THE FINAL REPORT

on the completion of the research project entitled

"Research on the composting process of dewatered sewage sludge"

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Introduction

According to the data of the GUS (Central Statistical Office) "Environmental Protection 2017" in 2016 there were 3253 municipal sewage treatment plants in Poland. They served nearly 28.3 million inhabitants of Poland which accounted for about 74% of the total population. Highly efficient wastewater treatment systems cause a constantly increasing amount of sewage sludge. In the period between 2005 and 2016 there was a marked increase in generated sludge while in the years 2005-2010 this increase amounted to 46.4% and in 2010-2016 only 7.9%. Compared to 2005, in 2016 the use of sludge in agriculture understood as the cultivation of all agricultural crops placed on the market, including crops intended for the production of feed, increased from 66 to 116 thousand tonnes of dry mass (d.m.).

The change in the method of managing of sewage sludge observed in recent years in the direction of their agricultural use is the result of, inter alia, the existing regulations which since January 1, 2016 prohibit the storage of sewage sludge. In addition, sewage sludge is a rich source of nutrients with high fertilizing potential. The scope of agricultural use of municipal sewage sludge is sanctioned by the Waste Act (Journal of Laws of 2013, item 21), while the rules for their application are set out in the Regulation of the Minister of Environment of February 6, 2015 on municipal sewage sludge (Journal of Laws of 2015 item .257).

Processing sewage sludge using the composting process fundamentally changes the properties of the final product. The resulting compost, after meeting certain requirements can be qualified as an organic fertilizer in accordance with the Regulation of the Minister of Agriculture and Rural Development of 18 June 2008 on the implementation of certain requirements of the Act on fertilizers and fertilization (Journal of Laws of 2008 No. 119, item. 765).

The company as "Wodociągi i Kanalizacja Sp.z.o.o. z Goleniowa" (GWiK) is one of many municipal companies using the method of biological treatment of sewage sludge in aerobic conditions. The composting process takes place in periodically transferred windrows located on a hardened and roofed surface. The technology of compost production involves the use of several components in the right proportion forming a compost mixture. Both sewage sludge and compost samples are periodically inspected for heavy metals and basic physicochemical indicators.

Legal conditions and the market situation related to the supply of components used for the production of compost, as well as the demand for the final product - compost, enforce to undertaking activities related to the optimization of production. In 2017 GWiK as a member of a consortium formed by five partners from Poland and other countries, obtained funds to start research on the composting process in industrial conditions. Project entitled: Sludge Technological Ecological Progress (STEP) - increased the quality and reuse of sewage sludge, obtained funding from the EU Interreg South Baltic program. One of the two planned pilot installations for process testing is the installation for composting located in the sewage treatment plant in Goleniów belonging to GWiK.

1. Scope of research

The main aim the research that was started in early 2018 was to determine the impact of the proportion between the number of components forming a mixture of organic materials on the course of composting process of sewage sludge.

2. Method

To achieving the assumed goal it had been required conducting field and laboratory tests.

2.1. Field research

Two independent stages have been planned during field research. Both stages lasted about 5 months. Each stage consisted of two parallel compost tests (research series) consisting in monitoring the composting process carried out in windrows of approx. 50 m^3 each. In both series of each stage a different proportion between components was used. The basic components were: mechanically dewatered sewage sludge, barley straw, wood chips and mature compost (inoculum). In the compost test no. 1 (series 1) the mass ratio between components forming the compost mixture was respectively: 4:1:(0.5+0.5), as described later in the report as: 4:1:1. In the compost test no. 2 (series 2), the mass ratio between the components was respectively: 8:1:(1+1), as described later in the report as: 8:1:2. In both stages, the proportions in the series were identical.

2.2. Laboratory tests

During field tests, compost samples for laboratory tests were systematically taken from each windrow. In order to obtain a representative sample six samples of compost with a mass of approx. 10 kg from various places of the windrow were collected. Then, after mixing, a sample of approx. 1 kg was discharged. The samples were secured by sealing in a sealed plastic container and stored at -20 ^{0}C. During stage no. I, 20 samples of composts were collected- 10 from each series and 3 samples of components / substrates used to form the composted mixture. In stage no. II, 22 samples of composts were collected- 11 from each series and analogously 3 samples of substrates. In total, 48 samples were targeted for physicochemical analysis. The scope of performed physicochemical analyzes together with research methodology is presented in Table 1a. The number of samples that were taken during the tests, including samples of raw materials and composts, was 1282.

Laboratory tests consisted of qualitative and quantitative analysis of selected parameters forming four groups, including: basic physicochemical indicators, heavy metals, chemical fractions of heavy metals and humic compounds. The type of indicators that were analyzed corresponds to the requirements set out in national regulations regulating the principles of agricultural use of compost produced on the basis of municipal sewage sludge, having the status of organic fertilizer or plant conditioner. The national and EU regulations regarding the rules of direct use of sewage sludge on agricultural land were also taken into account.

Table 1a. The scope of physicochemical tests

parameters	scope of analysis	method	number of samples						
			raw materials			compost			
						stage no. I		stage no. II	
			sludge	barley straw	chips	no.1	no.2	no.1	no.2
physical and chemical	dry mass (d.m.)	PN-R-04006	4	4	4	10	10	11	11
	organic matter (o.m.)	PN-Z-15011-3	4	4	4	10	10	11	11
	C org.	PN-Z-15011-1,3	4	4	4	10	10	11	11
	N tot.	PN-R-04006	4	4	4	10	10	11	11
	P tot.	PN-Z-15011-3	4	4	4	10	10	11	11
heavy metals	Cr	(AAS)	4	-	-	10	10	11	11
	Cd		4	-	-	10	10	11	11
	Ni		4	-	-	10	10	11	11
	Pb		4	-	-	10	10	11	11
	Hg		4	-	-	10	10	11	11
speciation analysis	Zn- fr.I	according with Tessier's method	4	-	-	10	10	11	11
	Zn- fr.II		4	-	-	10	10	11	11
	Zn- fr.III		4	-	-	10	10	11	11
	Zn- fr.IV		4	-	-	10	10	11	11
	Zn- fr.V		4	-	-	10	10	11	11
	Cu- fr.I		4	-	-	10	10	11	11
	Cu- fr.II		4	-	-	10	10	11	11
	Cu- fr.III		4	-	-	10	10	11	11
	Cu- fr.IV		4	-	-	10	10	11	11
	Cu- fr.V		4	-	-	10	10	11	11
	Ni- fr.I		4	-	-	10	10	11	11
	Ni- fr.II		4	-	-	10	10	11	11
	Ni- fr.III		4	-	-	10	10	11	11
	Ni- fr.IV		4	-	-	10	10	11	11
	Ni- fr.V		4	-	-	10	10	11	11
humic substance	FA	according with IHSS method	4	-	-	10	10	11	11
	HA		4	-	-	10	10	11	11
sum			108	20	20	270	270	297	297
total			1282						

3. Results

The results of the research are presented in the tables in annex no. 1 at the end of the report. Tables numbered from 1.1 to 17.1 show the results of laboratory tests obtained during stage no. I., while tables 18.2÷28.2 show the results of laboratory tests obtained during stage no. II. The results of statistical analysis of data obtained in both research stages in the form of diagrams are shown in figures 1÷36 also included in annex no. 1. Annex no. 2 presents the printouts from carbon and nitrogen determinations in raw materials and compost samples obtained during the elemental analysis using the varioMAX CN device.

3.1. Physical and chemical indicators

A series no.1 in both stages, as well as a series no. 2, were characterized by the same ratio between the raw materials used to prepare the batch. It can therefore be concluded that the second stage of the research was a repetition of the first stage. Both stages distinguished the time in which they were carried out. A stage no. I lasted from May to September 2018 and a stage no. II from October 2018 to March 2019 (Table 1.1 and 18.2). Thus, the weather factor could have a significant impact on the course of the composting process in both stages.

As a main component sewage sludge has been mixed with various raw materials. The prepared mixture was an butch to the composting. In both stages, the values of the organic matter in the sewage sludge were high and amounted to 81.4% d.m. in stage no. 1 and 78.2% d.m. in stage no. II. The share of organic carbon in sewage sludge expressed in % d.m. amounted to 33.9 and 40.4 respectively, combined with a high concentration of total nitrogen i.e. 7.48 and 7.54% d.m. in two subsequent stages, gave a low C/N ratio equal to 5. Addition of barley straw, as a source of bioavailable organic carbon, in which the nitrogen content was extremely low (about 0.7% d.m.) caused a significant increase in the C/N ratio in the input batch material.

Using different mass proportions of the same components (series no.1 and 2) i.e. non-stabilized mechanically dewatered sewage sludge, wood chips and mature compost in stage no. I in both series, at the beginning of the compost tests (c.a. second day) it was found same value C/N≈10 (tab.1.1 and 2.1).

The balance of the batch which was made taking into account the number of individual components consisting in the calculation of the weighted average C and N content, showed that the C/N ratio in the batch used in the first series should be 11.5 and in the second series - 8.5 (Fig. 4). Similarly, in the second stage the calculated C/N value in the series no.1- 12 and in the series no. 2- 10.5 (Figure 20). In stage no. II, at the beginning of series no. 1 the C/N value was 19 (Table 18.2) and in the 2nd series only 9 (Table 18.2). Despite the same proportion of raw materials in the first series of stage no. I and first series of stage no. II, the C/N values found at the beginning of the compost tests were clearly differed. The reason for the differences discussed was the high heterogeneity of compost which decreased over time as a result of multiple mixing. The compost samples collected for analysis in the first period of the composting test could be distinguished by a higher concentration of the given batch component and consequently, influence the values of the physicochemical parameters determined. For example, the higher proportion of straw in the sample resulted in a reduction of the nitrogen content per d.m. and as a result an increase in C/N values.

In all four conducted compost tests, there were changes in the concentration of organic carbon and nitrogen as expected (Figures 3 and 19). The process of mineralization of the organic substance caused a constant loss of total organic carbon. At the same time the nitrogen content in the first phase of composting decreased and then gradually increased. The initial drop in nitrogen concentration was related to the release of NH_4^+ ions and the emission of ammonia in the gas form (NH_3) which could increase odor nuisance. The slow increase in nitrogen concentration in the compost during the maturity phase should be considered favorable due to the fertilizer values of this element.

3.2. Heavy metals

The content of heavy metals in sewage sludge clearly determines the possibility of their agricultural application. In this respect, depending on the degree of processing of the sewage sludge, separate regulations may be applied. Other limit values for heavy metals concentration are set out in the regulations on the use of stabilized sludge[3] or non-stabilized sludge[2] after meeting the requirements for their application to the ground and others in the case of compost produced on the basis of sewage sludge[1].

When assessing the results of laboratory analyzes concerning the content of heavy metals in sewage sludge and compost samples in both test stages, it should be stated that in no case exceeded the limit values set out in separate regulations[1,2,3] (table 1b).

In general, concentrations of heavy metals during composting in stage no.I (Fig. 5÷8) and stage no. II (Fig.21÷24) grew. The observed increases were related to the successive loss of organic matter content causing a drop in dry matter. In an environment similar to neutral (pH≈7) heavy metals practically do not form soluble compounds. The total content of heavy metals does not change significantly but in terms of the dry mass the concentration increases. The phenomenon of concentration growth of heavy metals during composting confirm the values of Pearson correlation coefficients defining the level of linear dependence (Table 1c). Visualization of selected interdependencies between the change in Cu and Ni content and o.m. in compost during stage no. I in series no.1. shown in Figures 33 and 34.

Table. 1b. List of values of selected indicators by different sources [1,2,3]

No.	indicators	regulations			research					
					sewage sludge		matured compost			
		national[1]	national[2]	EU[3]	stage no.I	stage no.II	stage no. I		stage no. II	
							series no. 1	series no. 2	series no. 1	series no. 2
1.	Cd, mg/kg d.m.	5	20	20-40	0,5	0,5	1,25	0,50	0	0,75
2.	Cu, mg/kg d.m.	nl.	1000	1000-1750	225,3	252,3	201,25	253,50	184,75	220,0
3.	Ni, mg/kg d.m.	60	300	300-400	10,5	11,75	17,00	22,00	19,75	14,50
4.	Pb, mg/kg d.m.	140	750	750-1200	48,5	8,475	32,25	41,25	12,75	9,75
5.	Zn, mg/kg d.m.	nl.	2500	2500-4000	551,8	497,3	453,5	555,0	312,25	459,5
6.	Hg, mg/kg d.m.	2	16	16-25	0,55	0,46	0,371	0,548	0,423	0,413
7.	Cr, mg/kg d.m.	100	500	nl.	26,3	27,0	47,75	58,75	63,75	46,50
8.	N og., % d.m.	0,3	nl.	nl.	7,48	7,54	3,19	3,72	3,8	3,54
9.	P og., % d.m.	0,2	nl.	nl.	2,33	2,85	2,23	3,0	1,47	2,53
10.	K, % d.m.	0,2	nl.	nl.	nl.	nl.	nl.	nl.	nl.	nl.
11.	O.M., % d.m.	30	nl.	nl.	81,4	78,2	74,7	69,1	74,0	70,1

nl.: no limited

Table 1c. Values of correlation coefficients- r, between o.m. and heavy metals

No.	elements	organic matter			
		stage no. I		stage no. II	
		series no. 1	series no. 2	series no. 1	series no. 2
1	Zn	-0,31	-0,93	-0,85	-0,94
2	Cu	-0,34	-0,94	-0,97	-0,96
3	Cr	-0,18	-0,22	-0,26	0,10
4	Cd	-0,09	-0,71	-0,16	-0,26
5	Pb	-0,04	-0,67	-0,84	-0,87
6	Ni	-0,14	-0,28	-0,25	-0,07
7	Hg	0,39	-0,62	-0,94	-0,75

Actually each calculated value of the correlation coefficient describing the correlation between the elements and the organic matter shows a negative value, which means that along with the loss of o.m. concentration of heavy metals increases. The power of interdependence between variables is confirmed by the absolute value of the Pearson coefficient which in the case of $r \geq |0,7|$ means very strong correlation. The results listed in Table 1c are the result of calculations without any interference in the data structure. Removing outliers or replacing them with average values can fundamentally change the strength of the observed relationship. An example is the removal of one case from a database during the creation of a linear regression equation describing the correlation between the change in the content of lead and o.m. in stage no. I during series no. 1. Figures 35 and 36 illustrate the waveforms of the regression line using all the data respectively and after removing one case i.e.: I/1/3- Tab.3.1. The carried out modification caused a drop in the value of the correlation coefficient from $r = -0.04$ to $r = -0.51$.

The investigation results showed that heavy metal contents in the mature compost are below the limit values set for organic fertilizers[1]. However, It should be noted that in the case of nickel in all series of both stages, the concentration values were relatively high and reached levels of 28, 27, 33 and 24% of the limit value respectively. High concentrations were also found for zinc and copper. Although current regulations do not regulate the content of these elements in organic fertilizer, their high concentration in sewage sludge like nickel, may raise concerns. For this reason, research was carried out on the presence of all three elements in the form of various chemical forms characterized by different properties significantly affecting their bioavailability.

3.2.1. Speciation analysis

Speciation analysis allows to mark the chemical forms of a given element in the same sample of compost. The content of heavy metals that have been bounded in the form of various compounds is the result of the natural balance being established depending on environmental conditions. The partial objective of this analysis was to estimate the risk associated with the presence of mobile forms of heavy metals i.e.: nickel, copper and zinc constituting real threats to the environment. It is believed that the binding of heavy metals in the solid phase during the composting process e.g. in the structure of humic compounds and clay minerals, is extremely strong compared to other chemical forms. Thus, the risk of release of heavy metals to the soil medium and their bioaccumulation in crops is reduced.

Separation (fractionation) of heavy metal to different chemical groups characterized by specific properties was carried out in accordance with the Tessier method. According to this method, five groups are identified i.e.: exchangeable metals (fraction I), metals associated with carbonates (fraction II), metals associated with hydrated iron and manganese oxides (fraction III), metals bound to organic matter (fraction IV) and metals associated with silicates (fraction V). Fractions I and II are treated as unstable. It mean that heavy metals connected with these fractions can be released to the environment. However, in fractions IV and V metals are permanently connected.

Results of the speciation analysis of the compost samples collected in stage no. I (Table 4.1÷9.1 and 11.1÷16.1) and in stage no. II (tables 21.2÷ 23.2 and 25.2÷27.2) showed that during the composting large changes occur as to the allocation of Ni, Zn and Cu in all fractions. Lines of trend depicting the directions of transformation of chemical forms of the elements determined during composting, in both stages (Fig. 9÷14 and 25÷30), generally show that the share of metals in the fractions I and II decreases and increases in fractions IV and V. Average nickel content in fraction IV and V in the mature compost obtained in each series accounted for over 97% of the total content. This means that the risk of toxic effects of nickel in the case of agricultural use of compost is practically non-existent. A similar trend was found in the case of copper. Zinc accumulated to a lesser extent in fraction IV and V where the average percentage observed was c.a. 50%.

3.3. Humic compounds

The quality of organic fertilizer is determined by the content of biogenic compounds mainly in the form of nitrogen and phosphorus and the presence of humic substances. The transformation of organic matter in the composting phase leads to the formation of macromolecular compounds with the character of organic polymers. This process is called humification and the resulting substance with an extremely complex molecular structure is called humium. The precursor of humic compounds are mainly lignin, cellulose and hemicellulose. From these ones various products are formed i.a. amino acids and phenol. Phenol constituting a basic component of formed humic acids as a result of complex enzymatic reactions. In the initial phase of transformation of organic matter during the humification process, fulvic acids (FA) predominate which over time transform themselves into humic acids (HA). Change in organic carbon forms occurring in the form of so-called nonspecific and specific humic compounds during composting is the basis for determining indices that allow to evaluate the progress of the humification process defined as HA/FA and HA/Corg. The first index is described by the ratio of the carbon of humic acids to carbon of fulvic acids and this is expressed by the abbreviation PI (Polymerisation Index). The second index represents the percentage of carbon of humic acids in relation to the total organic carbon and is referred to as HI (Humification Index).

During the composting, large changes in the content of humic substance were observed. In a windrow (series no.1) of the first stage the approx. 60% decrease in the FA content of the up to the value of this parameter from the beginning of composting was found. In series no.2 this decline was more pronounced and amounted to nearly 50% (Table 17.1). At the same time, an increase in the HA content in both windrows was found. In the case of series no.2 the increase was around 13%. The conversion of fulvic acids into humic acids is one of the determinants of the progress of the humification process. Humic acids could be additionally generated from other humus substances available in the compost. A similar tendency was observed in the series no.2 of second stage where the concentration of KF dropped by 48% and KH increased by 3% (Table 28.2). However, in the series no.1 the changes in HA and FA content deviated from the expected .

PI and HI coefficients are commonly used to describe the transformation of humic substance during composting. The values of both humification indices, in the tested windrows during stage no. I, grew but not uniformly. In the first series, the PI index increased by nearly 66% and in the second series by 228%. The average initial values of the discussed index were similar for both windrows and amounted to 2.13 and 2.38 respectively. These data indicate that in the initial phase of composting low molecular weight fractions of fulvic acids dominated in both heaps. In the 2nd series of the second stage, the increase in the PI index value amounted to 213%. Assuming that the value of the PI index in the range of 3.6÷6.2 is characterized by mature compost. The moment in which the compost produced during research reached maturity corresponds to about 70 days for the 1st series and about 40 days for the 2nd series of. stage no. I. At the same time, the humification process during the series no. 2 was proceeding more stable as evidenced by the dynamics of changes in the PI index value. Therefore, it can be concluded that the duration of the thermophilic phase, which was much longer in the series no. 2, has a significant influence on the speed of the humification process. Similar conclusion regarding changes in the PI index during the two series in stage no. II. is not so unambiguous. Generated linear regression lines describing changes in the PI index value in stage no. II. (Fig. 32) compared to stage no. I. (Fig. 16), indicate small changes in this parameter over time. At the same time, a large spread of results is visible resulting in a low value of the determination coefficient expressing the quality of the fit of the model to the actual data.

4. Summary

The aim of the conducted research was to determine the influence of the proportions between individual components which after mixing created the starting material (the batch) for the composting process. Practically, a component that modified the C/N ratio in the batch and decided to meet the basic criterion conditioning the correct course of composting was a straw. Because straw is hard to access material research in the context of reducing the share of straw in the batch which determines the correct course of composting should be considered as necessary and expected by companies using this technology for municipal sewage sludge management.

The research has shown that the sludge composting process is correct even at the initial C/N≈ 10 ratio, which is significantly lower than the recommended value, i.e. 15÷ 25. Comparing the results of the four compost tests carried out (series) it turned out that the higher the amount of sludge in relation to the straw in the batch causes the higher temperature inside the compost windrow and the longer duration of the thermophilic phase. As a consequence, more favorable changes occurred as to the transformation of chemical forms of heavy metals and organic carbon forms. The indicators used to assess composting during the process of humification of organic matter confirmed the usefulness of the PI index expressing the ratio between the types of humic acids. Growing over time, PI index reach the values qualifying compost as mature although assessing changes in temperature inside the heap, not necessarily stable. It seems that the possible qualification of the degree of maturity should take into account the value of temperature monitored during composting or the results of the self-heating test of compost in a Dewar vessel.

It should be noted that the content of humic substance in the applied sewage sludge is extremely high. In the case of the HI index determining the share of humic compounds in the whole mass of organic compounds it causes high values far exceeding the criterion values given in the scientific literature already at the beginning of composting. Therefore, the use of HI index to assess the maturity of the composts tested is unjustified.

These studies did not provide for parasitological tests, however, the conditions of higher temperature, as well as longer time of its maintenance favorably affect the sterilization of compost. Used in the sewage treatment plant in Goleniów, the composting technology does not take into account aeration through the use of fans. Therefore, it was not possible to monitor the content of odorogenic gases, separated during composting, directly in the post-process air.

