laws No. 119, item 765).

In general, analyzed composts were mainly different in terms of the content of elements associated with their mineral part (ash components), especially the metal content. This is probably the consequence of the diversity of organic materials used for composting in compost production sites.

Research shows that composts produced from municipal wastes can be an important source of microelements in soil. The observed levels of zinc and copper in the analysed composts fall within the quantity range encountered in the literature (Gondek and Filipek-Mazur 2005, Gondek 2006, Sądej and Namiotko 2011, Gondek and Kopeć 2012).

Fractional composition of organic matter

The fractional composition of organic matter of the analysed composts is presented as the contribution of carbon in the identified fractions (Tab. 5). They can be arranged in the following sequence of increasing quantitative importance: $C_{\text{DEC}} < C_{\text{BIT}} < C_{\text{KF}} < C_{\text{KH}} < C_{\text{RES}}$. Among the identified fractions, the greatest variation was characteristic of the fractions after decalcification, bitumens, and that of fulvic acids.

Table 5. Values of descriptive statistics of fractional composition of organic matter of tested composts (% TOC)

Parameter	Mean	Range	Standard deviation	Coefficient of variation (%)
C_{DEC}	1.29	1.01-2.05	0.390	30.2
C_{BIT}	3.45	2.53-4.49	0.790	22.4
C_{HS}	26.7	23.3-31.2	2.74	10.2
C_{FA}	7.59	6.28-10.2	1.38	17.9
C_{HA}	19.1	16.4-20.9	1.78	9.30
C_{RES}	68.6	62.5-72.8	3.73	5.44
$C_{\text{KH}} / C_{\text{KF}}$	2.56	2.07-3.03	0.370	14.4

C_{DEC} – Fraction of carbon after decalcification; C_{BIT} – Carbon of bitumens; C_{HS} – Carbon of humic substances; C_{FA} – Carbon of fulvic acids; C_{HA} – Carbon of humic acids; C_{RES} – Carbon of residual fraction

The fraction separated by 0.05 M H_2SO_4 (C_{DEC}) was characterised by the lowest level of contribution (Tab. 5). It was represented mainly by simple low-molecular organic compounds, free and weakly bound with the mineral components of the analysed material. After fertiliser application, those compounds are the most labile in the soil environment, with a relatively short period of persistence in the

soil (Stevenson 1985, Turski 1988, Dębska 2004). The small content of that fraction can indicate stability of organic compounds present in the analysed composts (Drozd *et al.* 2003 and 2009). Spent mushroom substrate has a considerably higher content of that fraction (Kalembasa *et al.* 2012, Becher and Pakuła 2014).

Organic solvents isolated a small amount (mean of 3.45%) of carbon resources (C_{BIT}) from the analysed composts (Tab. 5). The bitumens fraction (lipid) is a highly diversified group of organic compounds, that include e.g. waxes, tars, resins, fatty acids and their esters, and many other compounds with aliphatic character and a high energy value (Becher and Kalembasa 2006, Neves *et al.* 2009). Generally, the oxygen degradation of organic matter, characteristic for the process of composting, high biological activity and richness in elements with alkaline character (participating in reactions of lipids saponification) are not conducive to the accumulation of lipid substances (Turski 1988, Wiesenberg *et al.* 2004, Becher and Kalembasa 2006, Kalembasa and Becher 2009).

Apart from the processes of mineralisation of organic matter, another characteristic process taking place during composting is the synthesis of humic substances in the process of humification. Conventionally, those substances are isolated through extraction with alkaline solutions. From the analysed composts we isolated (0.1 M NaOH) from 23.3 to 31.2% of carbon representing humic substances (C_{HS}) (Tab. 5). Among those substances, the more stable humic acids (C_{HA}) decidedly dominated over the labile and more reactive fulvic acids (C_{FA}). This was reflected in the value of the ratio of carbon of humic acids to that of fulvic acids (C_{HA}/C_{FA}), varying in the range of 2.07-3.03. The value of that parameter is another trait that can indicate stabilisation of the processes of degradation and an advanced process of humification in the analysed materials. According to numerous researchers (Kalembasa 2000, Veeken *et al.* 2000, Dębska 2004, Dębska *et al.* 2009), with the progress of the process of humification of “fresh” organic substance the importance of the contribution of the fraction of humic acids increases. A distinct domination of humic acids is an important quality feature of humus in arable soils, as it indicates humus stabilisation and a favourable and stable effect on the physical and physicochemical properties of soils (Stevenson 1985, Turski 1988, Becher *et al.* 2013, Mocek 2015).

In the analysed composts, carbon of the residual fraction (C_{RES}) constituted approximately 2/3 of the total resources of organic carbon (Tab. 5). One should suppose that in the analysed materials, apart from the most stable humic substances, a considerable part of that fraction consists of non-humified organic compounds – the most resistant to microbiological degradation (mainly cellulose, hemicellulose, lignins), genetically related to the material used in the compost production. Due to the lack of clay minerals, very stable complexes of humic substances with mineral components are rather rarely encountered in composts (Stevenson 1985, Turski 1988, Mocek 2015).

Properties of humic acids

In the opinion of many authors (Stevenson 1985, Turski 1988, Senesi *et al.* 2003, Szombathová *et al.* 2004, Kalembasa and Becher 2009), humic acids constitute one of the most interesting and researched fractions of humus – they are characterised by relatively stable properties and determine the physical and chemical properties of soils.

In the analysed composts, as demonstrated in the fractional composition of organic matter, humic acids account for about 1/5 of the total resources of organic matter. The elemental composition (% atomic) obtained in the study is similar to that found in humic acids isolated from the arable-humus horizons of soils under intensive agricultural use (Turski 1988, Senesi *et al.* 2003, Szombathová *et al.* 2004, Kalembasa and Becher 2009, Becher *et al.* 2013). Generally, the obtained results of qualitative analyses of humic acids suggest that, irrespective of their origin, they display a similarity of chemical structure, which is particularly indicated by the atomic ratios and the spectrophotometric properties (Tab. 6).

Table 6. Values of descriptive statistics of properties of humic acids isolated from the tested composts

Parameter	Mean	Range	Standard deviation	Coefficient of variation (%)
elemental composition (% atomic)				
C	36.5	35.7-37.3	0.593	1.62
H	39.7	38.6-41.3	1.04	2.62
N	2.80	2.18-3.16	0.358	12.8
O	21.0	19.5-21.6	0.742	3.53
atomic ratios				
H/C	1.09	1.03-1.15	0.045	4.10
N/C	0.077	0.060-0.088	0.010	13.1
O/C	0.576	0.544-0.593	0.018	3.17
O/H	0.529	0.473-0.556	0.030	5.70
degree of internal oxidation of molecules				
ω	0.292	0.202-0.361	0.057	19.6
spectrophotometric parameters				
A4/6	6.56	5.17-7.32	0.737	11.2
$\Delta\log K$	0.811	0.771-0.859	0.034	4.20

ω – Degree of internal oxidation of molecules; A4/6 – Absorbance ratio (A465/A665); $\Delta\log K = \log A_{400} - \log A_{600}$

The obtained values of H/C (1.03-1.15) indicate that the structure of the analysed humic acids corresponds to aromatic systems coupled with an aliphatic chain containing up to 10 atoms of carbon (Visser 1983). H/C values higher than one may

indicate a domination of aliphatic structures, but also suggest a significant contribution of aromatic structures in the molecules of the analysed humic acids (Turski 1988, Amir *et al.* 2010).

For the analysed humic acids positive values of the degree of internal oxidation of molecules (ω) were obtained. That parameter, and the values of the atomic ratios O/C and O/H, suggest that the synthesis of the humic acids took place under conditions of good oxygenation (Veeken *et al.* 2000, Amir *et al.* 2010).