5. Conclusions

Analysis of the obtained research results allows to formulate the following final conclusions:

1. The mass ratio between raw materials, forming a batch for the composting process, in the form of: dehydrated sewage sludge and barley straw, constituting the basic (balanced) source of organic carbon and nitrogen, structural material and inoculum in the form of wood chips and mature compost, amounting to 8/1/1/1 guaranteeing the value of the $C/N \approx 10$, enables the right course of the composting process.
2. There was no inhibitory effect of increased concentration of total nitrogen in the compost associated with high concentrations of this element in sewage sludge (7.48% and 7.54% d.m. in both stages) on the course of the composting process through the interaction of toxic nitrogen species e.g. in the form of ammonia, which is formed as a result of decay of protein substances which indicates the proper oxygenation of the prism thus preventing the formation of anaerobic conditions.
3. The content of heavy metals in sewage sludge did not exceed the limit values allowing for their agricultural use and thus it is possible to use sludge for processing in the biological process under aerobic conditions for the production of certified compost as organic fertilizer in accordance with the requirements of the Act on fertilizers and fertilization.
4. The results of the speciation analysis related to the determination of heavy metal concentrations i.e.: Zn, Cu and Ni in sequentially separated chemical forms isolated from compost samples, characterized by different levels of bioavailability, showed that composting time has a favorable influence to the allocation of heavy metals by systematic increasing the share of heavy metals bound in stable fractions at the expense of fractions which reliably release elements attached to them.
5. The humification process evaluated on the basis of changes in fulvic acid concentrations transformed into more complex chemical structures including humic acids considered the final effect of these transformations, had a significant impact on

the formation of mature compost with a high concentration of humic compounds giving characteristic organoleptic properties i.e. color, aroma and crumbly structure.

6. A reliable indicator describing the effectiveness of the humification process occurring during composting of sewage sludge is the PI index whose value above 3.6 can be considered proper for mature compost provided that the temperature inside the compost windrow within a few days after the last transfer does not rise above the ambient temperature.

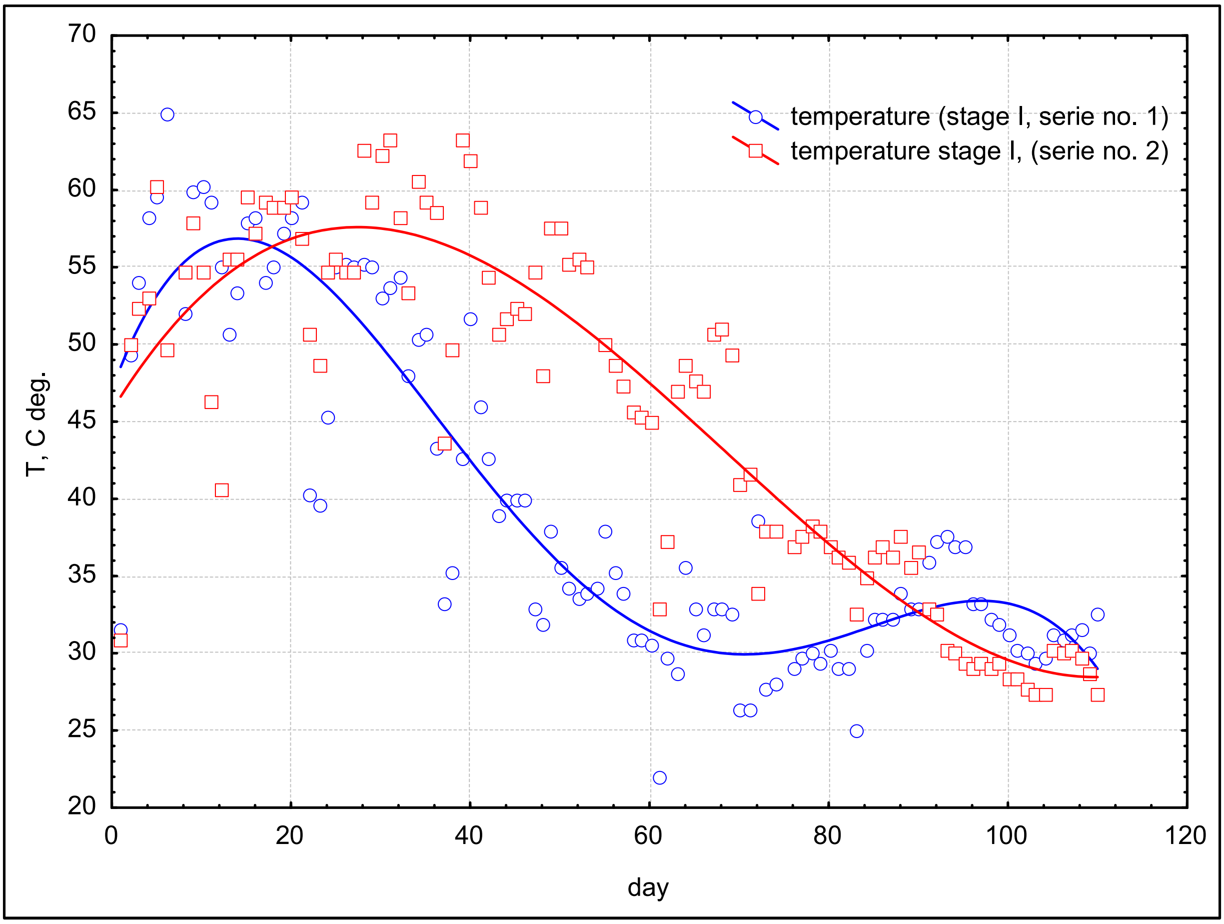

Fig. 1. Temperature changes in both compost samples, stage no.I.

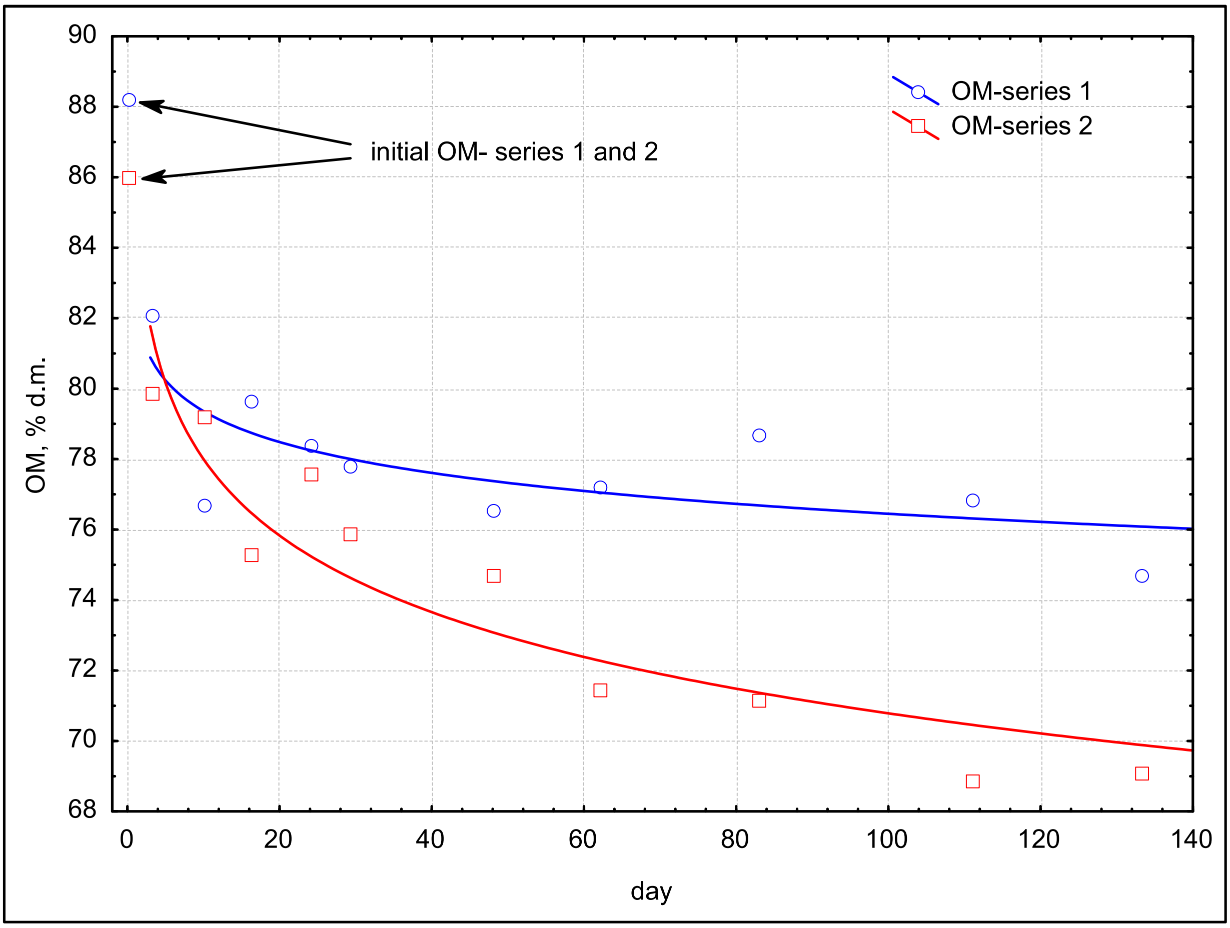

Fig. 2. Changes in the content of organic matter during composting, stage no.I.

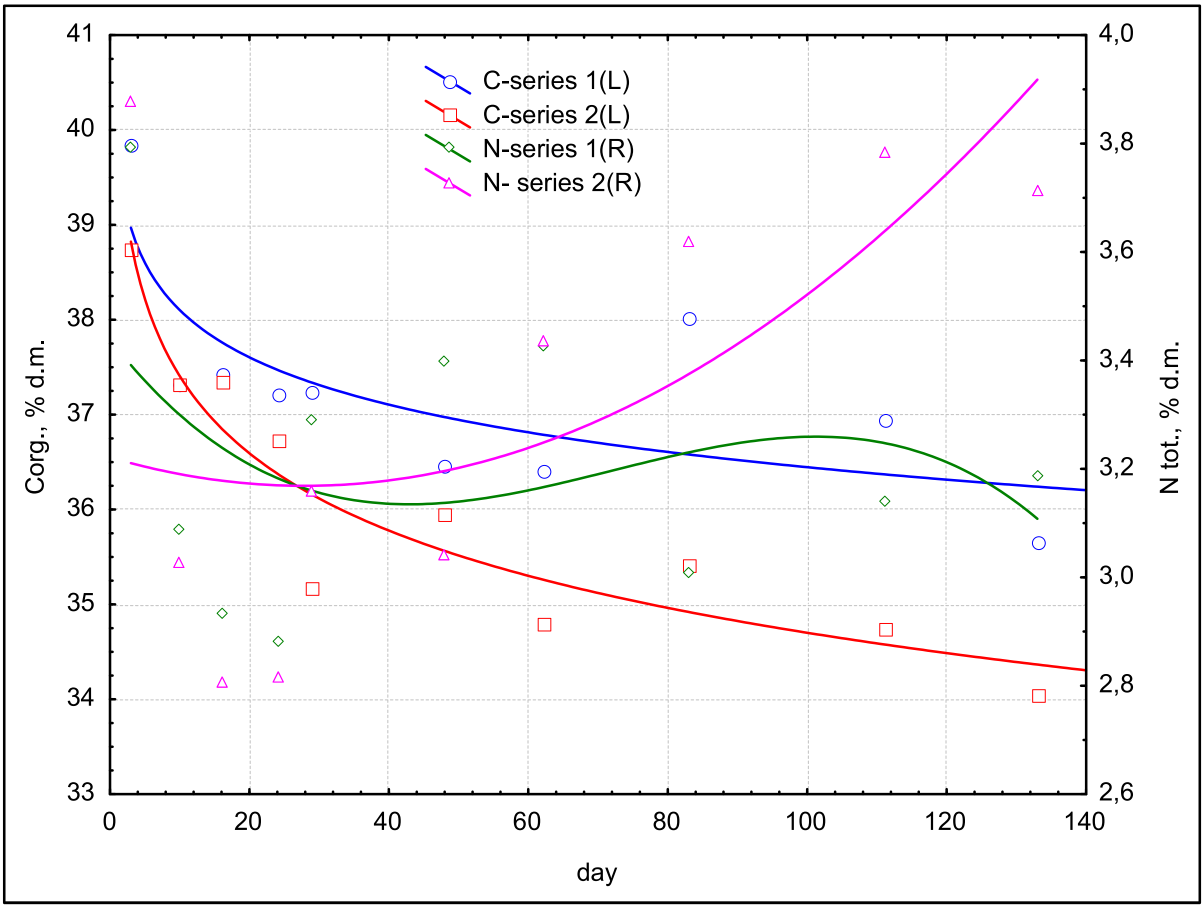

Fig.3. Changes in the concentration of organic carbon and total nitrogen during composting, stage no.I

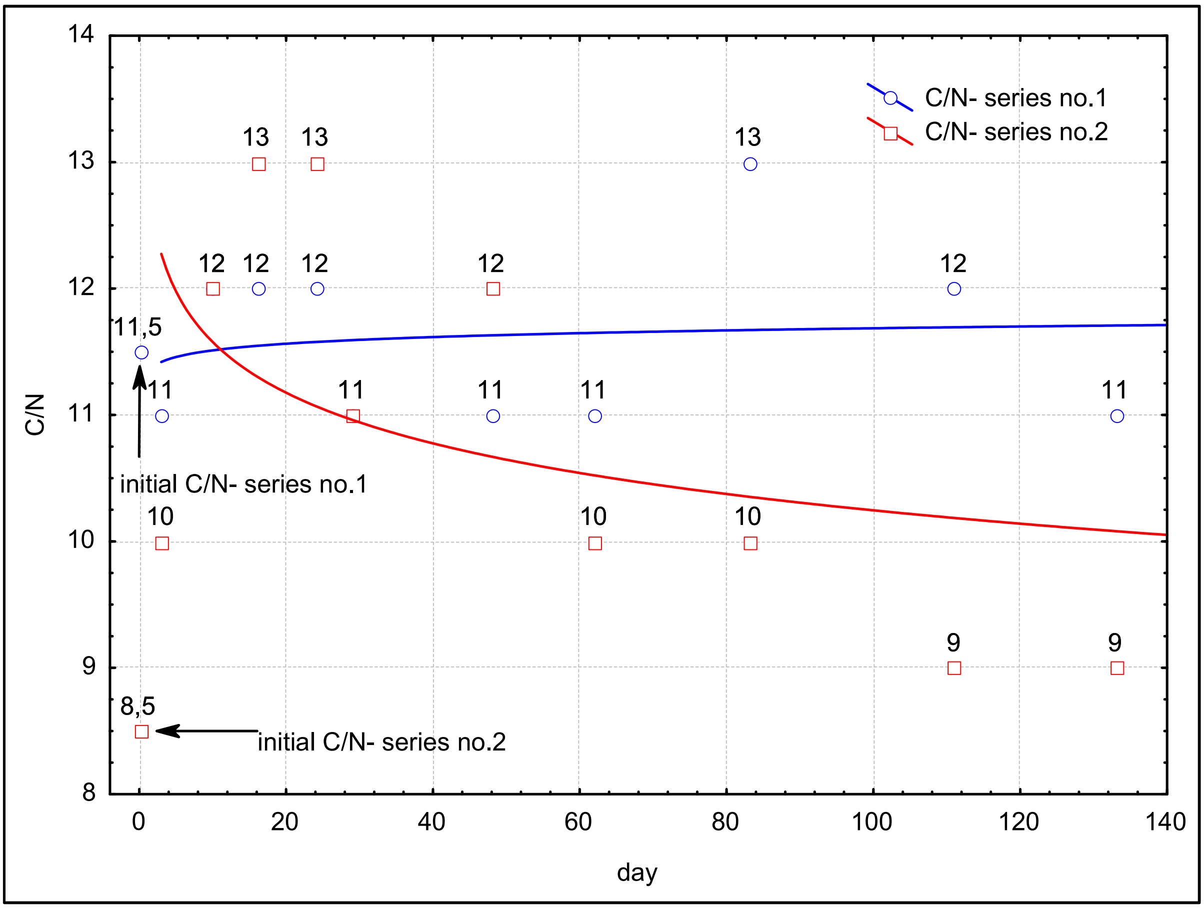

Fig. 4. Changes in the C/N ratio in compost, stage no.I.

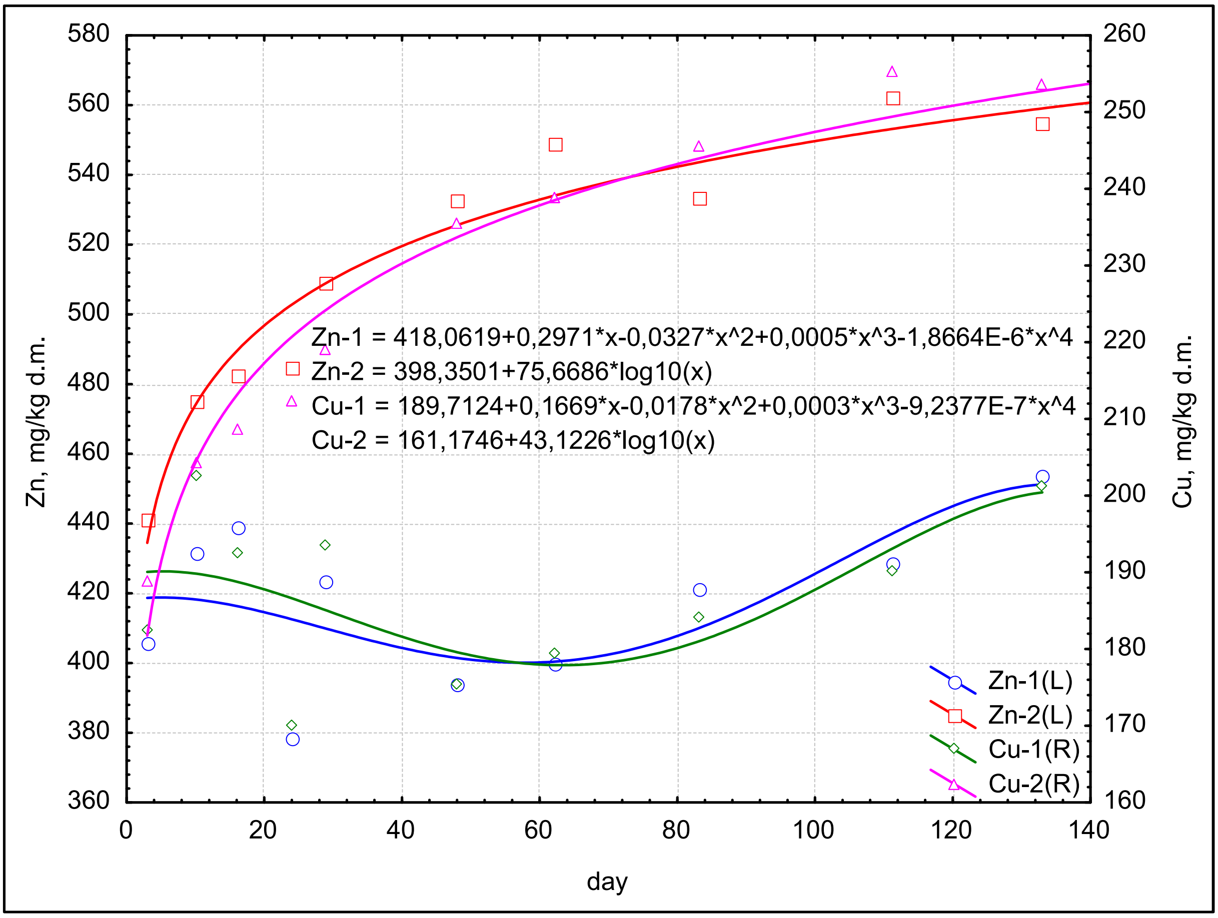

Fig. 5. Changes in concentration of zinc and copper in compost, stage no.I.

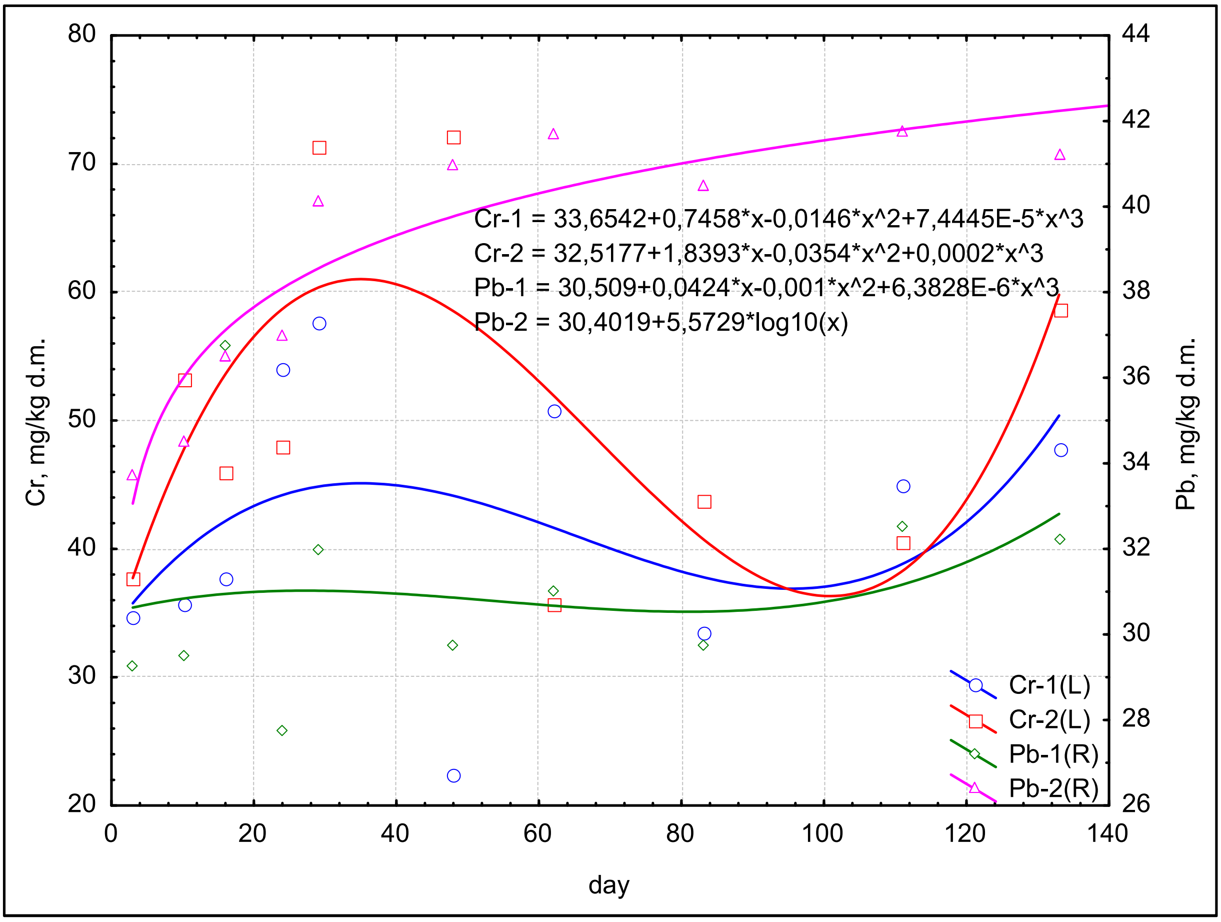

Fig. 6. Changes in concentration of lead and chromium in compost, stage no.I.

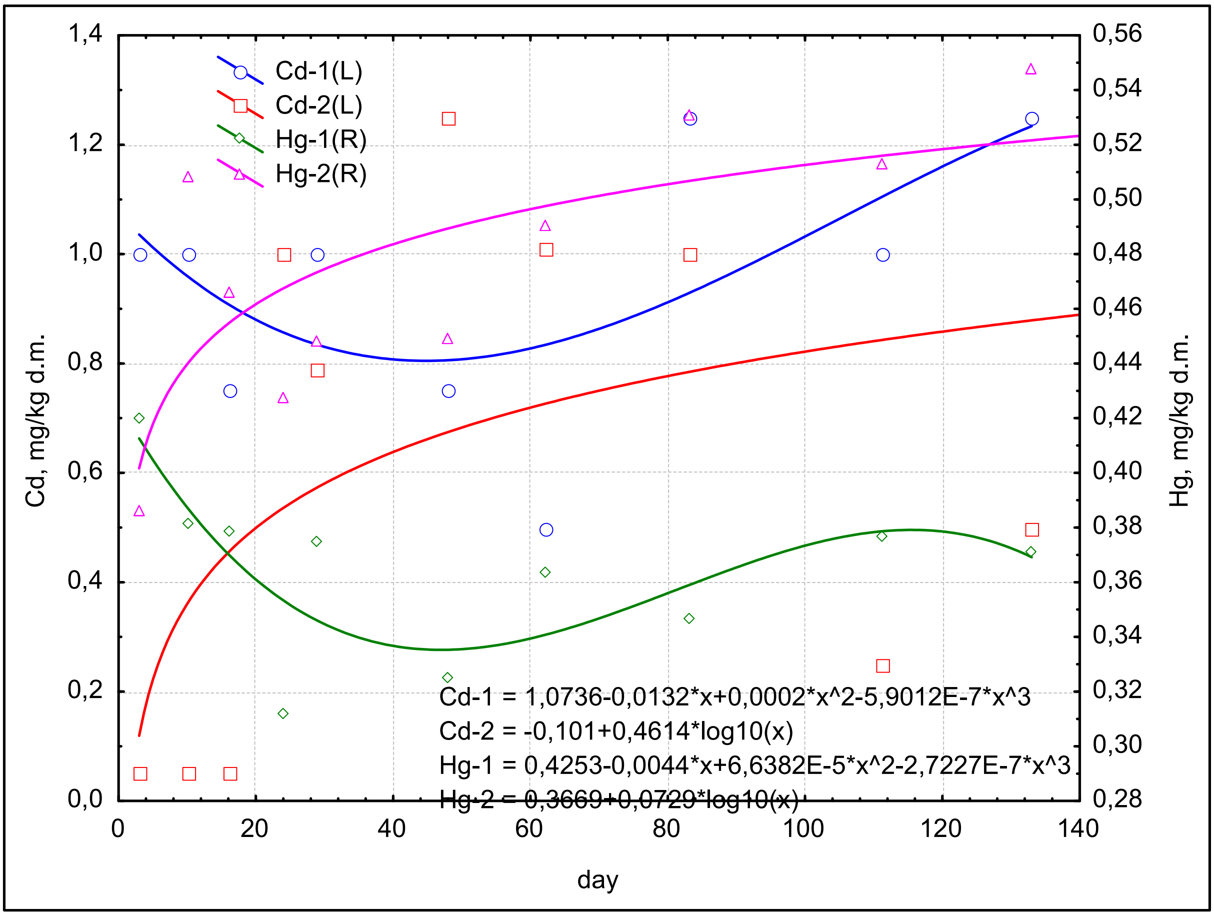

Fig. 7. Changes in the concentration of cadmium and mercury in compost, stage no.I.

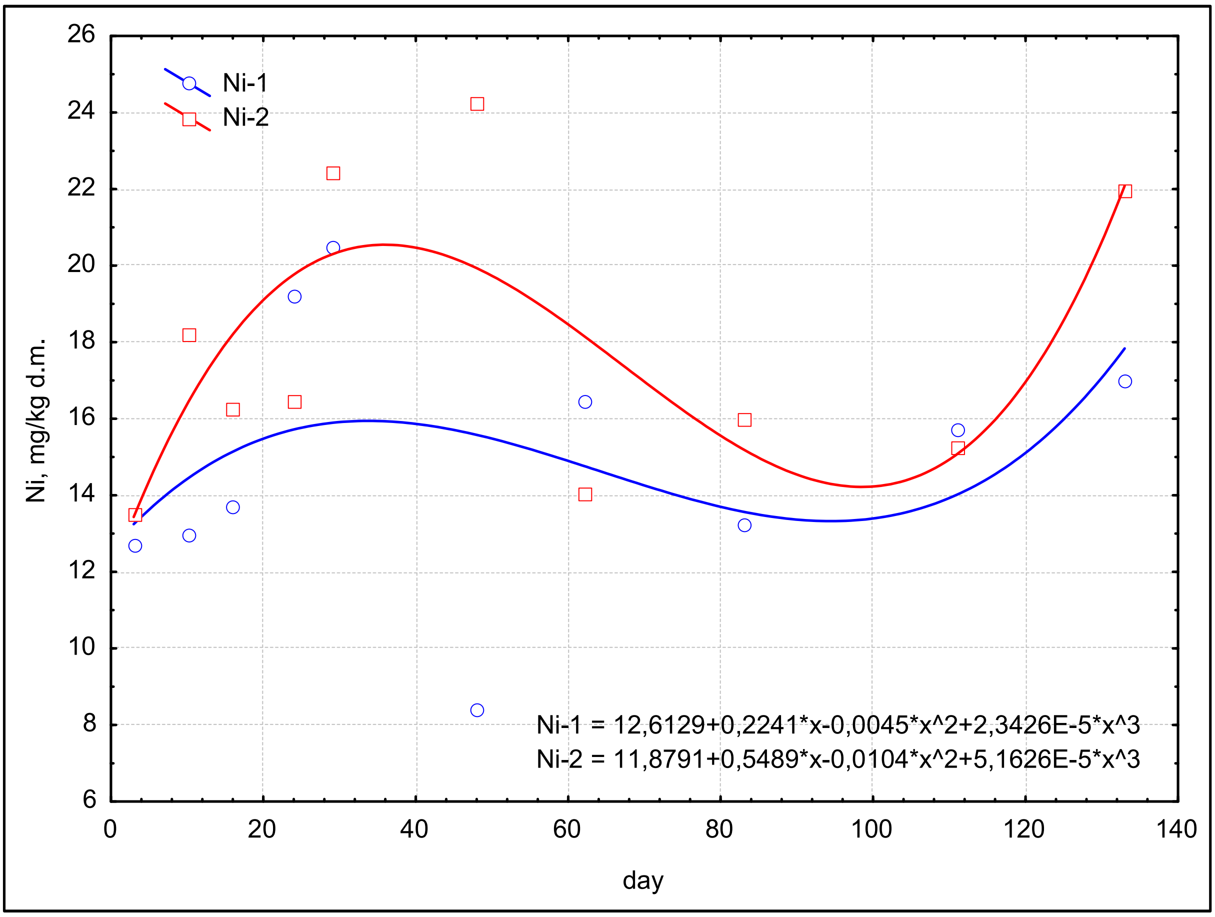

Fig. 8. Changes in nickel concentration in compost, stage no.I.

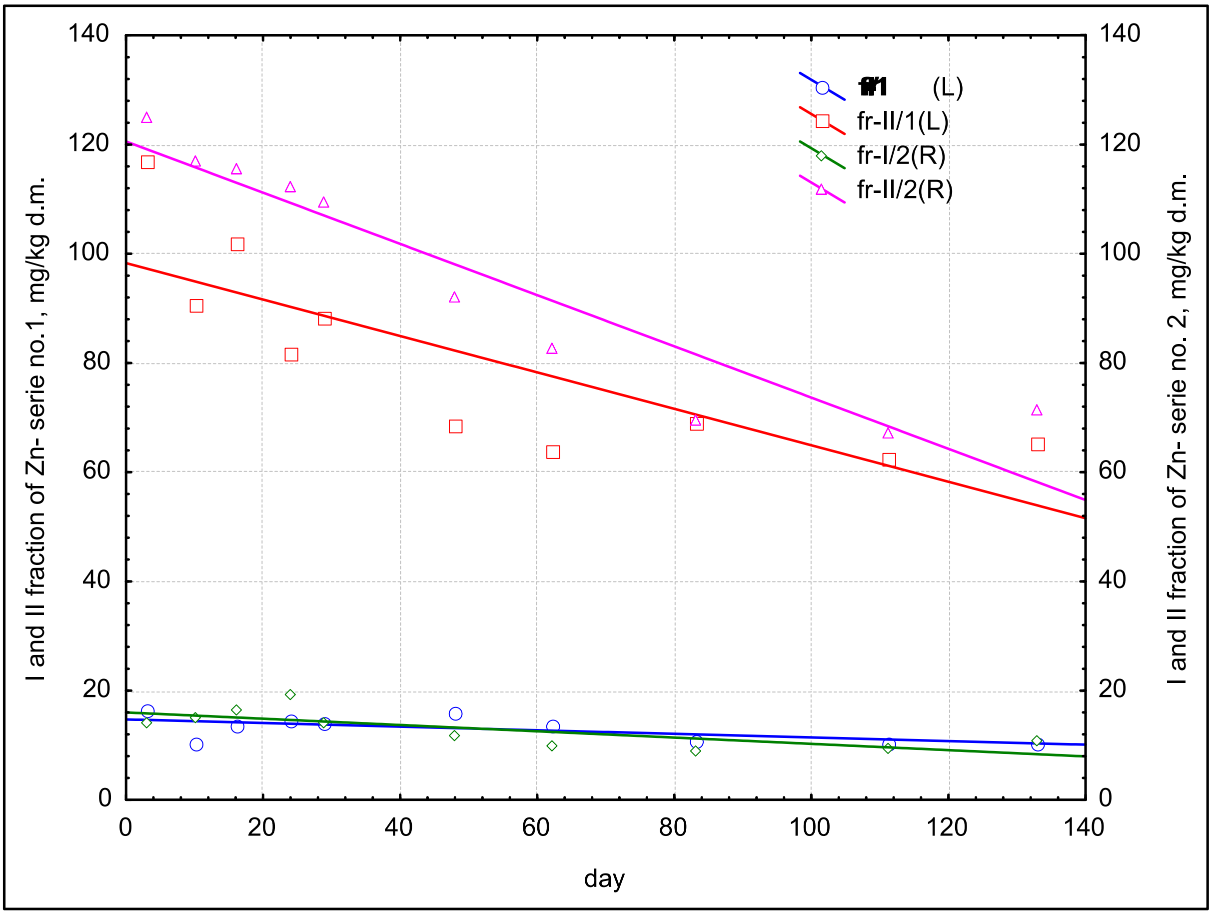

Fig. 9. Changes in the content of extracted fractions I and II of zinc, stage no.I.

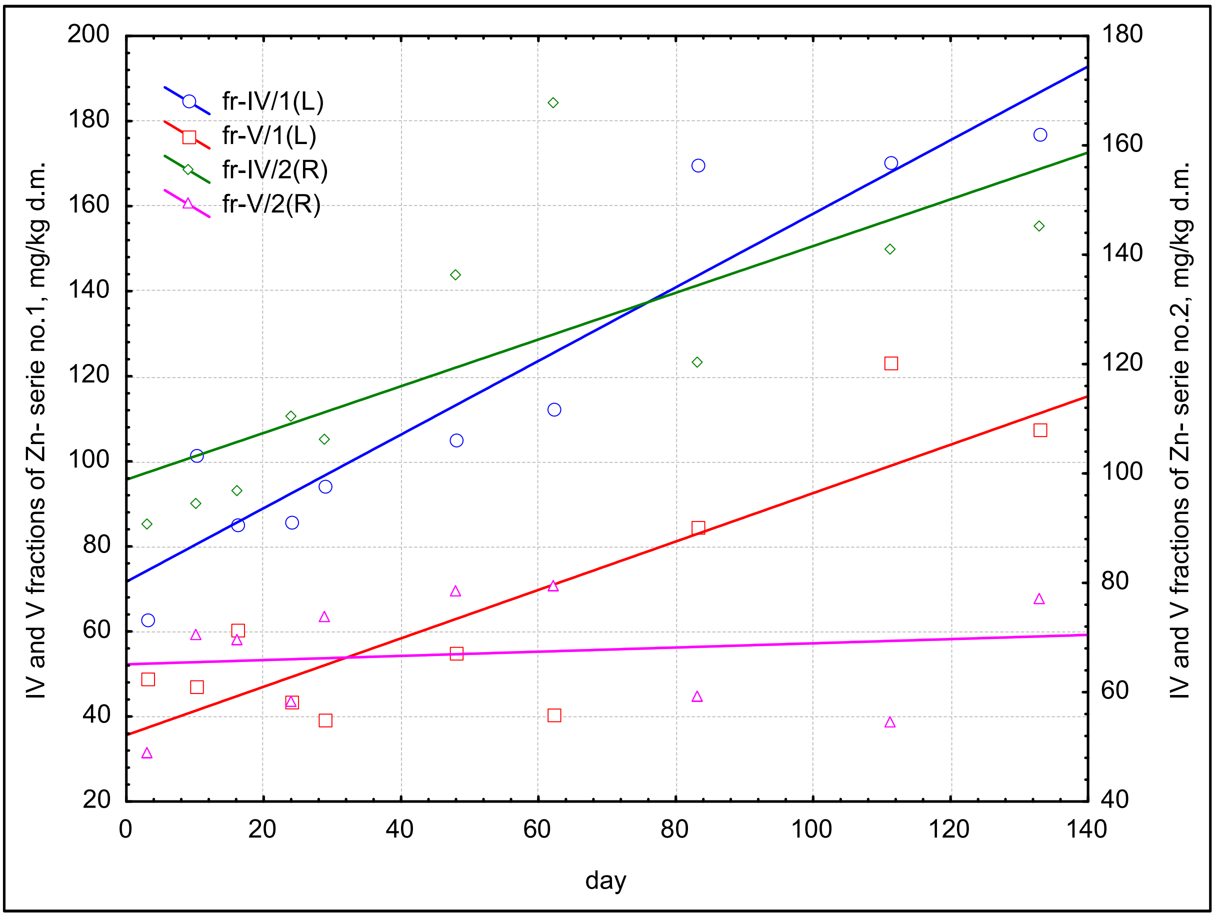

Fig. 10. Changes in the content of extracted fractions IV and IV of zinc, stage no.I.

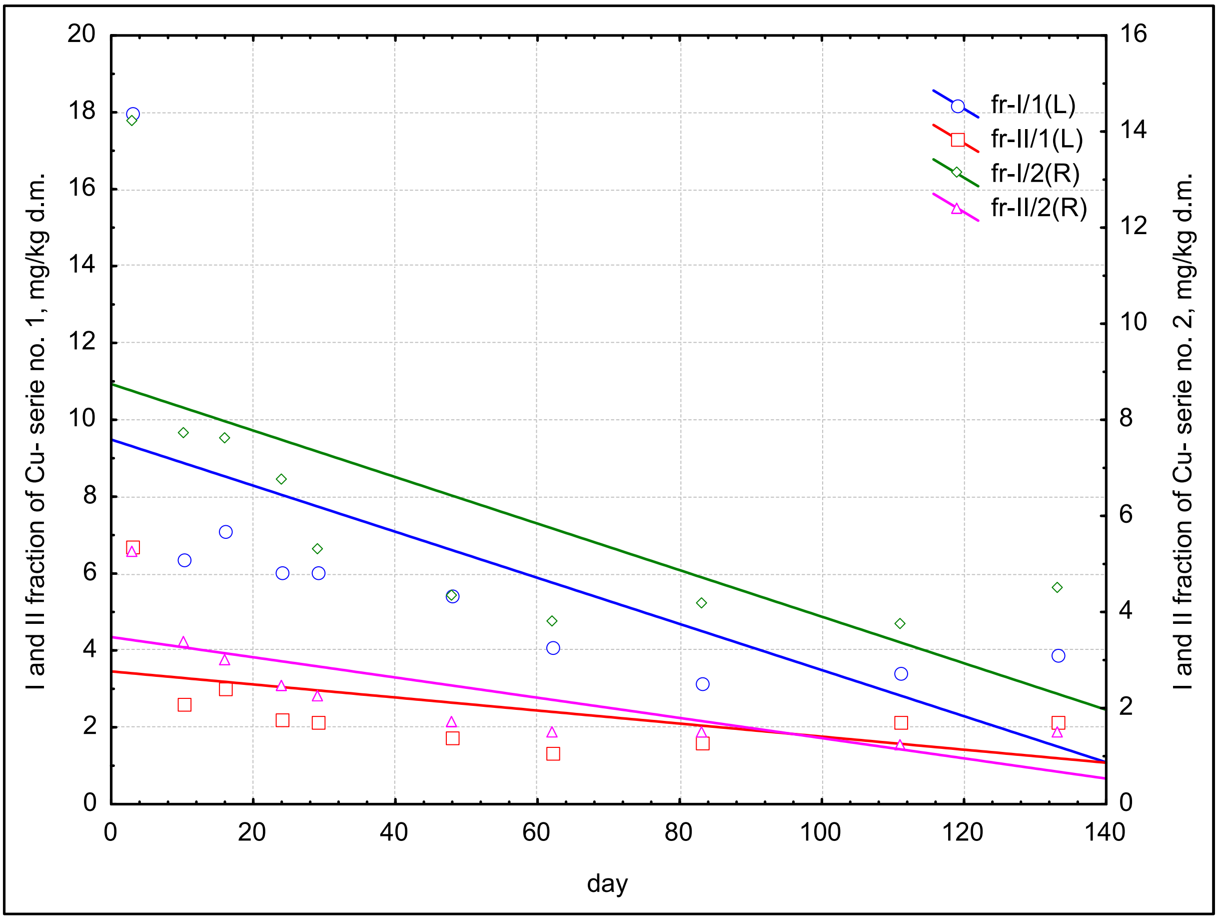

Fig. 11. Changes in the content of extracted fractions I and II of copper, stage I.

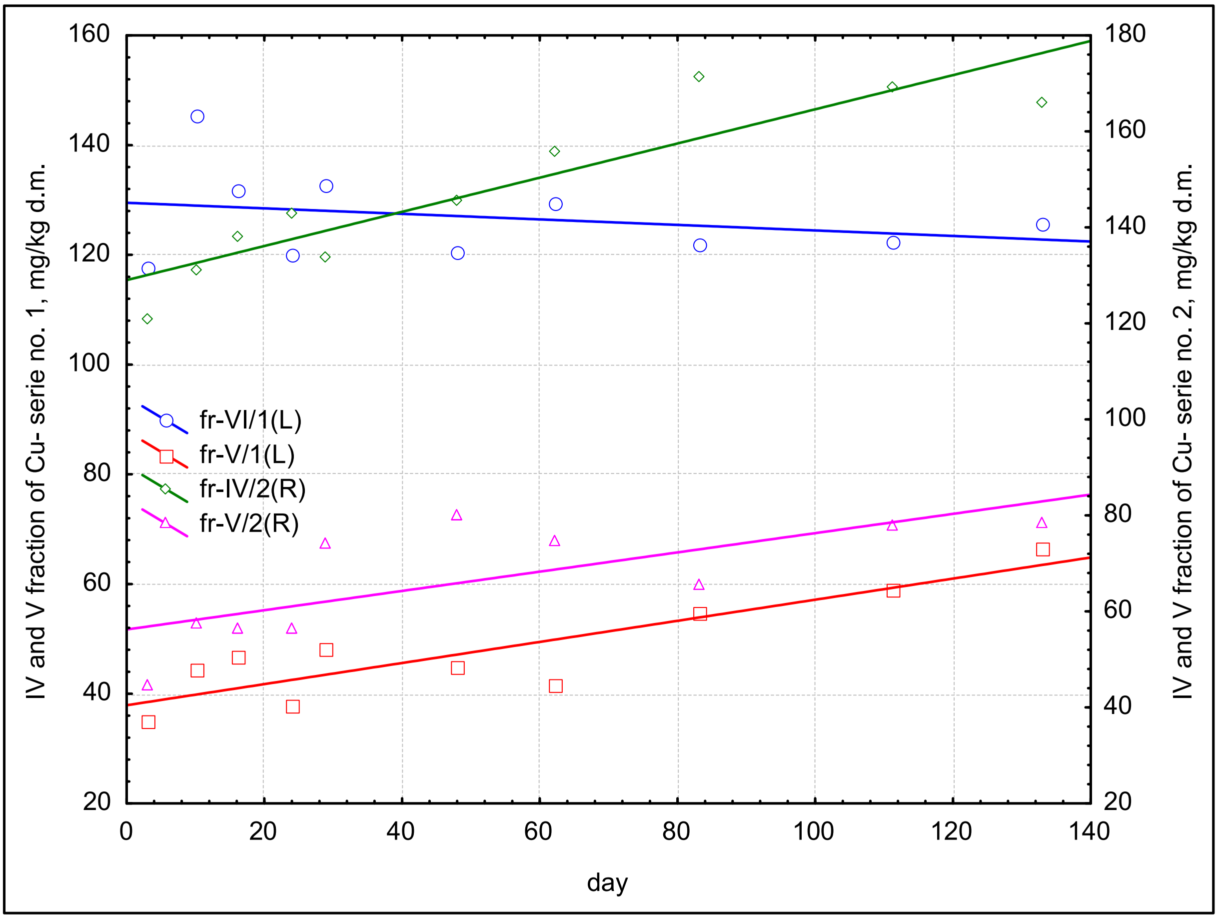

Fig. 12. Changes in the content of extracted fractions IV and V of copper, stage I.