In this study fairly high values of the quotient of absorbance (A4/6) were obtained. They indicate a rather low “maturity” of humic acids, and suggest their low molecular weight and low condensation of aromatic centres (Chen *et al.* 1977, Howarda *et al.* 1988, Senesi *et al.* 2003). In correspondence to the values of A4/6, also the mean value of coefficient $\Delta\log K$ indicates a rather low degree of their humification (Kumada 1987). In accordance with Kumada’s classification proposal (1987), the obtained values of parameter $\Delta\log K$ allow to classify the analysed humic acids at the boundary of type B (medium degree of humification – $\Delta\log K$ in the range of 0.6-0.8) and type R (low degree of humification – $\Delta\log K$ values in the range of 0.8-1.1). Compared to humic acids of arable soils, for the analysed humic acids a similar elemental composition was obtained, as well as values of atomic ratios, and higher values of spectrophotometric parameters (Dębska *et al.* 2009, Kalembasa and Becher 2009, Becher *et al.* 2013).

CONCLUSIONS

1. The analysed composts, produced from municipal wastes, were characterised by a similarity of their chemical nature. The composts should be considered to be chemically and biologically stabilised, and containing organic matter transformed to a notable degree in the process of humification.

2. Humic acids of the analysed composts were considered to be insufficiently mature, i.e. characterised by a low content and low condensation of aromatic centres, a high level of aliphatic structures, low molecular weight and probably weak binding with the mineral fraction of the analysed materials.

3. Heavy metals contained in the analysed composts do not constitute a barrier to fertiliser use and do not pose a threat to the natural environment. The notable content of stable humic substances and low content of labile forms of organic matter, alkaline reaction and presence of carbonates, contribute to the immobilisation of heavy metals in the analysed composts.

4. The analysed composts have a considerable potential for enriching soils in soil humus and biogenic elements. Their use as fertiliser will contribute to a relatively rapid increase and stabilisation of the content of humus in soil.

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WŁAŚCIWOŚCI CHEMICZNE KOMPOSTÓW Z ODPADÓW KOMUNALNYCH W KONTEKŚCIE NAWOZOWEGO WYKORZYSTANIA

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Streszczenie. W pracy naukowej podjęto problem badawczy oceny właściwości chemicznych, w tym ilości i jakości materii organicznej, kompostu produkowanego na bazie frakcji organicznej odpadów komunalnych. Badaniami objęto sześć kompostów pochodzących ze środkowo-wschodniej Polski. Wykonano następujące analizy: odczyn, zasolenie, zawartość węglanów, zawartość C, N, P, K, metali ciężkich, skład frakcyjny materii organicznej (frakcje: po dekalcytacji, bituminów, kwasów fulwowych, kwasów huminowych i poekstrakcyjna pozostałość) oraz właściwości kwasów huminowych (skład elementarny i właściwości spektrofotometryczne). Badane komposty charakteryzowały się podobieństwem natury chemicznej. Uznano je za ustabilizowane chemicznie i biologicznie. Oznaczają się one znacznym potencjałem wzbogacania gleb w próchnicę glebową i pierwiastki biogenne. Metale ciężkie zawarte w badanych kompostach nie stanowiły bariery przy nawozowym wykorzystaniu. Udział węgla substancji humusowych (wydzielonych 0,1 M NaOH) wynosił 23,3-31,2. Wśród substancji humusowych zdecydowanie przeważały bardziej stabilne kwasy huminowe, przy stosunku węgla kwasów huminowych do fulwowych od 2,07 do 3,03. Skład elementarny kwasów huminowych badanych kompostów był zbliżony do występujących w poziomach próchnicznych intensywnie użytkowanych gruntów ornych. Parametry spektrofotometryczne świadczyły o małym stopniu humifikacji kompostów.

Słowa kluczowe: kompost, substancje humusowe, kwasy huminowe