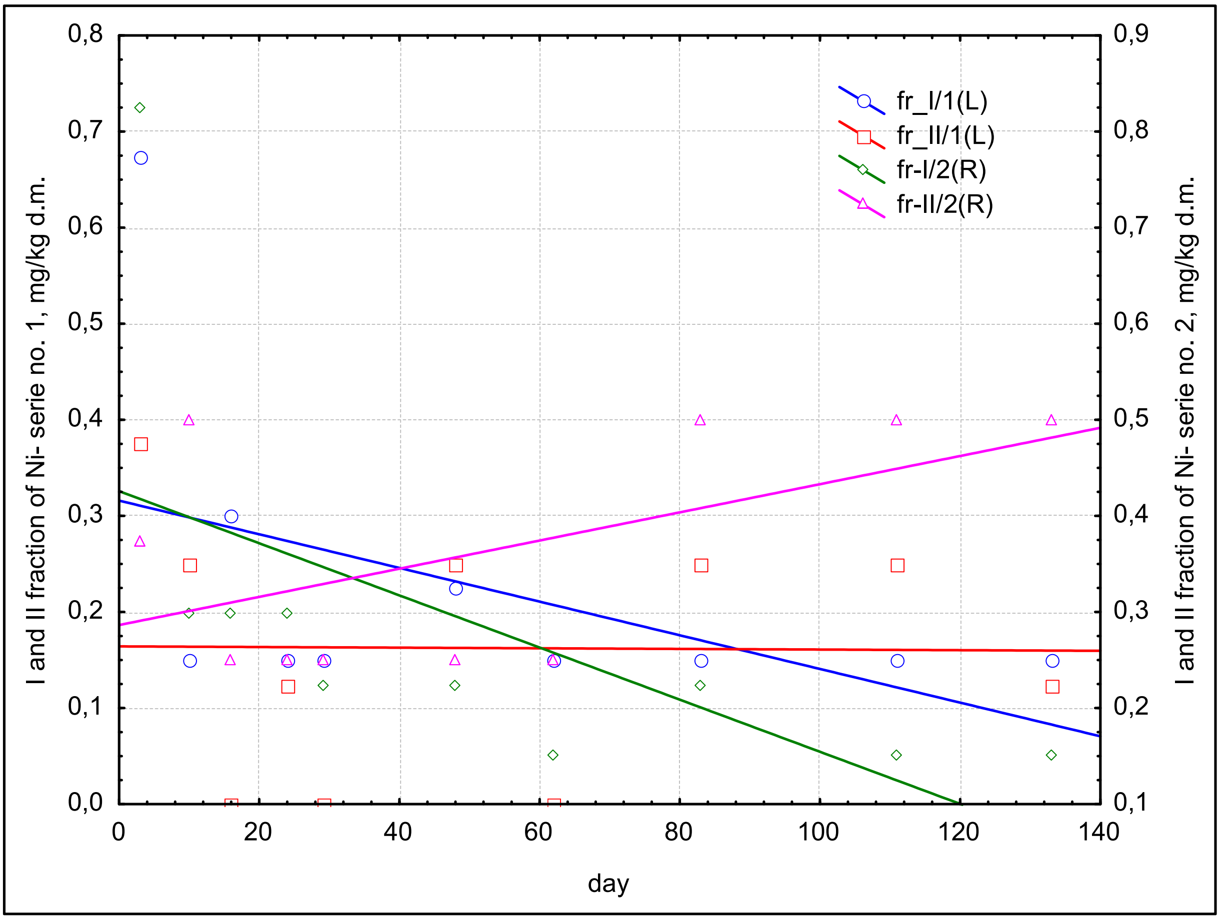

Fig. 13. Changes in the content of extracted fractions I and II of nickel, stage no.I.

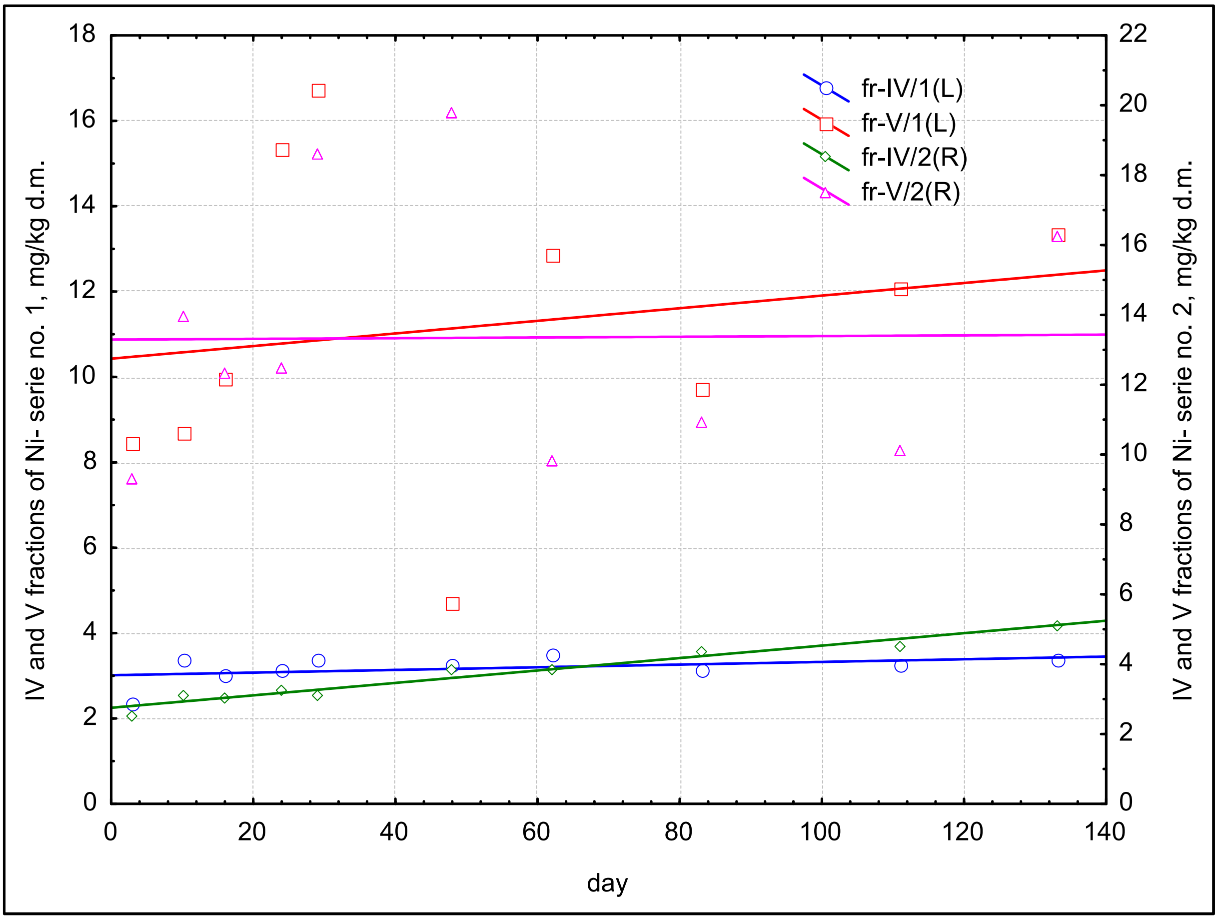

Fig. 14. Changes in the content of extracted fractions IV and V of nickel, stage no.I.

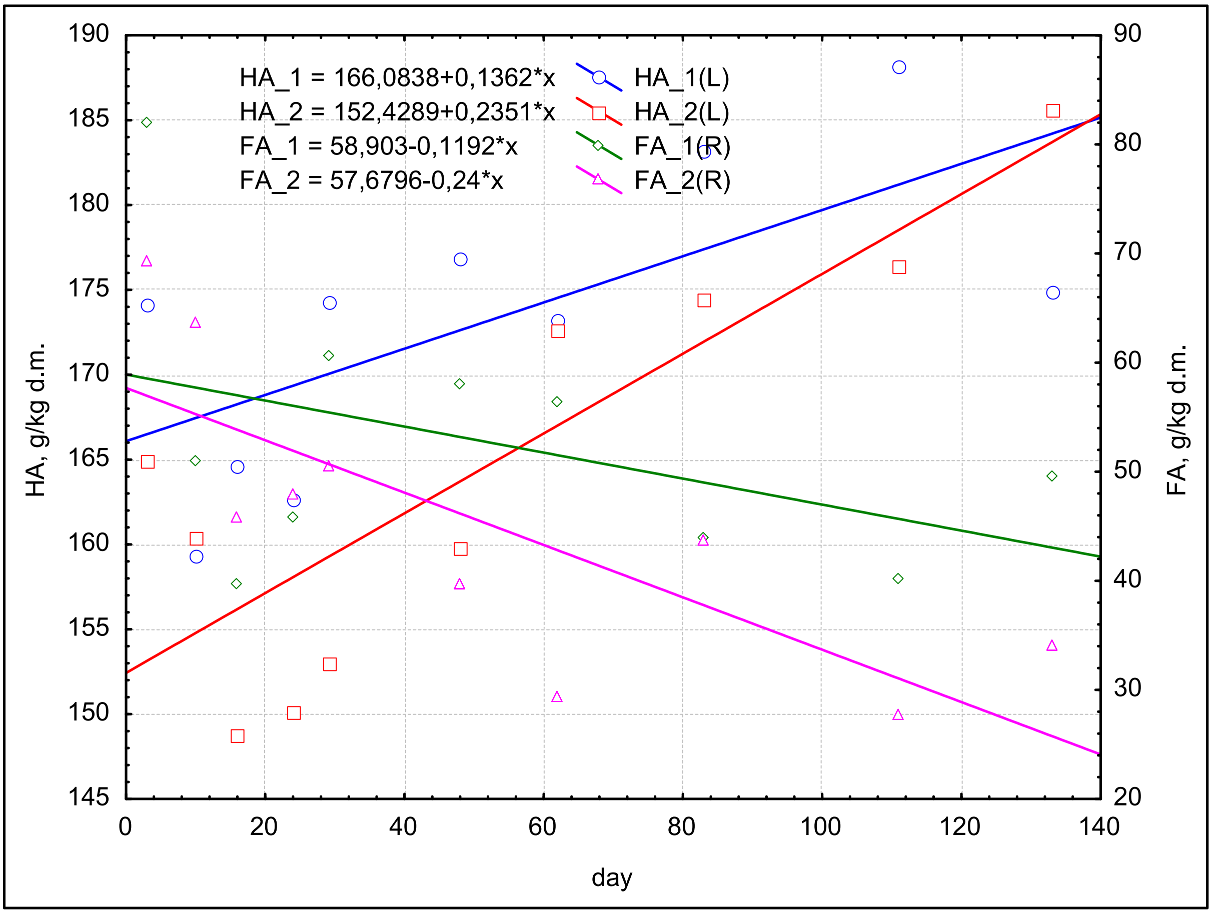

Fig. 15. Changes in the content of humic acids (HA) and fulvic acids (FA), stage no.I.

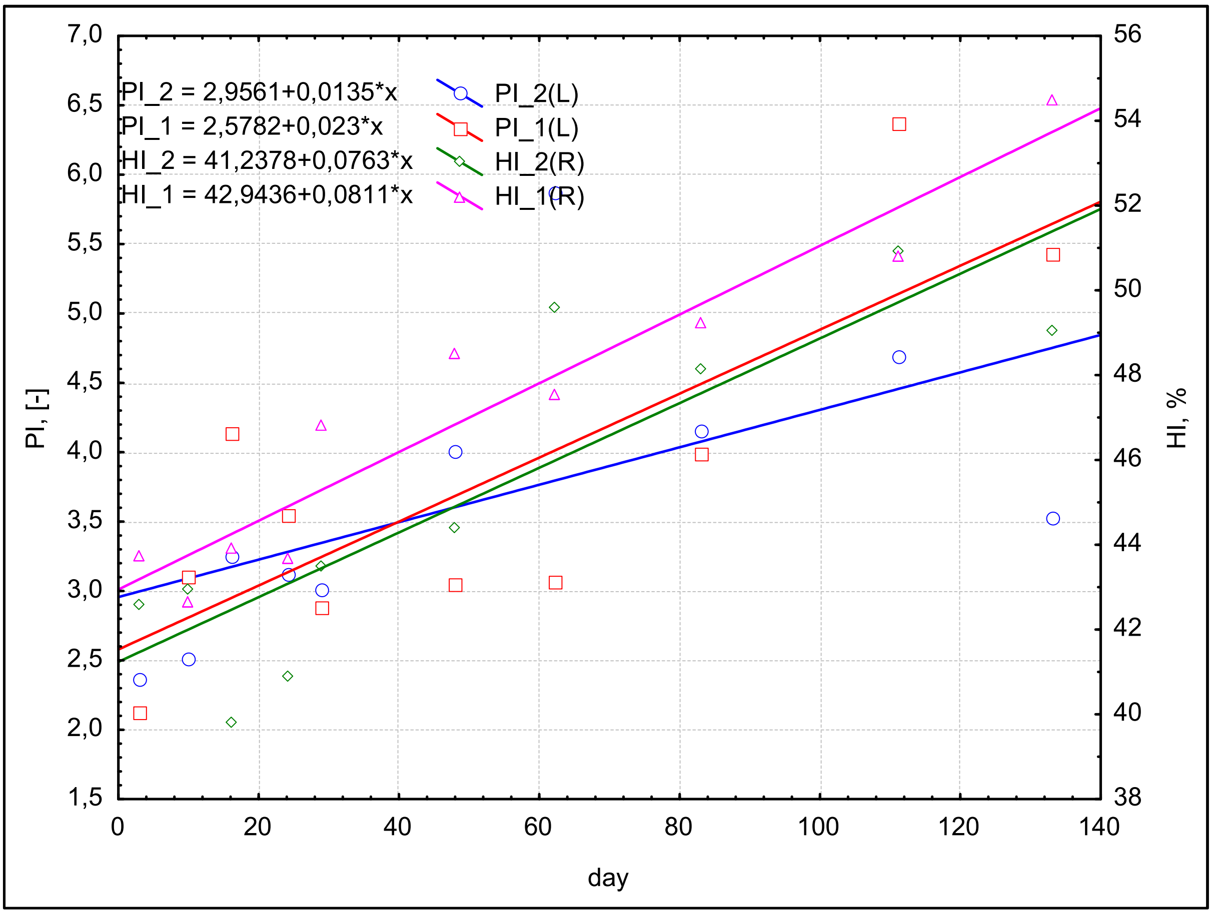

Fig. 16. Changes in the values of humification indices PI and HI, stage no.I.

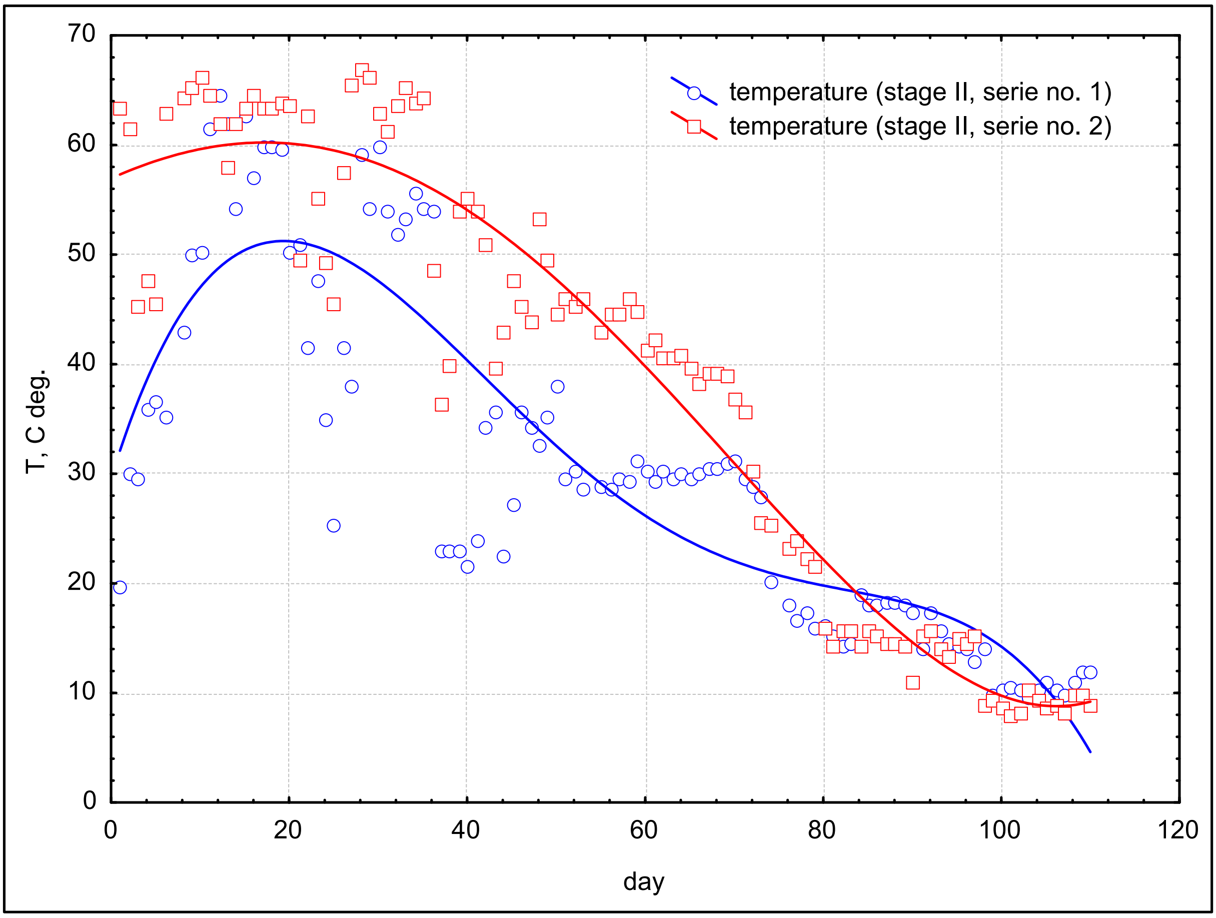

Fig. 17. Temperature changes in both compost samples, stage no.II.

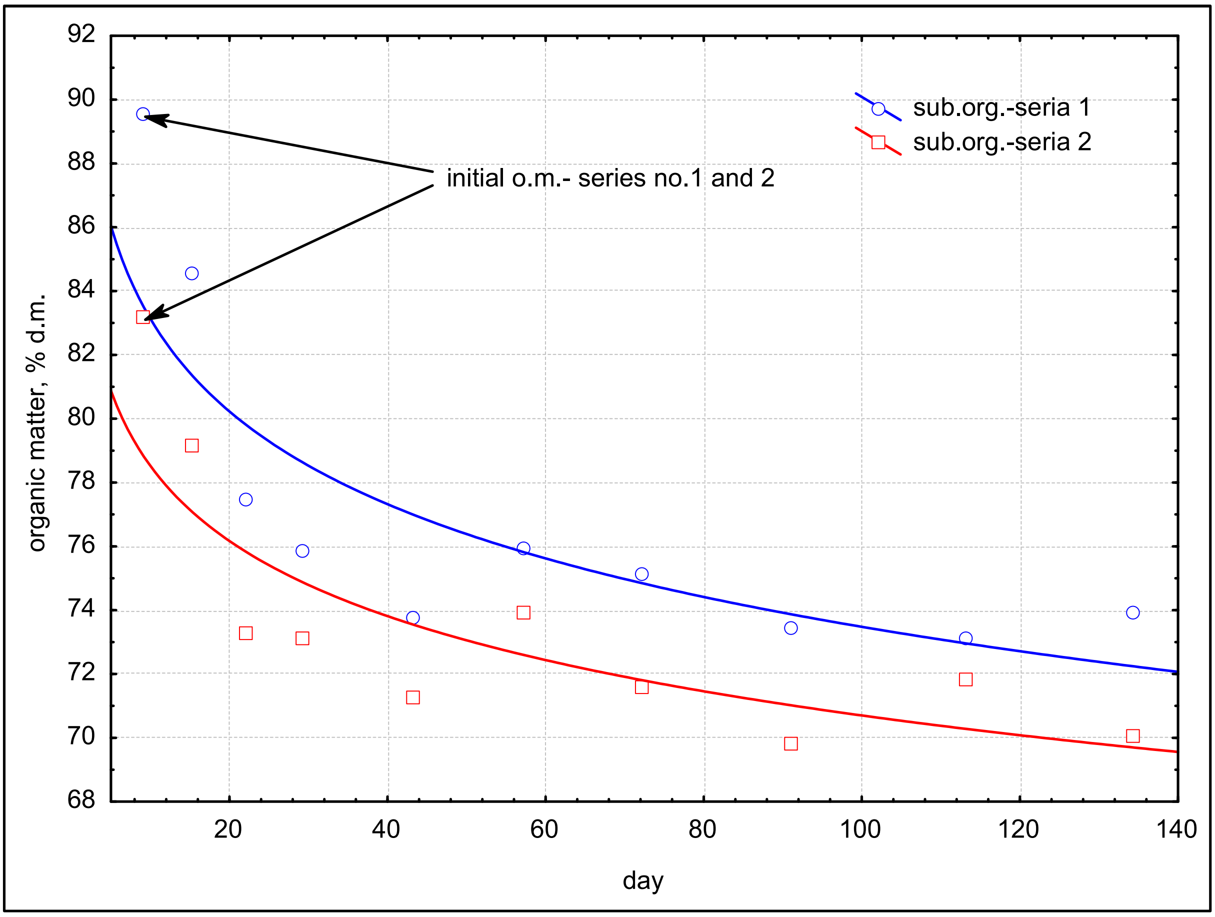

Fig. 18. Changes in the content of organic matter during composting, stage no.II.

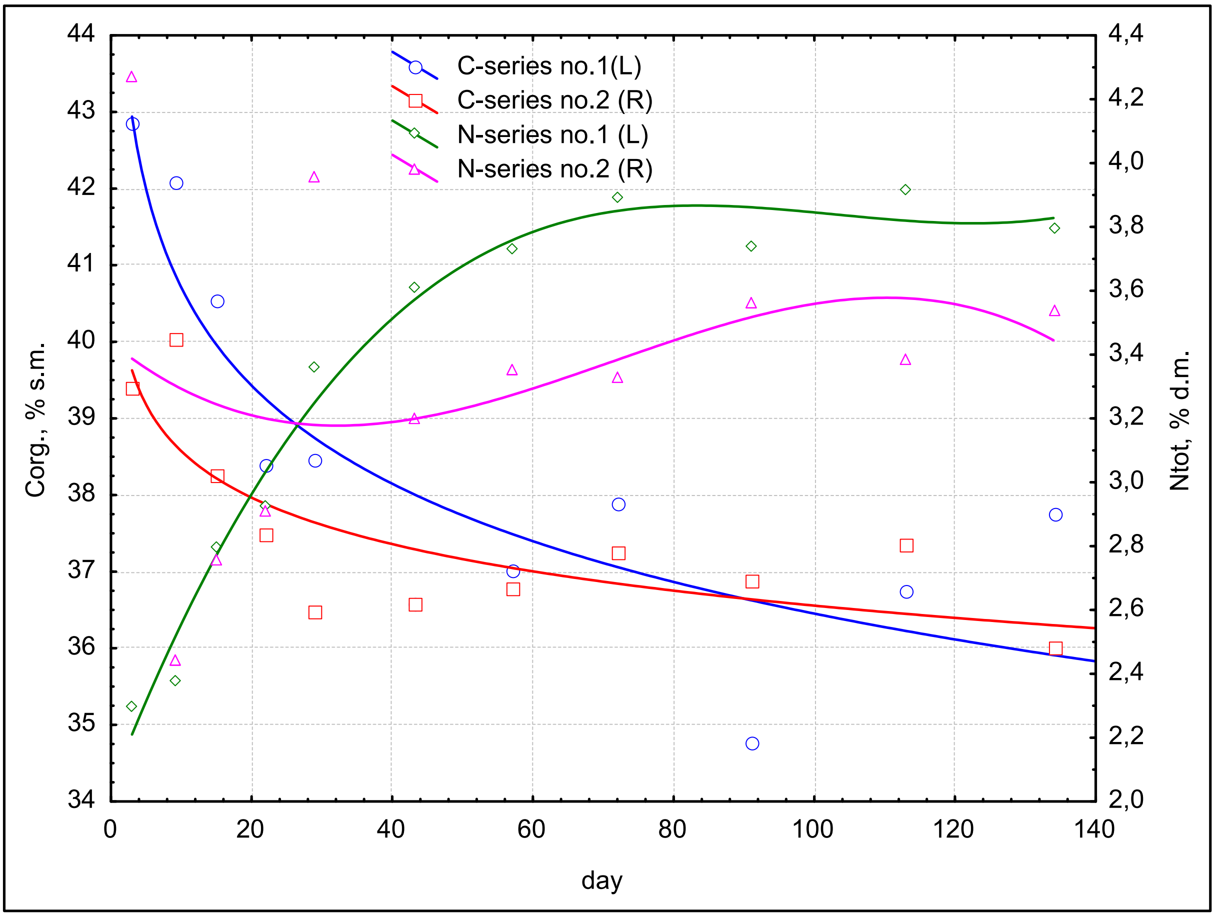

Fig. 19. Changes in the concentration of organic carbon and total nitrogen during composting, stage II

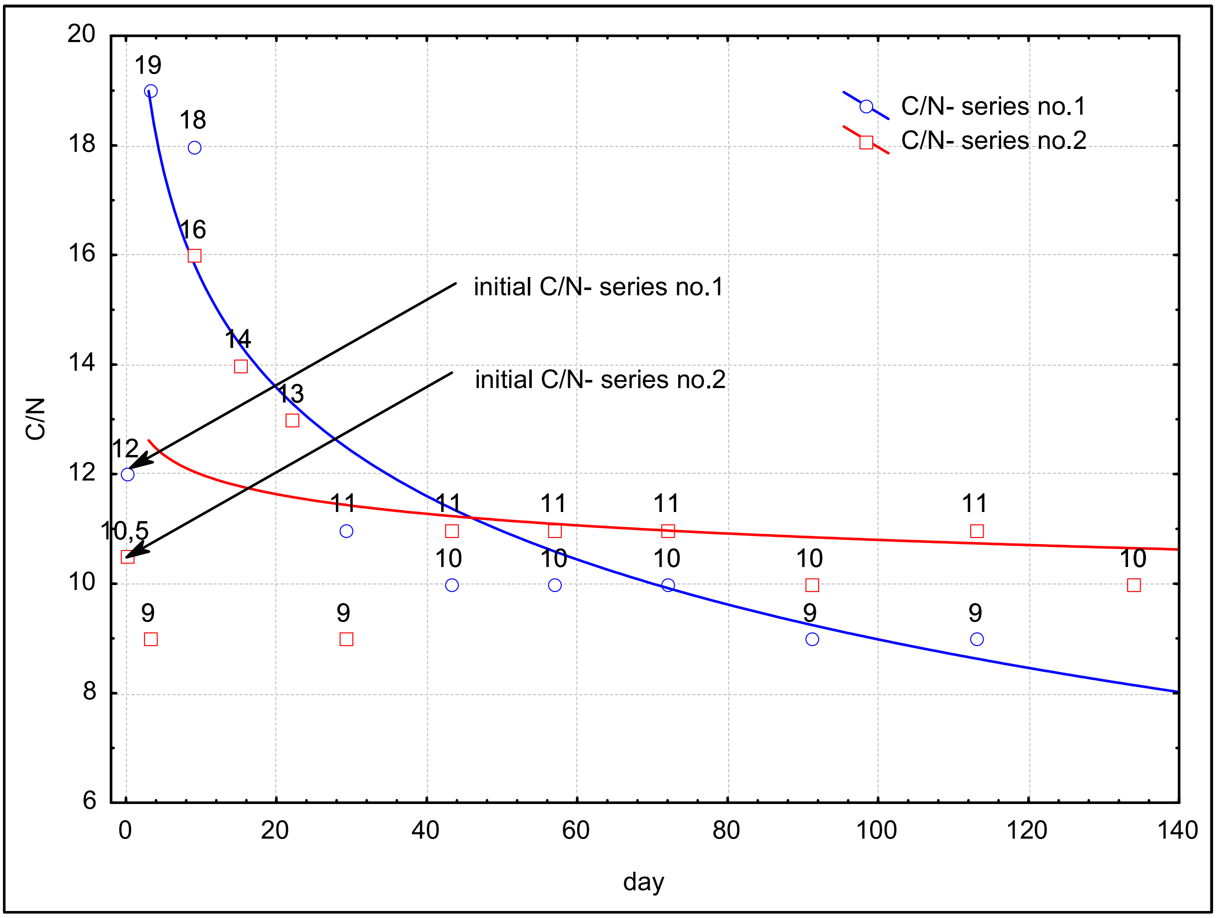

Fig. 20. Changes in the C/N proportion in compost, stage no.II.

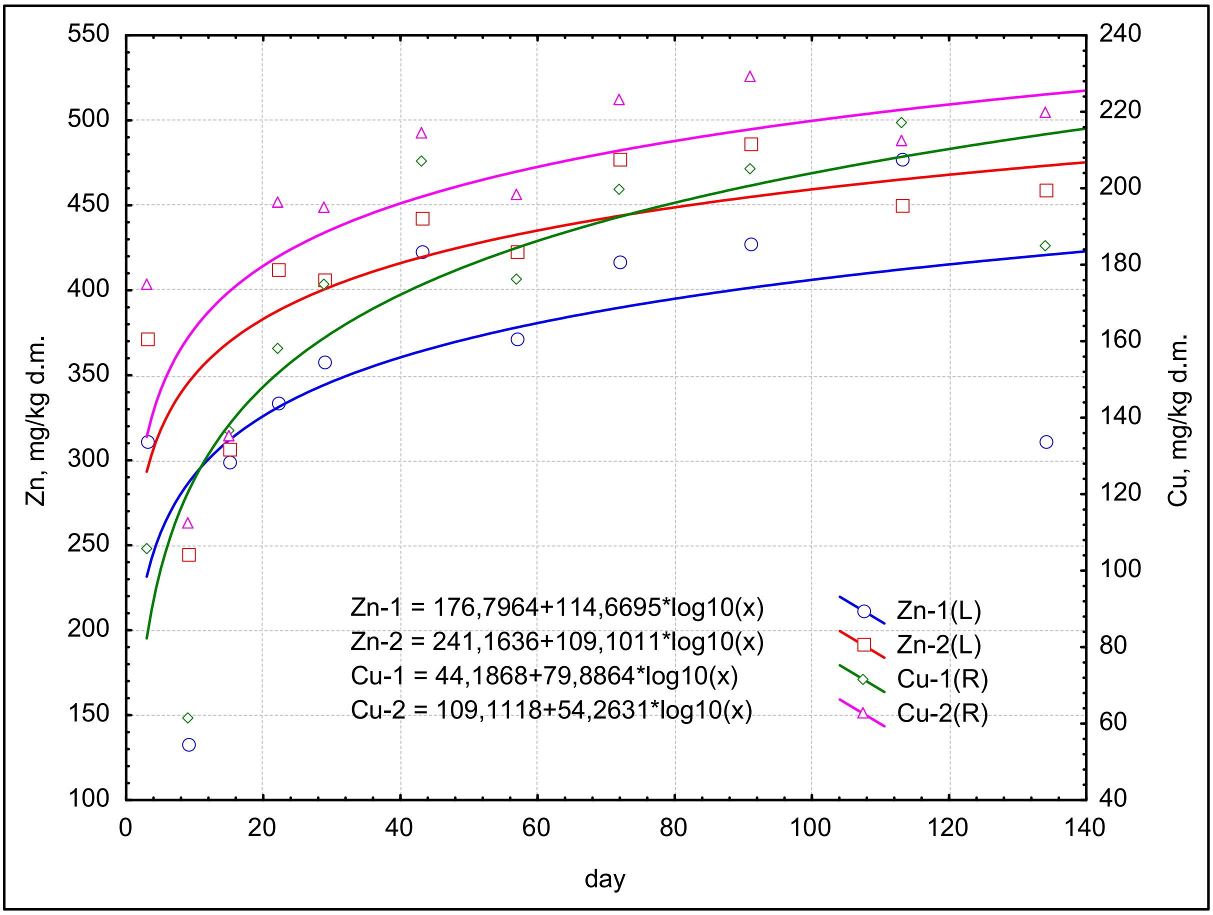

Fig. 21. Changes in concentration of zinc and copper in compost, stage no.II.

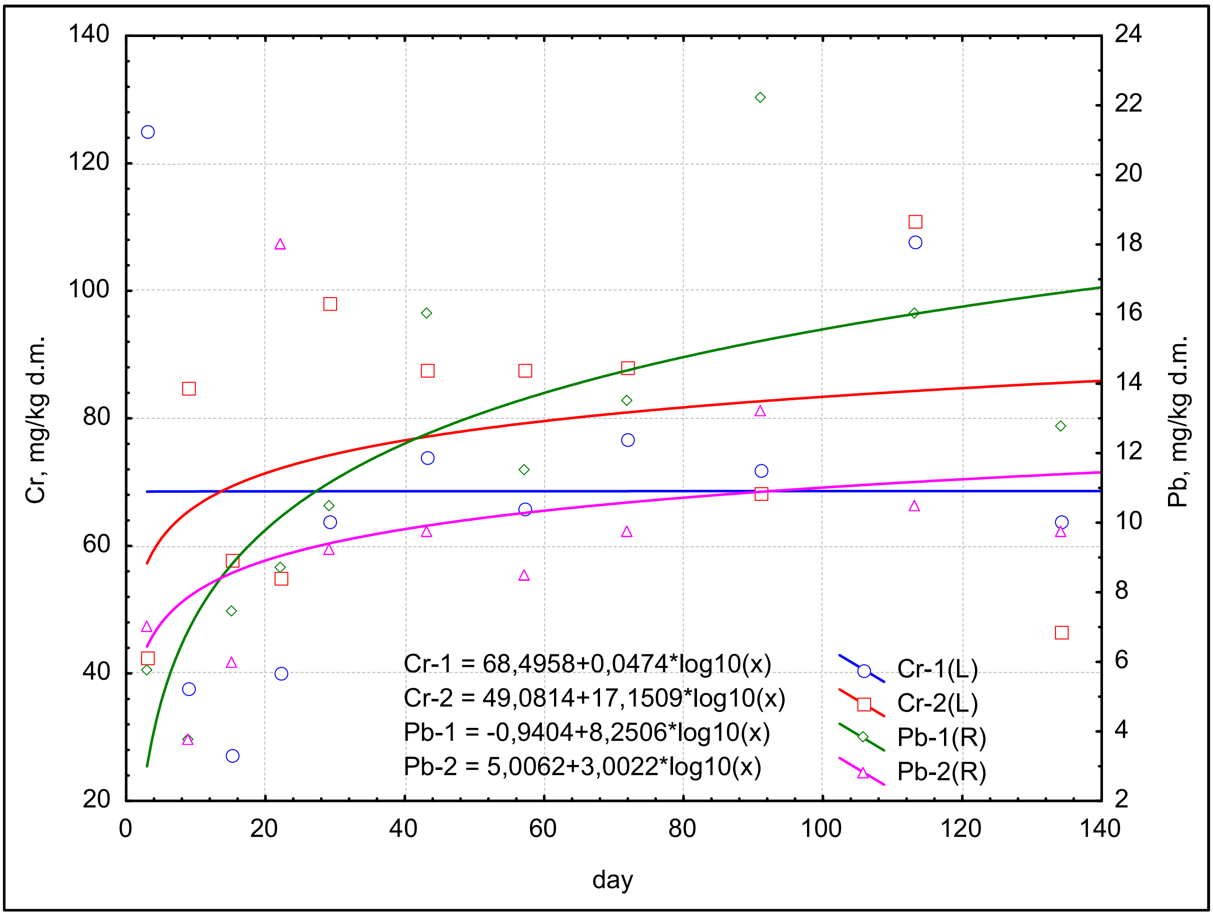

Fig. 22. Chromium and lead concentration changes in compost, stage no.II.

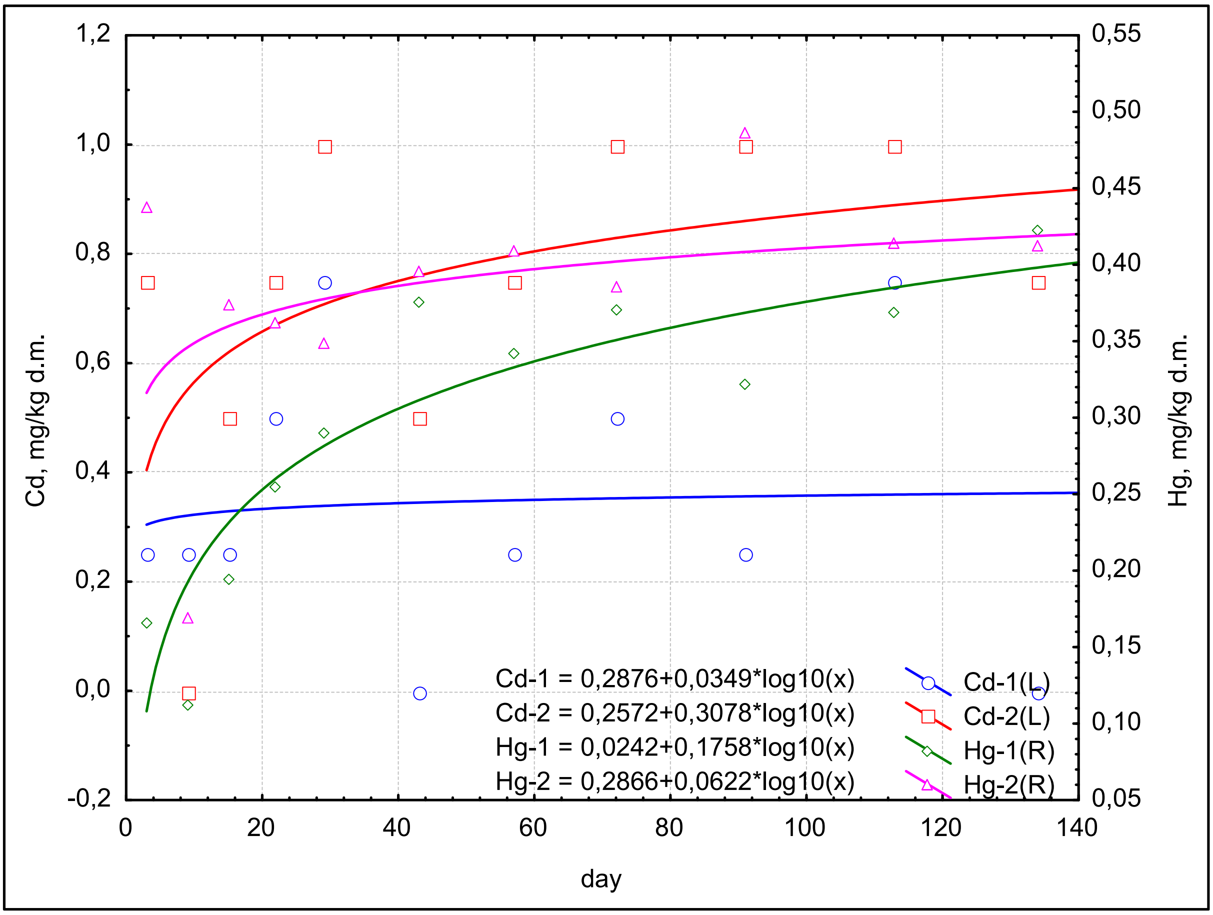

Fig. 23. Changes in the concentration of cadmium and mercury in compost, stage no.II.

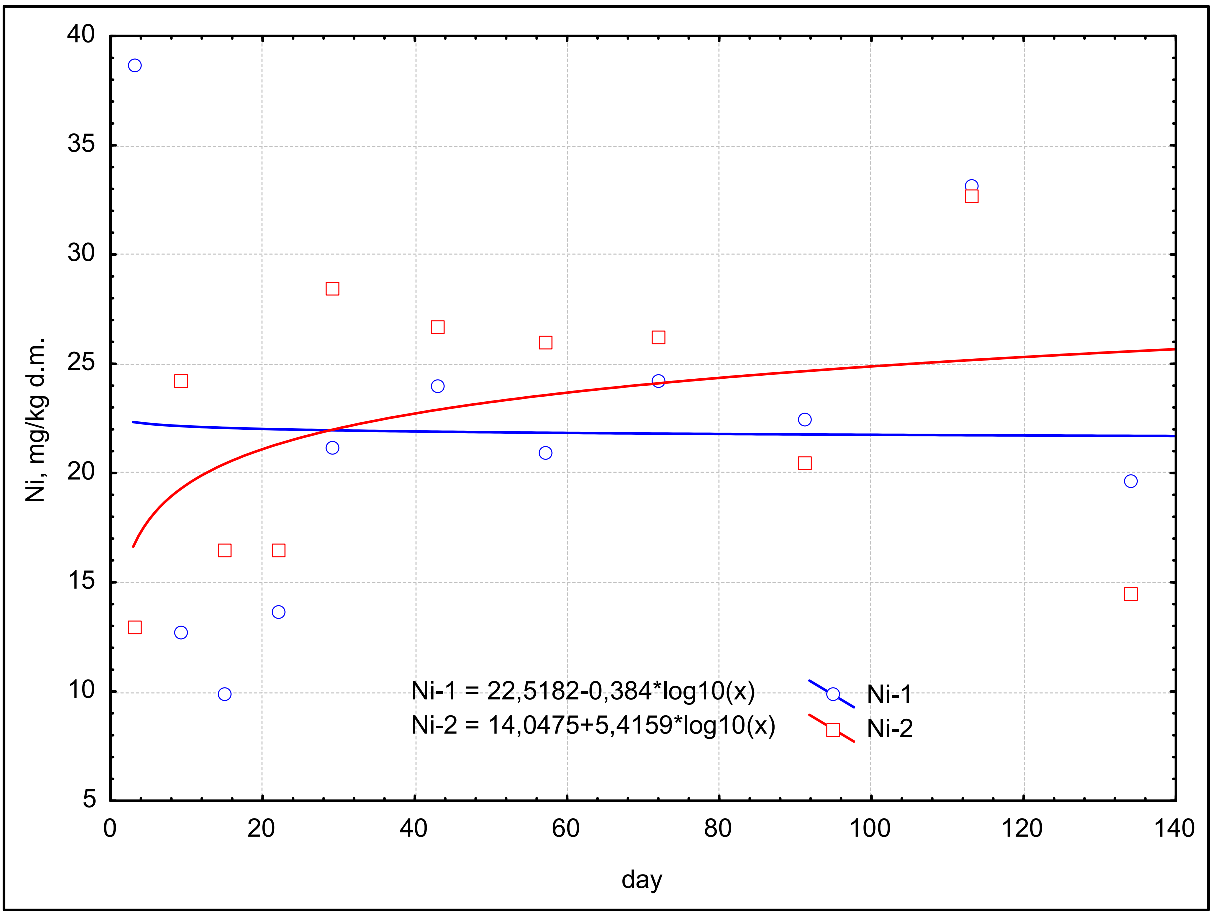

Fig. 24. Changes in nickel concentration in compost, stage no.II.

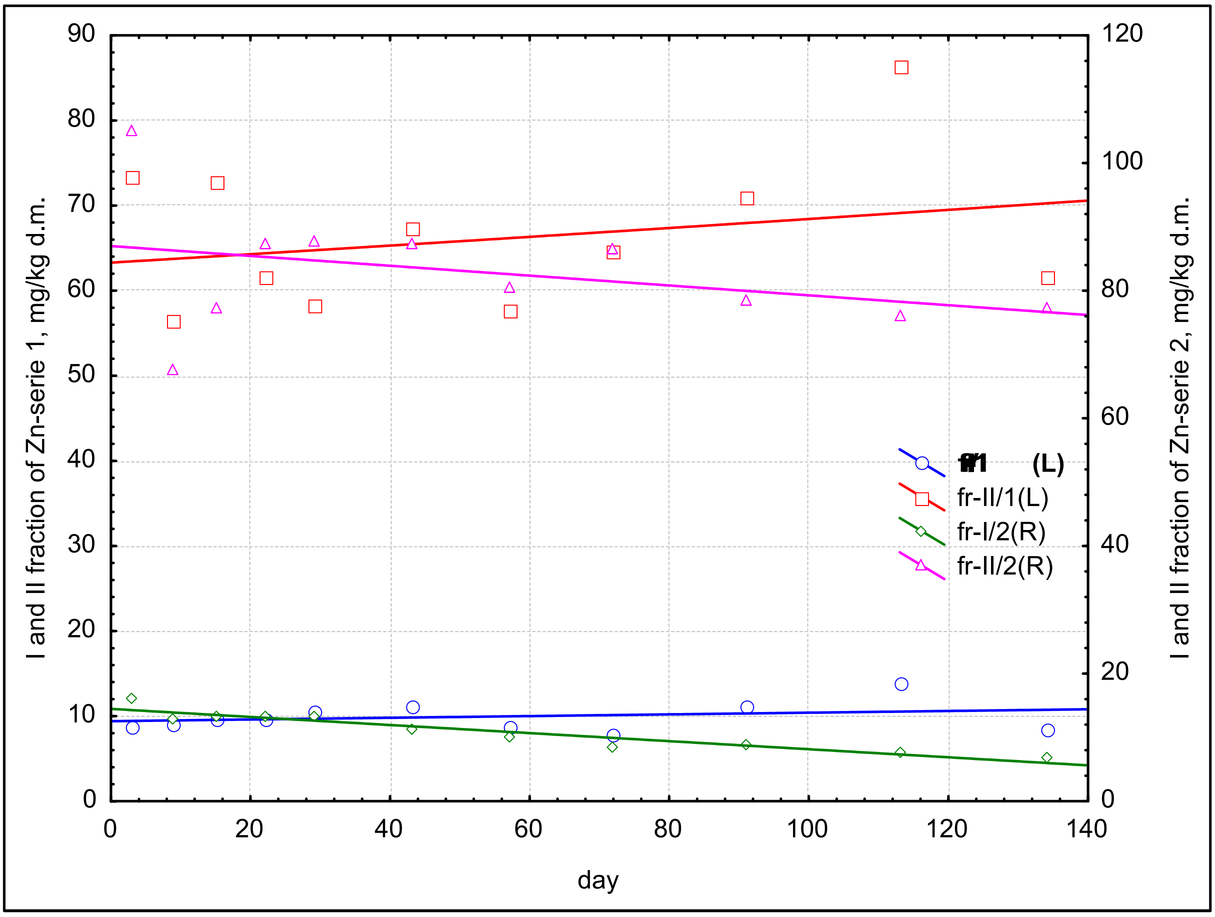

Fig. 25. Changes in the content of extracted fractions I and II of zinc, stage no.II.

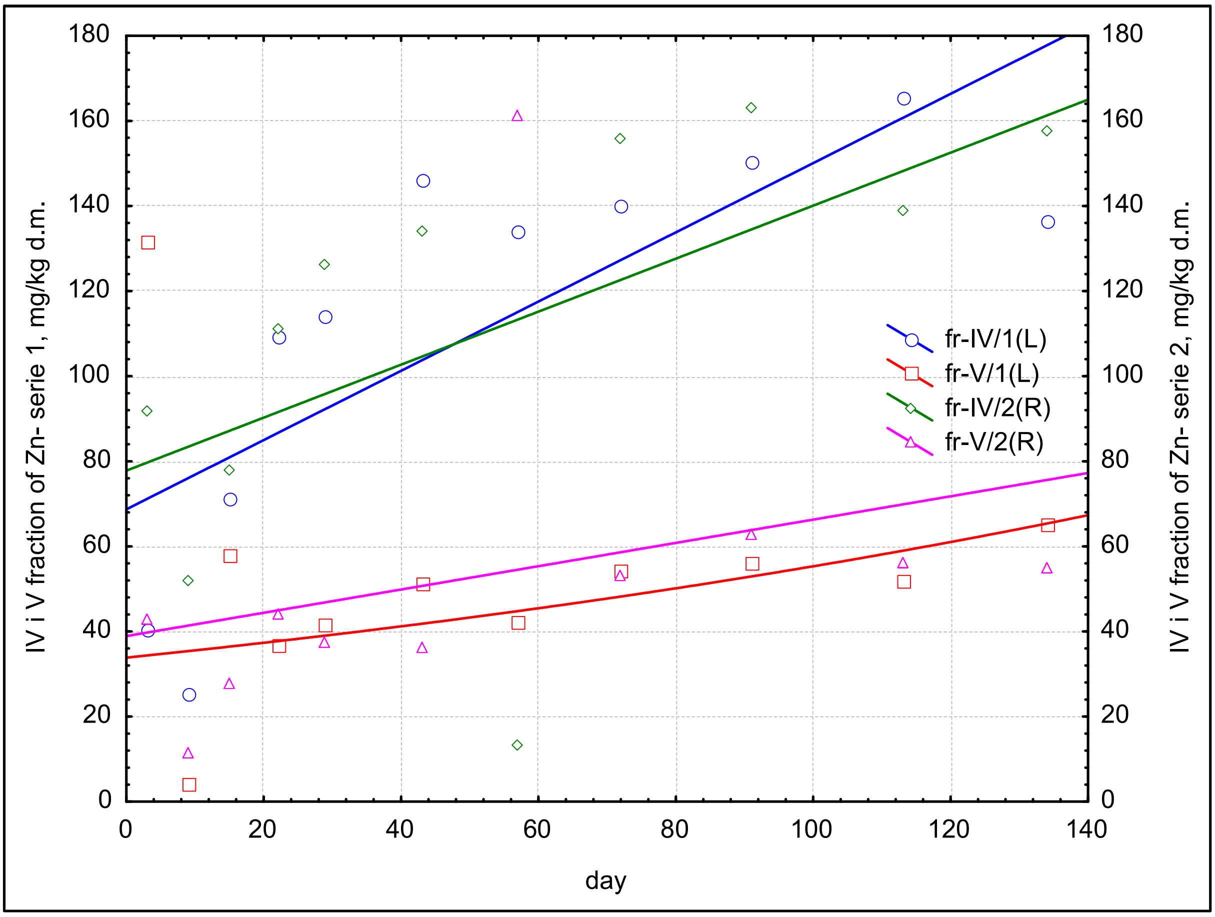

Fig. 26. Changes in the content of extracted fraction IV and V of zinc, stage no.II.

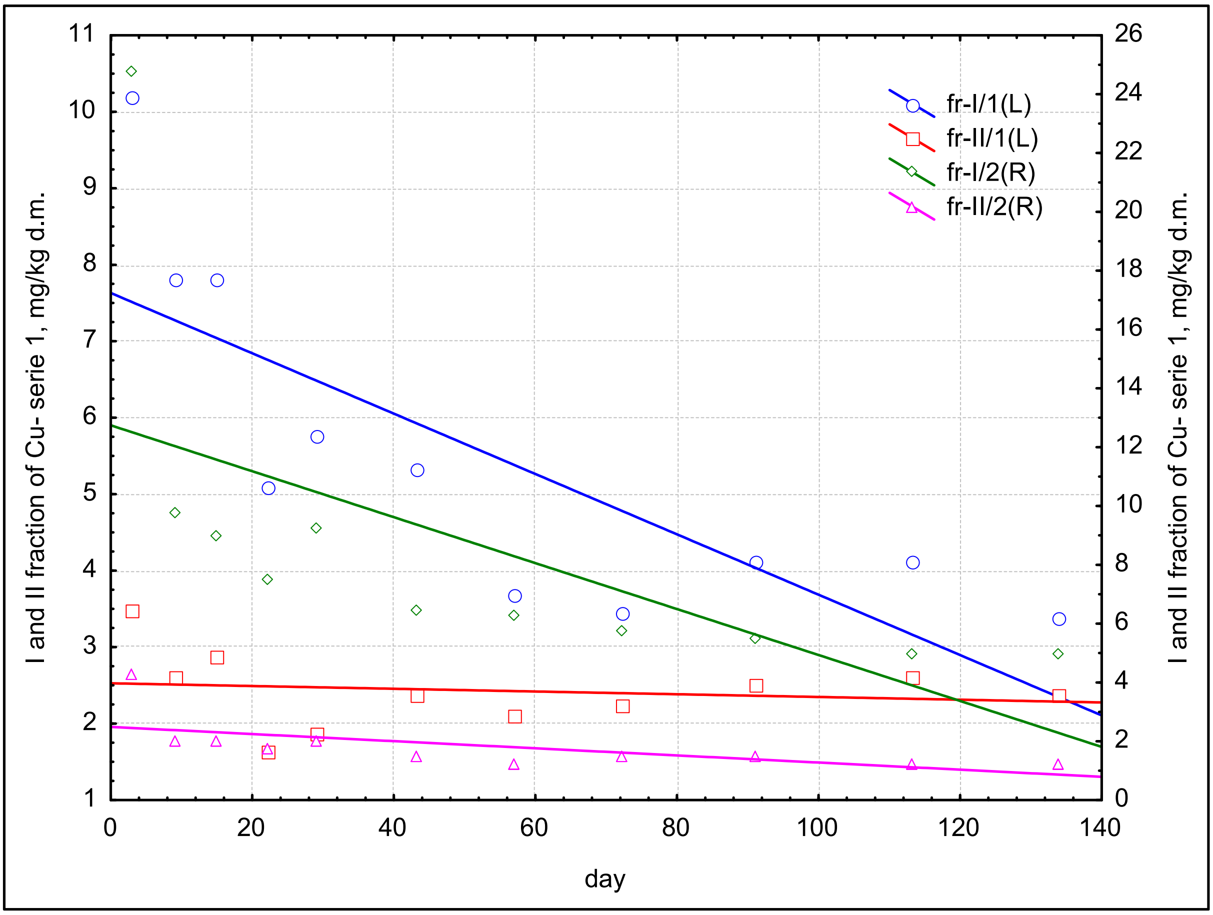

Fig. 27. Changes in the content of extracted fractions I and II of copper, stage no.II.

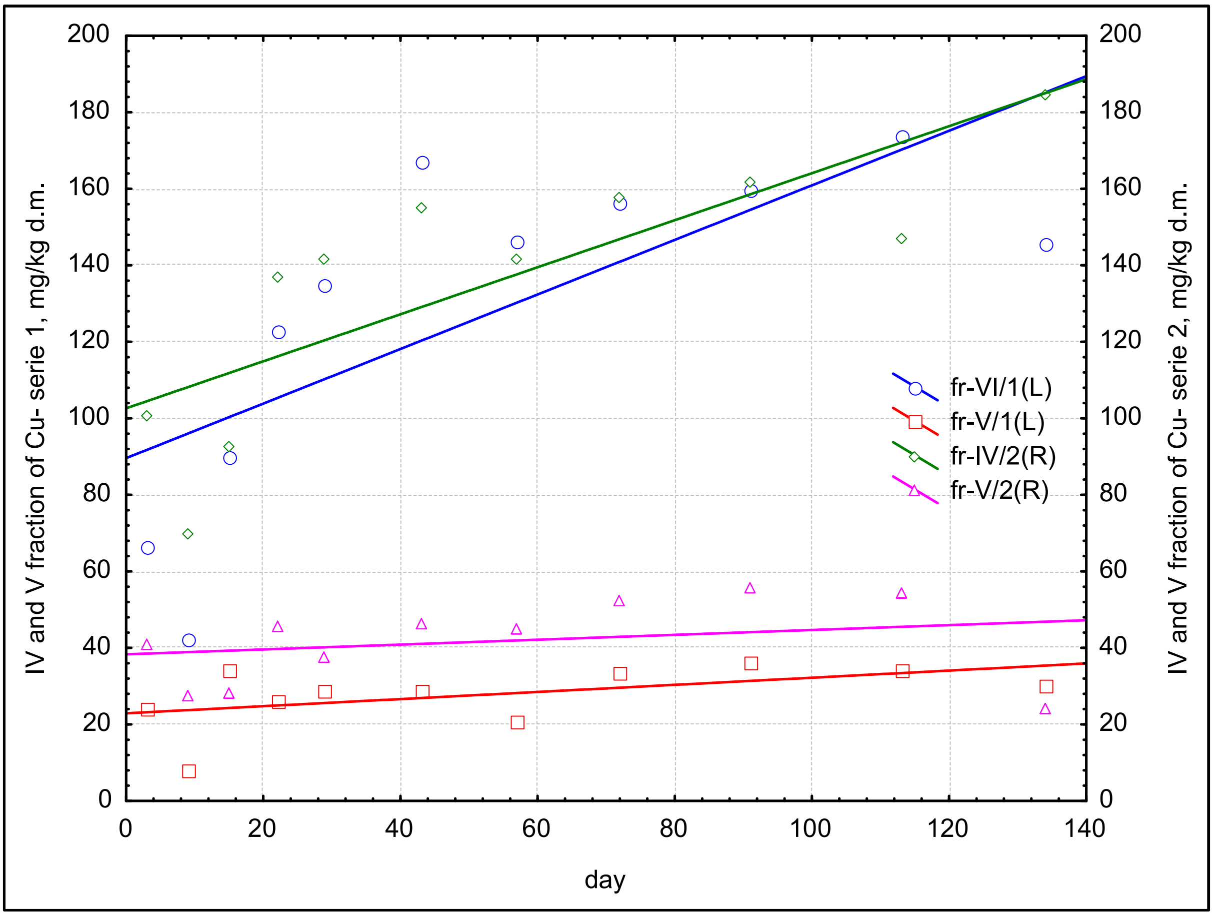

Fig. 28. Changes in the content of extracted fraction IV and V of copper, stage no.II.

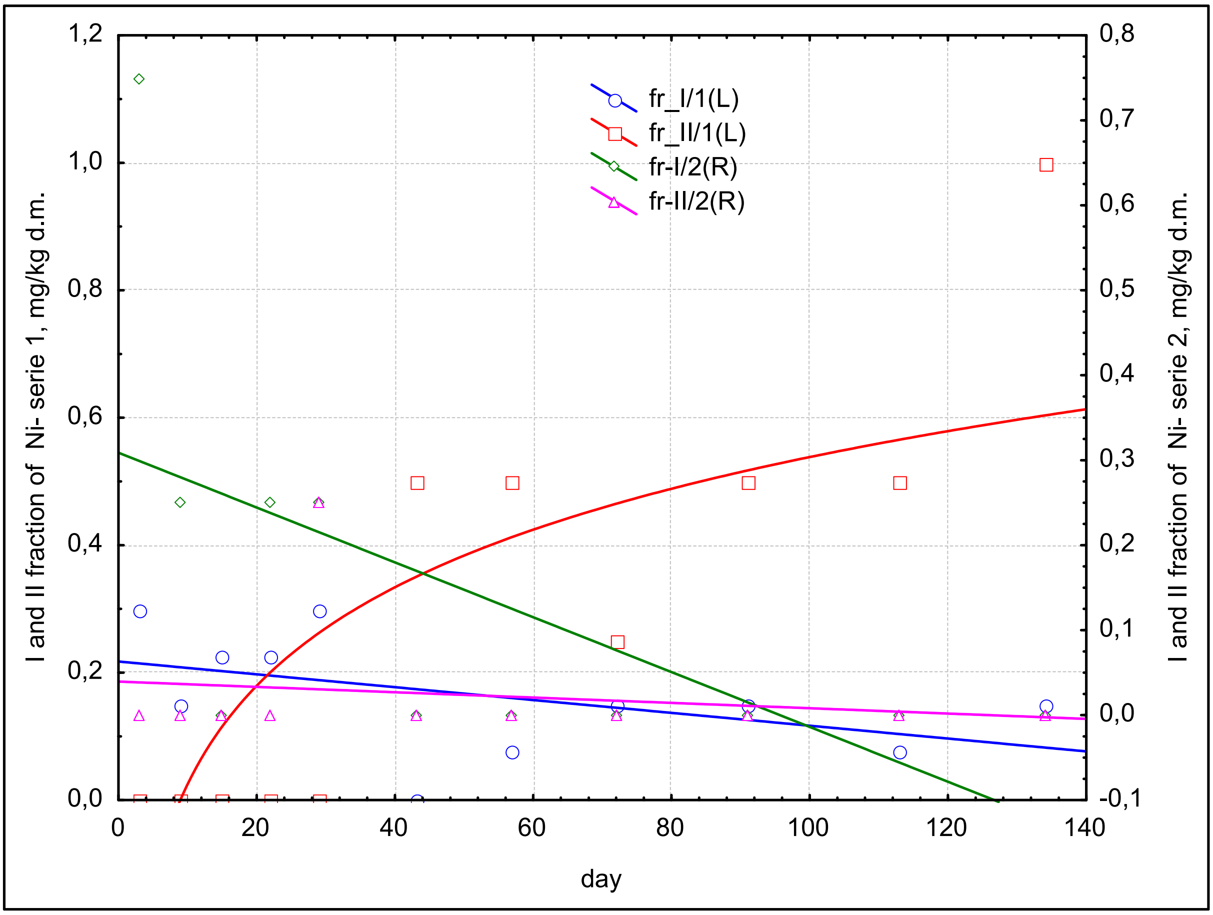

Fig. 29. Changes in the content of extracted fractions I and II of nickel, stage no.II.

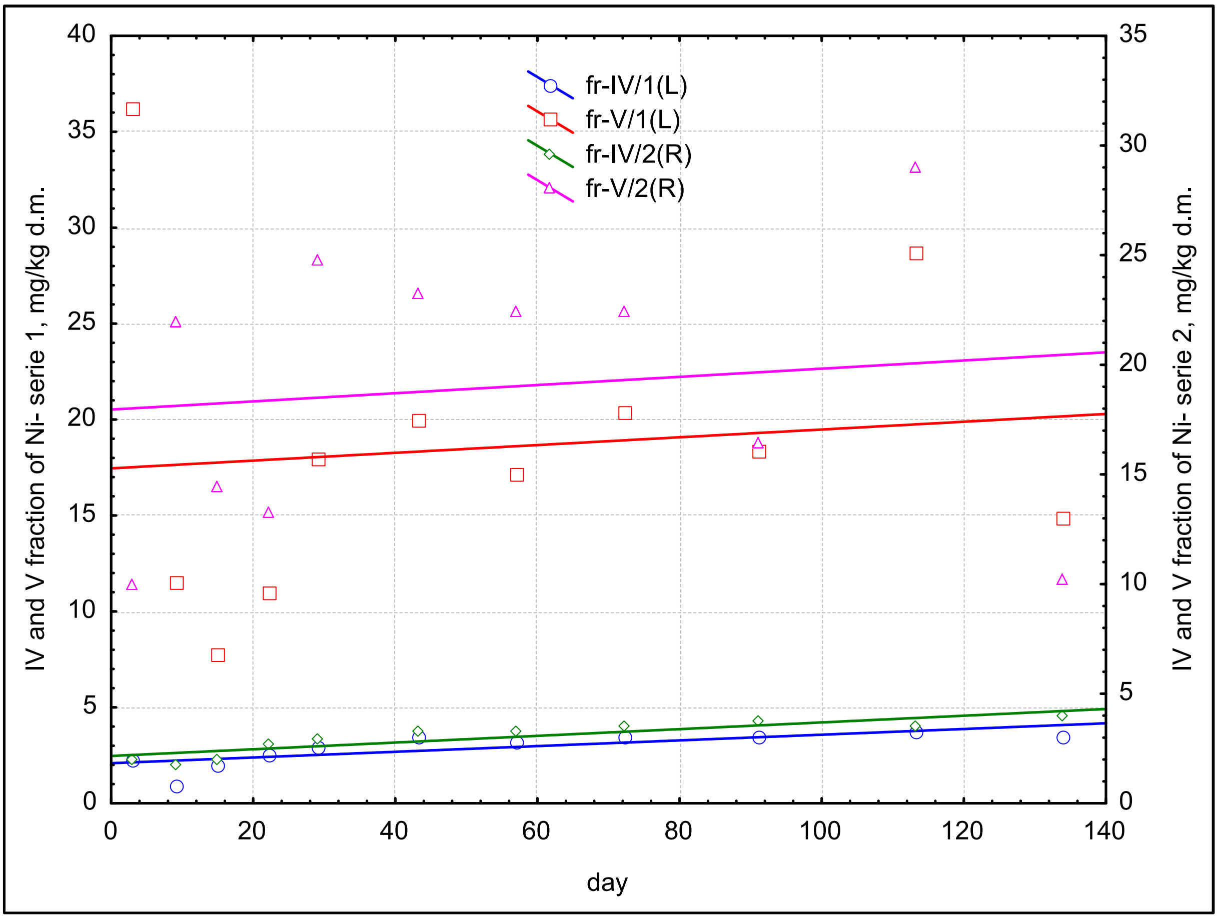

Fig. 30. Changes in the content of extracted fraction IV and V of nickel, stage no.II.

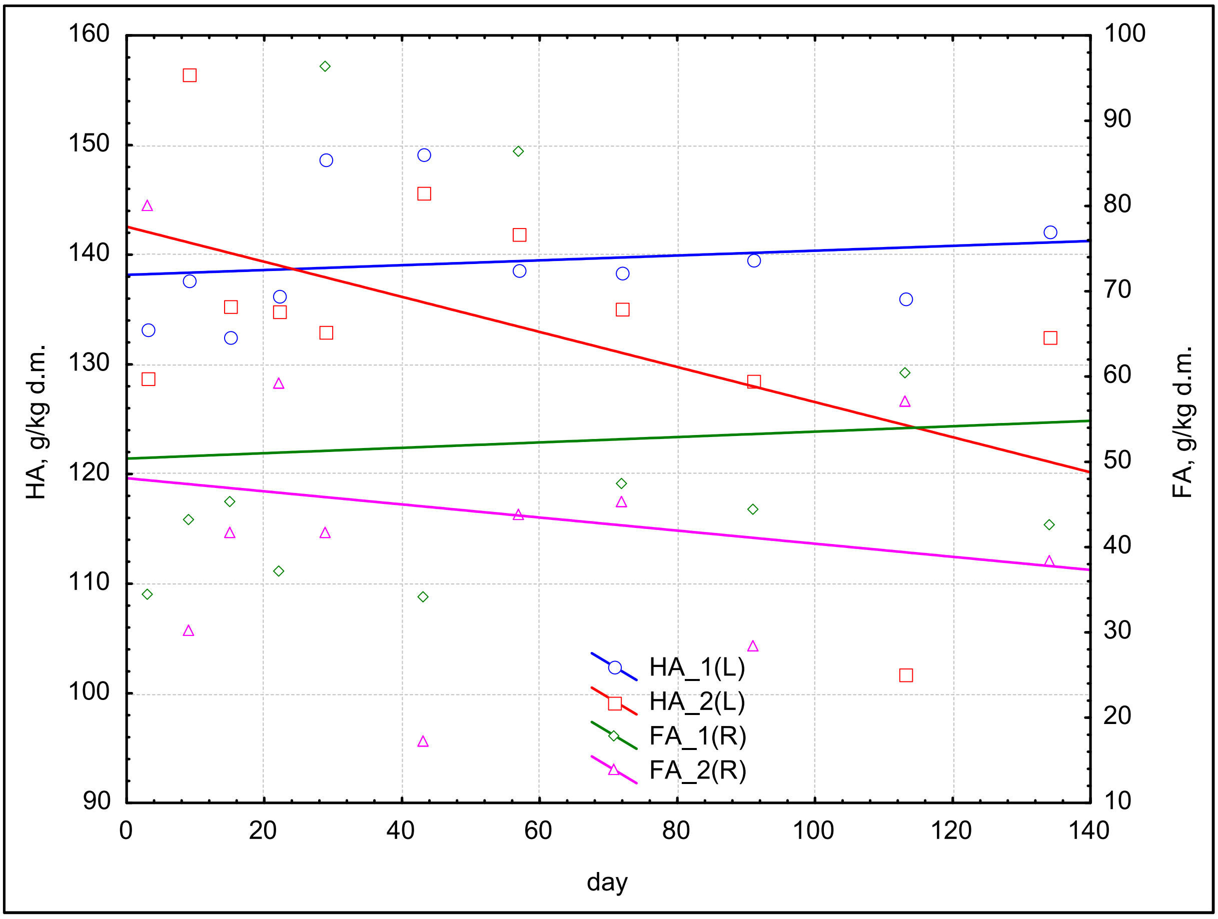

Fig. 31. Changes in the content of humic acids (HA) and fulvic acids (FA), stage no.II.

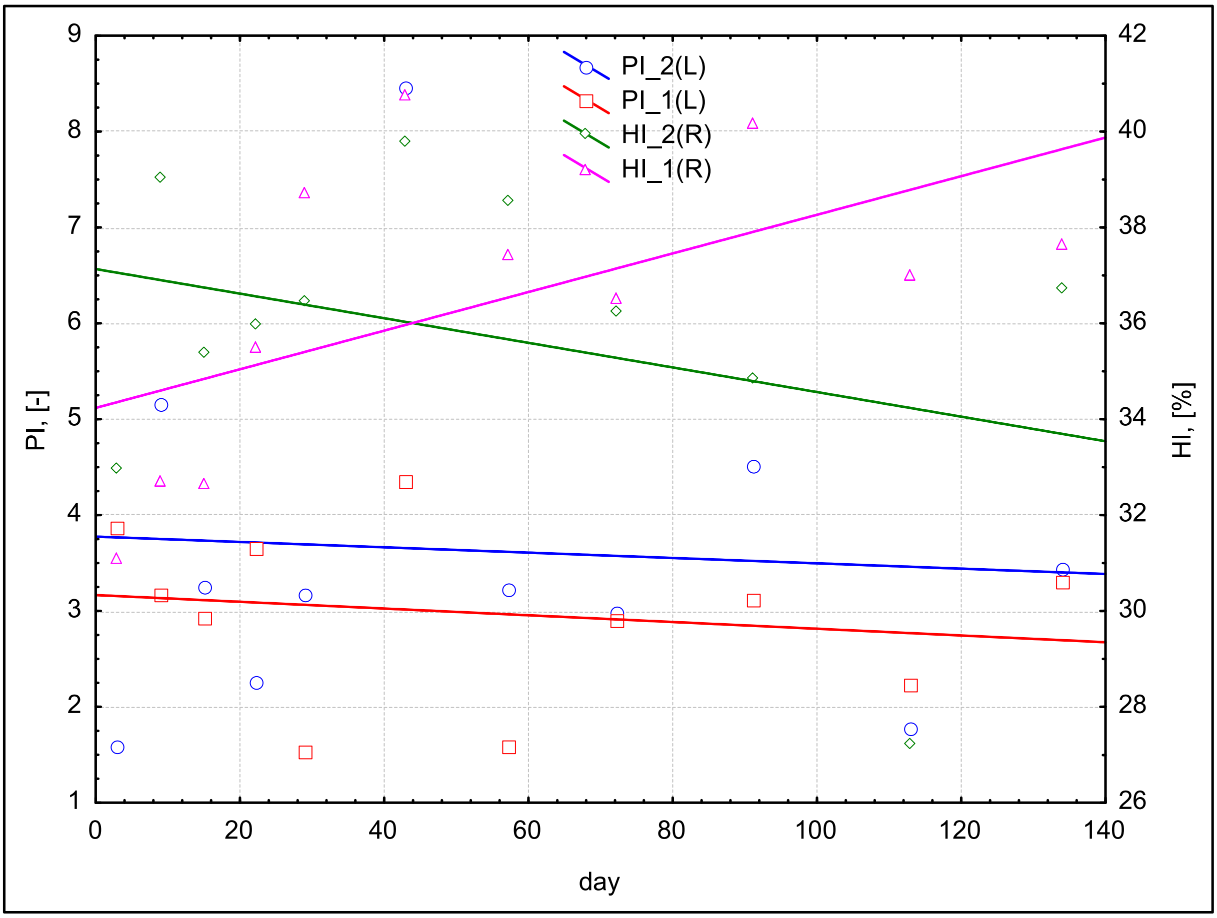

Fig. 32. Changes in the PI and HI humification indices, stage no.II.

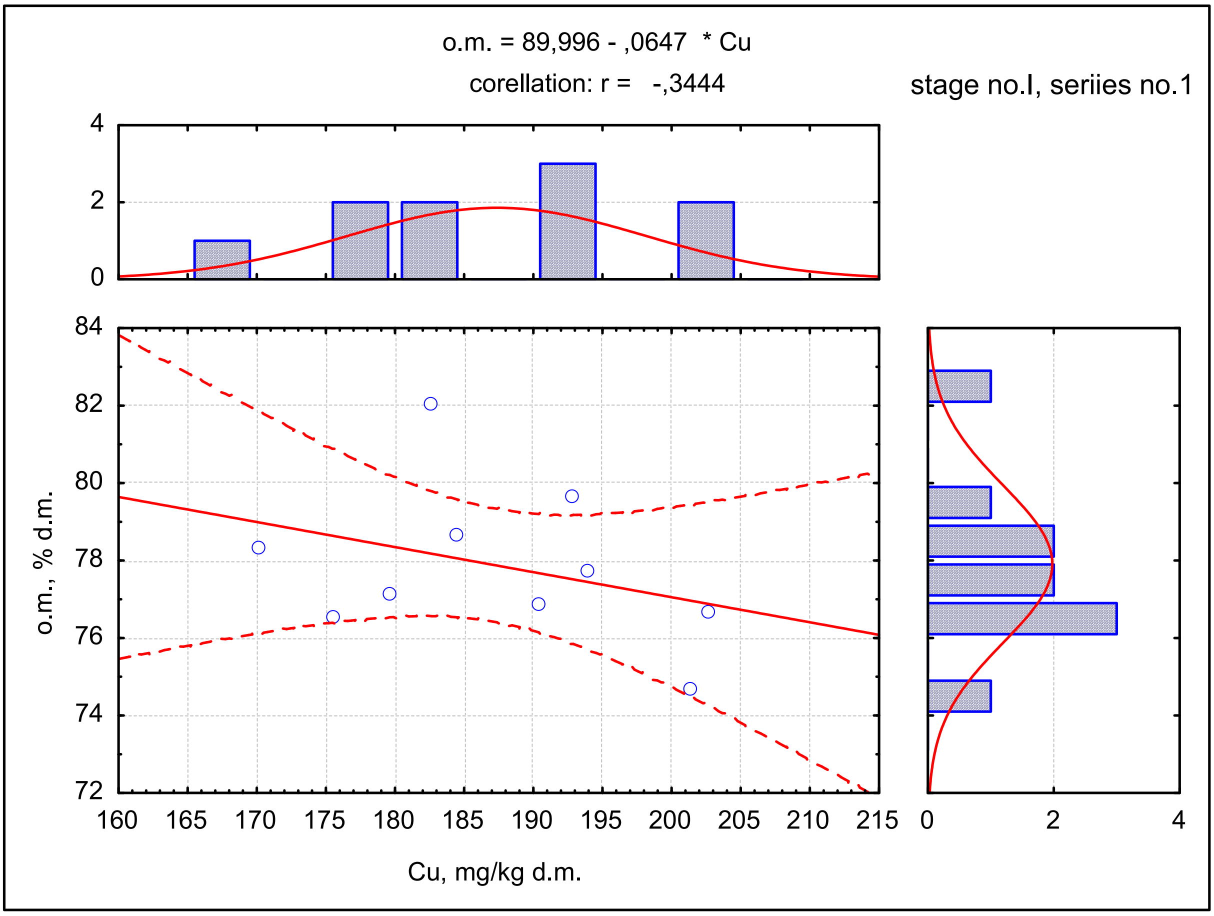

Fig. 33. Correlation between o.m. and Cu, stage no.I (series no.1).

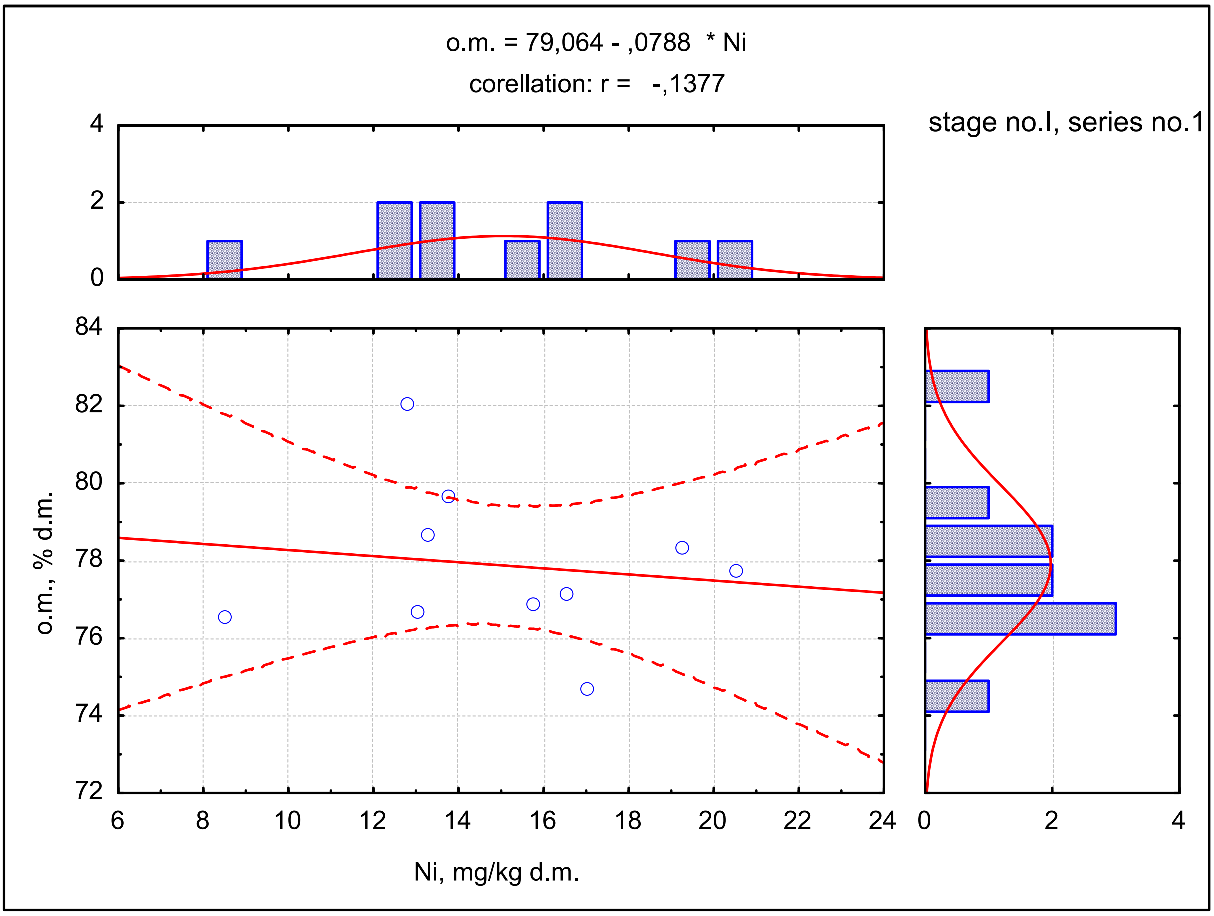

Fig. 34. Correlation between o.m. and Ni, stage no.I (series no.1).

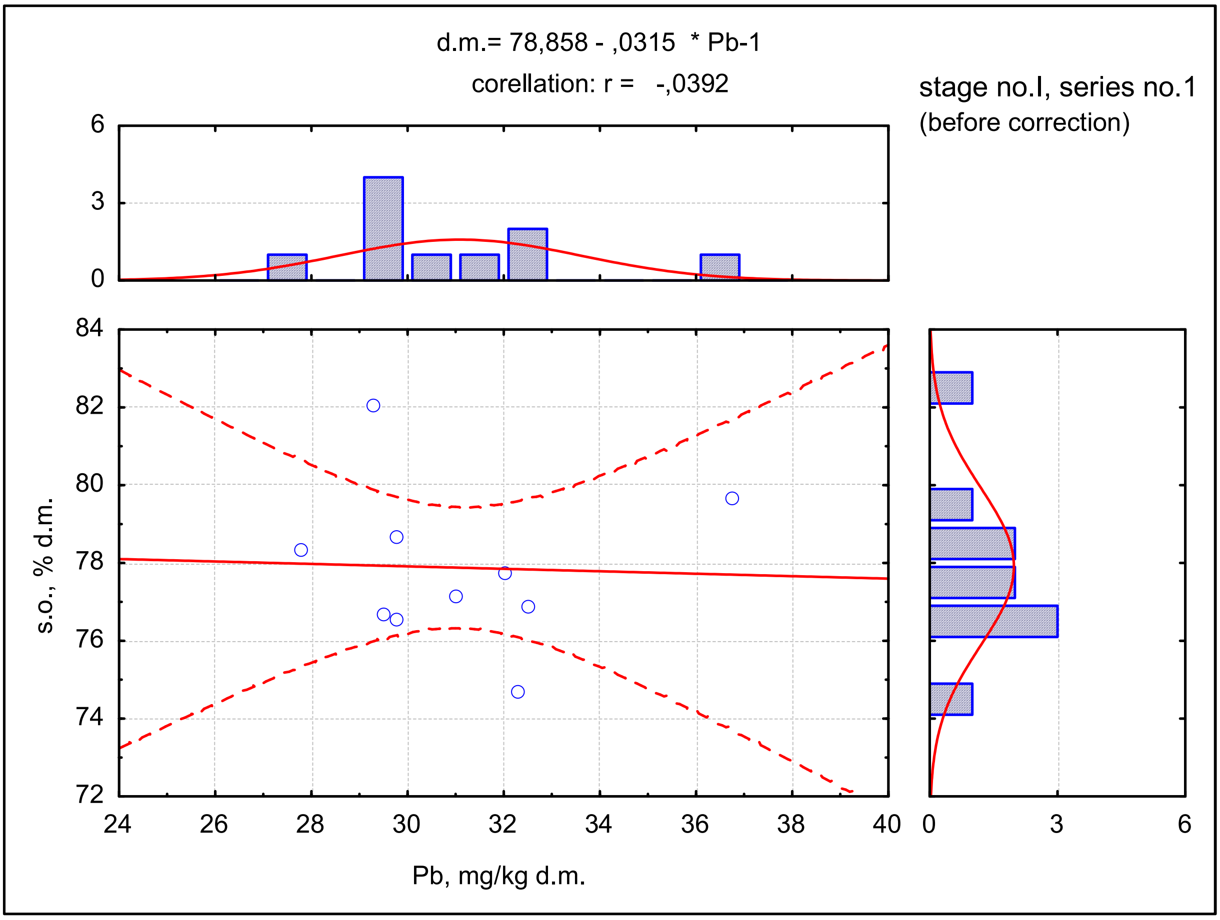

Fig. 35. Correlation between o.m. and Pb, stage no.I (series no.1) - before correction.

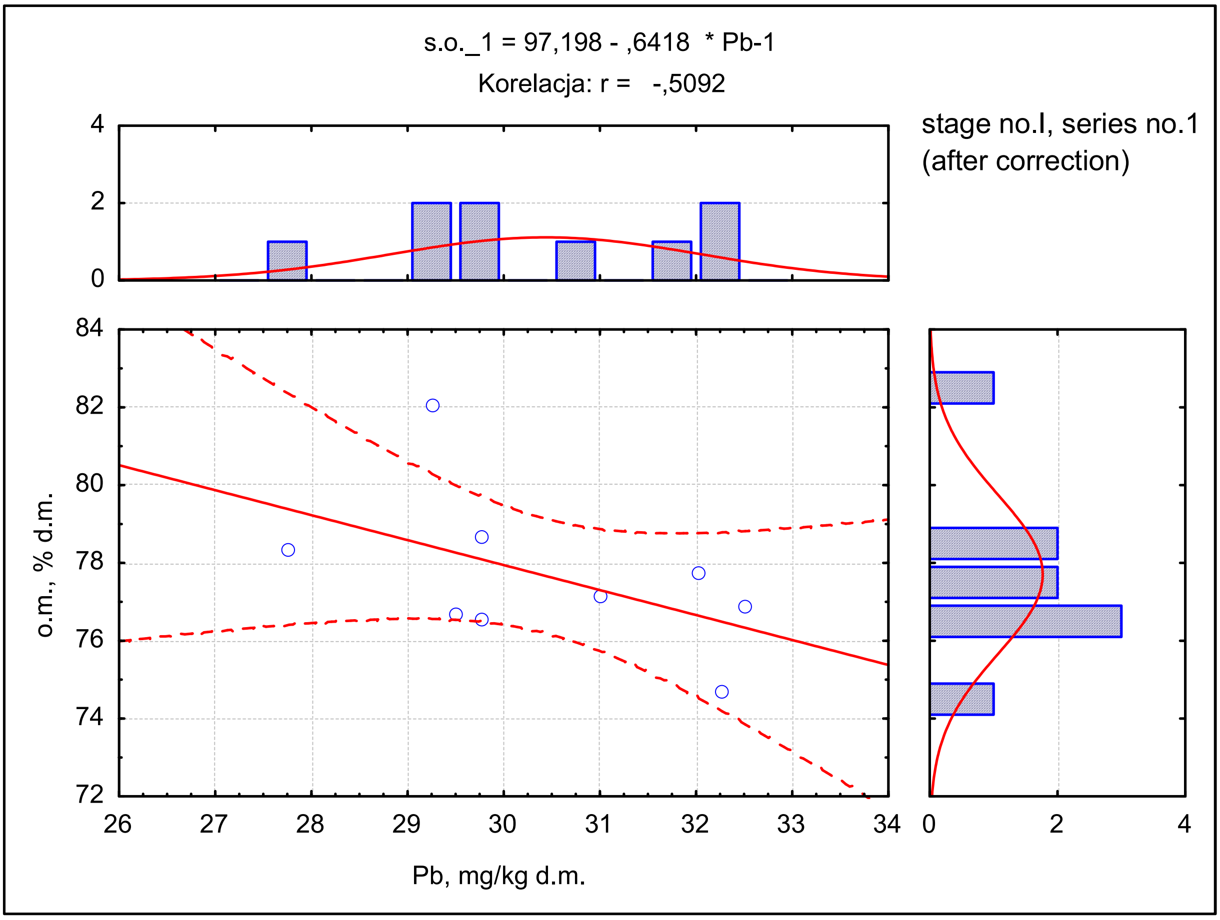

Fig. 36. Correlation between o.m. and Pb, stage no.I (series no.1.) - after correction.

Table 1.1. Values of physicochemical indicators in the samples of composts and substrates in stage no. I - series no.1.

No.	STAGE I, series 1	data of sampling	the sample identification	d.m. %	o.m. % d.m.	C tot., % d.m.	avarage C tot. , % d.m.	N tot., % d.m.	avarage N tot., % d.m..	P tot., % d.m.	C/N
1	compostt (4-1-1)	May 4, 2018	I/1/1_1	21,7	82,1	39,83	39,84	3,815	3,796	2	10
			I/1/1_2			39,84		3,776			
2		11-May	I/1/2_1	28	76,7	37,47	37,33	3,032	3,091	2	12
			I/1/2_2			37,18		3,15			
3		17-May	I/1/3_1	36,1	79,7	37,87	37,45	2,813	2,936	2	13
			I/1/3_2			37,02		3,059			
4		25-May	I/1/4_1	39,8	78,4	37,24	37,22	2,815	2,885	2	13
			I/1/4_2			37,20		2,954			
5		30-May	I/1/5_1	31,3	77,8	37,16	37,24	3,295	3,291	2	11
			I/1/5_2			37,31		3,286			
6		18-Jun	I/1/6_1	37,7	76,6	36,55	36,47	3,415	3,400	2	11
			I/1/6_2			36,39		3,385			
7		02-Jul	I/1/7_1	36,6	77,2	36,50	36,43	3,405	3,428	2	11
			I/1/7_2			36,35		3,45			
8		23-Jul	I/1/8_1	39,1	78,7	38,29	38,04	3,065	3,012	2,31	13
			I/1/8_2			37,78		2,958			
9		20-Aug	I/1/9_1	41,4	76,9	37,05	36,95	3,133	3,141	1,91	12
			I/1/9_2			36,85		3,149			
10		11 - Sept	I/1/10_1	42,5	74,7	35,63	35,67	3,199	3,186	2,23	11
			I/1/10_2			35,70		3,172			
11	sludge sewage	04-May	os._1	21,4	81,4	41,83	33,915	7,502	7,48	2,33	5
			os._2			39,32		7,348			
			os._3			41,59		7,451			
12	straw	04-May	sł._1	62,4	94,2	45,74	45,7	0,694	0,70	-	66
			sł._2			45,08		0,731			
			sł._3			45,66		0,699			
13	wood cheaps	04-May	zrę._1	34,7	87	45,36	44,36	1,062	1,14	-	39
			zrę._2			43,06		1,264			
			zrę._3			43,36		1,21			

Table 2.1. Values of physicochemical indicators in the samples of composts and substrates in stage no. I - series no. 2.

No.	STAGE I, series 1	the sample identification	d.m. %	o.m. % d.m.	C tot., % d.m.	avarage C tot. , % d.m.	N tot., % d.m.	avarage N tot., % d.m..	P tot., % d.m.	C/N
1	compost (8-1-2)	I/2/1_1	20,5	79,9	38,66	38,76	3,933	3,878	2,61	10
		I/2/1_2			38,85		3,823			
2		I/2/2_1	25	79,2	37,02	37,32	3,111	3,030	2,63	12
		I/2/2_2			37,62		2,949			
3		I/2/3_1	28,4	75,3	37,36	37,35	2,828	2,808	2,46	13
		I/2/3_2			37,34		2,788			
4		I/2/4_1	28,9	77,6	36,61	36,75	2,83	2,816	2,42	13
		I/2/4_2			36,88		2,802			
5		I/2/5_1	30,5	75,9	35,21	35,17	2,897	3,159	2,48	11
		I/2/5_2			35,13		3,42			
6		I/2/6_1	34,2	74,7	35,96	35,96	3,049	3,044	2,77	12
		I/2/6_2			35,96		3,039			
7		I/2/7_1	33,6	71,5	34,95	34,81	3,42	3,436	2,81	10
		I/2/7_2			34,66		3,452			
8		I/2/8_1	47,1	71,2	35,46	35,42	3,618	3,619	2	10
		I/2/8_2			35,37		3,62			
9		I/2/9_1	56,7	68,9	34,88	34,74	3,771	3,787	3	9
		I/2/9_2			34,59		3,802			
10		I/2/10_1	59,1	69,1	33,96	34,06	3,737	3,716	3	9
		I/2/10_2			34,16		3,694			

Table 3.1. The content of heavy metals in samples of compost and sewage sludge in stage no.I - series no.1.

No.	STAGE I, series 1	the sample identification	Zn, mg/kg d.m.	Cu, mg/kg d.m..	Cr, mg/kg d.m..	Cd, mg/kg d.m.	Pb, mg/kg d.m.	Ni, mg/kg d.m.	Hg, mg/kg d.m..
1	compost (4-1-1)	I/1/1	405,50 ± 4,24	182,50 ± 4,95	34,75 ± 0,35	1,00 ± 0,00	29,25 ± 1,06	12,75 ± 1,06	0,420±0,066
2		I/1/2	431,75 ± 22,98	202,50 ± 2,83	35,75 ± 0,35	1,00 ± 0,00	29,50 ± 0,71	13,00 ± 0,00	0,382±0,045
3		I/1/3	439,00 ± 27,58	192,75 ± 1,06	37,75 ± 0,35	0,75 ± 0,35	36,75 ± 0,35	13,75 ± 0,35	0,379±0,021
4		I/1/4	378,50 ± 21,92	170,00 ± 8,49	54,00 ± 2,83	1,00 ± 0,00	27,75 ± 2,47	19,25 ± 1,06	0,312±0,033
5		I/1/5	423,25 ± 15,20	193,75 ± 6,72	57,75 ± 6,72	1,00 ± 0,00	32,00 ± 0,71	20,50 ± 0,71	0,375±0,034
6		I/1/6	393,75 ± 30,05	175,50 ± 0,71	22,50 ± 2,12	0,75 ± 0,35	29,75 ± 0,35	8,25 ± 0,35	0,325±0,016
7		I/1/7	400,25 ± 20,86	179,50 ± 2,12	50,75 ± 1,06	0,50 ± 0,00	31,00 ± 0,71	16,50 ± 0,00	0,364±0,025
8		I/1/8	421,00±8,48	184,25±0,35	33,50 ± 0,71	1,25 ± 0,35	29,75±0,35	13,25±0,35	0,347±0,020
9		I/1/9	429,00±1,41	190,25±1,06	45,00 ± 2,12	1,00 ± 0,71	32,50±0,707	15,75±0,35	0,377±0,020
10		I/1/10	453,50±12,02	201,25±1,06	47,75 ± 0,35	1,25 ± 0,35	32,25±1,06	17,00±0,71	0,371±0,003
11	sewage sludge		551,75±3,18	225,25±2,47	26,25±1,06	0,50±0,00	48,50±0,00	10,50±0,71	0,551±0,075
12	86/278/EEC		2500÷4000	1000÷1700	-	20÷40	750÷1200	300÷400	16÷25
13	Dz.U. poz.257, 2015 r.		2500	1000	500	20	750	300	16

Table 4.1. The zinc content in the fractions extracted with the Tessier method, stage I, series no.1

No.	STAGE I series 1	Zn, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	I/1/1_1	16,35	122,50	157,00	65,25	41,40	402,50
	I/1/1_2	16,80	111,50	163,00	60,50	56,70	408,50
2	I/1/2_1	9,90	89,75	183,00	103,25	29,60	415,50
	I/1/2_2	10,65	91,75	180,75	100,25	64,60	448,00
3	I/1/3_1	13,20	106,25	179,50	84,50	36,05	419,50
	I/1/3_2	13,95	97,75	174,75	86,50	85,55	458,50
4	I/1/4_1	13,95	85,25	154,50	85,25	24,05	363,00
	I/1/4_2	14,85	78,75	150,75	86,50	63,15	394,00
5	I/1/5_1	13,65	90,00	183,75	95,25	29,85	412,50
	I/1/5_2	14,55	87,00	190,00	93,25	49,20	434,00
6	I/1/6_1	16,05	69,75	148,00	108,75	29,95	372,50
	I/1/6_2	16,35	67,25	149,00	102,25	80,15	415,00
7	I/1/7_1	13,20	63,50	176,75	112,50	19,55	385,50
	I/1/7_2	13,80	64,00	163,00	112,75	61,45	415,00
8	I/1/8_1	8,85	69,50	162,75	120,50	59,40	421,00
	I/1/8_2	8,85	69,50	162,75	120,50	59,40	421,00
9	I/1/9_1	9,45	69,25	169,75	137,00	42,55	428,00
	I/1/9_2	9,15	64,75	144,25	145,00	66,85	430,00
10	I/1/10_1	11,25	69,25	157,25	139,75	84,50	462,00
	I/1/10_2	10,35	74,00	139,25	151,25	70,15	445,00
11	sludge 1/1	30,45	146,50	261,50	91,00	24,55	554,00
	sludge 1/2	27,45	146,75	245,00	91,25	39,05	549,50

Table 5.1. Average content and percentage of zinc in fractions extracted with the Tessier method, stage I, series no.1.

No.	STAGE I series 1	Zn, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	I/1/1	16,58	117,00	160,00	62,88	49,05	405,50
2	I/1/2	10,28	90,75	181,88	101,75	47,10	431,75
3	I/1/3	13,58	102,00	177,13	85,50	60,80	439,00
4	I/1/4	14,40	82,00	152,63	85,88	43,60	378,50
5	I/1/5	14,10	88,50	186,88	94,25	39,53	423,25
6	I/1/6	16,20	68,50	148,50	105,50	55,05	393,75
7	I/1/7	13,50	63,75	169,88	112,63	40,50	400,25
8	I/1/8	8,85	69,50	162,75	120,50	59,40	421,00
9	I/1/9	9,30	67,00	157,00	141,00	54,70	429,00
10	I/1/10	10,80	71,63	148,25	145,50	77,33	453,50
11	sludge	28,95	146,63	253,25	91,13	31,80	551,75
Zn, [%]							
12	I/1/1	4,09	28,85	39,46	15,51	12,10	100,00
13	I/1/2	2,38	21,02	42,13	23,57	10,91	100,00
14	I/1/3	3,09	23,23	40,35	19,48	13,85	100,00
15	I/1/4	3,80	21,66	40,32	22,69	11,52	100,00
16	I/1/5	3,33	20,91	44,15	22,27	9,34	100,00
17	I/1/6	4,11	17,40	37,71	26,79	13,98	100,00
18	I/1/7	3,37	15,93	42,44	28,14	10,12	100,00
19	I/1/8	2,10	16,51	38,66	28,62	14,11	100,00
20	I/1/9	2,17	15,62	36,60	32,87	12,75	100,00
21	I/1/10	2,38	15,79	32,69	32,08	17,05	100,00
22	sludge	5,25	26,57	45,90	16,52	5,76	100,00

Table 6.1. The copper content in fractions extracted with the Tessier method, stage I, series no.1

No.	STAGE I series 1	Cu, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	I/1/1_1	18,30	6,75	5,75	112,75	42,45	186,00
	I/1/1_2	17,70	6,75	4,75	122,50	27,30	179,00
2	I/1/2_1	6,15	2,50	3,75	146,00	42,10	200,50
	I/1/2_2	6,60	2,75	3,50	145,00	46,65	204,50
3	I/1/3_1	7,05	3,00	4,00	130,50	48,95	193,50
	I/1/3_2	7,20	3,00	3,50	133,50	44,80	192,00
4	I/1/4_1	6,00	2,25	4,00	120,50	43,25	176,00
	I/1/4_2	6,15	2,25	3,25	120,00	32,35	164,00
5	I/1/5_1	5,85	2,00	4,75	131,00	54,90	198,50
	I/1/5_2	6,30	2,25	4,25	135,00	41,20	189,00
6	I/1/6_1	5,25	1,75	3,00	120,00	45,00	175,00
	I/1/6_2	5,70	1,75	2,75	121,00	44,80	176,00
7	I/1/7_1	4,05	1,50	3,00	126,50	45,95	181,00
	I/1/7_2	4,20	1,25	3,00	132,25	37,30	178,00
8	I/1/8_1	3,30	1,75	3,00	123,50	52,95	184,50
	I/1/8_2	3,00	1,50	2,75	120,50	56,25	184,00
9	I/1/9_1	3,60	2,25	3,00	124,00	56,65	189,50
	I/1/9_2	3,30	2,00	3,00	121,25	61,45	191,00
10	I/1/10_1	4,05	2,25	2,50	128,75	64,45	202,00
	I/1/10_2	3,75	2,00	2,75	123,00	69,00	200,50
11	sludge 1/1	29,55	8,50	8,75	131,25	45,45	223,50
	sludge 1/2	25,95	9,25	9,25	131,50	51,05	227,00

Table 7.1. Average content and percentage of copper in fractions extracted with the Tessier method, stage I, series no.1.

No.	STAGE I	Cu, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	suma
1	I/1/1	18,00	6,75	5,25	117,63	34,88	182,50
2	I/1/2	6,38	2,63	3,63	145,50	44,38	202,50
3	I/1/3	7,13	3,00	3,75	132,00	46,88	192,75
4	I/1/4	6,08	2,25	3,63	120,25	37,80	170,00
5	I/1/5	6,08	2,13	4,50	133,00	48,05	193,75
6	I/1/6	5,48	1,75	2,88	120,50	44,90	175,50
7	I/1/7	4,13	1,38	3,00	129,38	41,63	179,50
8	I/1/8	3,15	1,63	2,88	122,00	54,60	184,25
9	I/1/9	3,45	2,13	3,00	122,63	59,05	190,25
10	I/1/10	3,90	2,13	2,63	125,88	66,73	201,25
11	sludge	27,75	8,88	9,00	131,38	48,25	225,25
		Cu, [%]					
12	I/1/1	9,86	3,70	2,88	64,45	19,11	100,00
13	I/1/2	3,15	1,30	1,79	71,85	21,91	100,00
14	I/1/3	3,70	1,56	1,95	68,48	24,32	100,00
15	I/1/4	3,57	1,32	2,13	70,74	22,24	100,00
16	I/1/5	3,14	1,10	2,32	68,65	24,80	100,00
17	I/1/6	3,12	1,00	1,64	68,66	25,58	100,00
18	I/1/7	2,30	0,77	1,67	72,08	23,19	100,00
19	I/1/8	1,71	0,88	1,56	66,21	29,63	100,00
20	I/1/9	1,81	1,12	1,58	64,45	31,04	100,00
21	I/1/10	1,94	1,06	1,30	62,55	33,16	100,00
22	sludge	12,32	3,94	4,00	58,32	21,42	100,00

Table 8.1. The nickel content in fractions extracted with the Tessier method, stage I, series no.1

No.	STAGE I series 1	Ni, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	I/1/1_1	0,75	0,50	1,00	2,50	7,25	12,00
	I/1/1_2	0,60	0,25	0,75	2,25	9,65	13,50
2	I/1/2_1	0,15	0,25	0,50	3,50	8,60	13,00
	I/1/2_2	0,15	0,25	0,50	3,25	8,85	13,00
3	I/1/3_1	0,30	0,00	0,50	3,00	10,20	14,00
	I/1/3_2	0,30	0,00	0,50	3,00	9,70	13,50
4	I/1/4_1	0,15	0,25	0,50	3,00	16,10	20,00
	I/1/4_2	0,15	0,00	0,50	3,25	14,60	18,50
5	I/1/5_1	0,15	0,00	0,25	3,50	17,10	21,00
	I/1/5_2	0,15	0,00	0,25	3,25	16,35	20,00
6	I/1/6_1	0,15	0,00	0,00	3,25	4,60	8,00
	I/1/6_2	0,30	0,50	0,00	3,25	4,85	8,50
7	I/1/7_1	0,15	0,00	0,00	3,50	12,85	16,50
	I/1/7_2	0,15	0,00	0,00	3,50	12,85	16,50
8	I/1/8_1	0,15	0,25	0,00	3,25	9,35	13,00
	I/1/8_2	0,15	0,25	0,00	3,00	10,10	13,50
9	I/1/9_1	0,15	0,25	0,00	3,25	12,35	16,00
	I/1/9_2	0,15	0,25	0,00	3,25	11,85	15,50
10	I/1/10_1	0,15	0,25	0,00	3,50	13,60	17,50
	I/1/10_2	0,15	0,00	0,00	3,25	13,10	16,50
11	sludge 1/1	2,25	2,50	1,25	1,50	2,50	10,00
	sludge 1/2	1,80	2,75	1,25	1,50	3,70	11,00

Table 9.1. Average content and percentage of nickel in fractions extracted with the Tessier method, stage I, series no.1.

No.	STAGE I	Ni, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	suma
1	I/1/1	0,68	0,38	0,88	2,38	8,45	12,75
2	I/1/2	0,15	0,25	0,50	3,38	8,73	13,00
3	I/1/3	0,30	0,00	0,50	3,00	9,95	13,75
4	I/1/4	0,15	0,13	0,50	3,13	15,35	19,25
5	I/1/5	0,15	0,00	0,25	3,38	16,73	20,50
6	I/1/6	0,23	0,25	0,00	3,25	4,73	8,45
7	I/1/7	0,15	0,00	0,00	3,50	12,85	16,50
8	I/1/8	0,15	0,25	0,00	3,13	9,73	13,25
9	I/1/9	0,15	0,25	0,00	3,25	12,10	15,75
10	I/1/10	0,15	0,13	0,00	3,38	13,35	17,00
11	sludge	2,03	2,63	1,25	1,50	3,10	10,50
		Ni, [%]					
12	I/1/1	5,29	2,94	6,86	18,63	66,27	100,00
13	I/1/2	1,15	1,92	3,85	25,96	67,12	100,00
14	I/1/3	2,18	0,00	3,64	21,82	72,36	100,00
15	I/1/4	0,78	0,65	2,60	16,23	79,74	100,00
16	I/1/5	0,73	0,00	1,22	16,46	81,59	100,00
17	I/1/6	2,66	2,96	0,00	38,46	55,92	100,00
18	I/1/7	0,91	0,00	0,00	21,21	77,88	100,00
19	I/1/8	1,13	1,89	0,00	23,58	73,40	100,00
20	I/1/9	0,95	1,59	0,00	20,63	76,83	100,00
21	I/1/10	0,88	0,74	0,00	19,85	78,53	100,00
22	sludge	19,29	25,00	11,90	14,29	29,52	100,00

Table 10.1. The content of heavy metals in samples of compost in stage no.I - series no.2.

No.	STAGE I, series 2	the sample identification	Zn, mg/kg d.m.	Cu, mg/kg d.m..	Cr, mg/kg d.m..	Cd, mg/kg d.m.	Pb, mg/kg d.m.	Ni, mg/kg d.m.	Hg, mg/kg d.m..
1	compost (8-1-2)	I/2/1	441,50±4,95	189,00±3,53	37,75 ± 2,47	0,05 ± 0,00	33,75±0,35	13,50±0,71	0,386±0,064
2		I/2/2	475,25±1,77	204,25±0,35	53,25 ± 1,77	0,05 ± 0,71	34,50±0,71	18,25±0,35	0,508±0,054
3		I/2/3	482,75±16,61	208,75±1,77	46,00 ± 1,41	0,05 ± 0,35	36,50±2,12	16,25±0,35	0,466±0,076
4		I/2/4	484,50±19,80	212,25±2,47	48,00 ± 2,83	1,00 ± 0,71	37,00±1,41	16,50±1,41	0,428±0,042
5		I/2/5	509,31±18,12	219,08±2,94	71,34 ± 4,72	0,79 ± 0,30	40,13±3,71	22,47±2,08	0,448±0,035
6		I/2/6	532,50±18,38	238,95±5,59	72,25 ± 3,89	1,25 ± 0,35	41,0±0,00	24,25±0,35	0,449±0,014
7		I/2/7	548,71±2,53	235,50±0,71	35,68 ± 0,25	1,01 ± 0,01	41,71±1,00	14,07±0,81	0,491±0,064
8		I/2/8	533,50 ± 44,55	245,75 ± 1,77	43,75 ± 1,77	1,00 ± 0,00	40,50 ± 0,00	16,00 ± 1,41	0,531±0,033
9		I/2/9	562,00 ± 30,41	255,25 ± 2,47	40,50 ± 1,41	0,25 ± 0,35	41,75 ± 0,35	15,25 ± 0,35	0,513±0,033
10		I/2/10	555,00 ± 31,11	253,50 ± 4,95	58,75 ± 7,42	0,50 ± 0,00	41,25 ± 0,35	22,00 ± 2,12	0,548±0,050

Table 11.1. The zinc content in the fractions extracted with the Tessier method.
stage I, series no.2.

No.	STAGE I series 2	Zn , [mg/kg d.m.] - two subsamples					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	I/2/1_1	14,25	128,25	163,00	87,50	45,00	438,00
	I/2/1_2	14,25	121,50	162,75	94,00	52,50	445,00
2	I/2/2_1	14,70	119,50	174,50	94,00	73,80	476,50
	I/2/2_2	15,15	114,50	182,50	94,75	67,10	474,00
3	I/2/3_1	16,35	115,25	192,00	94,75	52,65	471,00
	I/2/3_2	16,95	116,00	175,75	99,50	86,30	494,50
4	I/2/4_1	19,20	116,50	197,00	95,25	42,55	470,50
	I/2/4_2	19,65	108,25	170,25	125,75	74,60	498,50
5	I/2/5_1	14,25	106,50	211,00	93,50	71,25	496,50
	I/2/5_2	13,95	112,25	199,75	119,25	76,92	522,12
6	I/2/6_1	12,00	93,25	207,75	135,00	71,50	519,50
	I/2/6_2	11,85	91,00	218,75	138,00	85,90	545,50
7	I/2/7_1	9,90	84,75	220,75	159,75	71,77	546,92
	I/2/7_2	10,05	80,75	196,75	175,75	87,20	550,50
8	I/2/8_1	10,80	70,00	190,00	169,50	61,70	502,00
	I/2/8_2	10,80	68,50	207,25	170,50	107,95	565,00
9	I/2/9_1	10,20	64,25	188,25	172,25	105,55	540,50
	I/2/9_2	10,35	61,25	202,50	168,50	140,90	583,50
10	I/2/10_1	10,35	64,25	195,25	173,25	89,90	533,00
	I/2/10_2	10,50	66,25	193,50	181,00	125,75	577,00

Table 12.1. Average content and percentage of zinc in fractions extracted with the Tessier method, stage I, series no.2.

No.	STAGE I series 2	Zn , [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	I/2/1	14,25	124,88	162,88	90,75	48,75	441,50
2	I/2/2	14,93	117,00	178,50	94,38	70,45	475,25
3	I/2/3	16,65	115,63	183,88	97,13	69,48	482,75
4	I/2/4	19,43	112,38	183,63	110,50	58,58	484,50
5	I/2/5	14,10	109,38	205,38	106,38	74,09	509,31
6	I/2/6	11,93	92,13	213,25	136,50	78,70	532,50
7	I/2/7	9,98	82,75	208,75	167,75	79,48	548,71
8	I/2/8	10,80	69,25	198,63	170,00	84,83	533,50
9	I/2/9	10,28	62,75	195,38	170,38	123,23	562,00
10	I/2/10	10,43	65,25	194,38	177,13	107,83	555,00
Zn, [%]							
11	I/2/1	3,23	28,28	36,89	20,55	11,04	100,00
12	I/2/2	3,14	24,62	37,56	19,86	14,82	100,00
13	I/2/3	3,45	23,95	38,09	20,12	14,39	100,00
14	I/2/4	4,01	23,19	37,90	22,81	12,09	100,00
15	I/2/5	2,77	21,48	40,32	20,89	14,55	100,00
16	I/2/6	2,24	17,30	40,05	25,63	14,78	100,00
17	I/2/7	1,82	15,08	38,04	30,57	14,49	100,00
18	I/2/8	2,02	12,98	37,23	31,87	15,90	100,00
19	I/2/9	1,83	11,17	34,76	30,32	21,93	100,00
20	I/2/10	1,88	11,76	35,02	31,91	19,43	100,00

Table 13.1. The copper content in the fractions extracted with the Tessier method. stage I, series no.2.

No.	STAGE I series 2	Cu, [mg/kg d.m.] - two subsamples					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	1/2/1	14,25	5,25	4,25	120,00	47,75	191,50
	1/2/2	14,25	5,25	4,00	121,50	41,50	186,50
2	2/2/1	7,65	3,25	4,25	133,50	55,85	204,50
	2/2/2	7,80	3,50	4,50	129,00	59,20	204,00
3	3/2/1	7,50	3,00	4,00	137,50	55,50	207,50
	3/2/2	7,80	3,00	3,50	138,50	57,20	210,00
4	4/2/1	6,90	2,50	3,50	141,00	56,60	210,50
	4/2/2	6,60	2,50	3,00	145,25	56,65	214,00
5	5/2/1	5,10	2,25	3,50	126,50	79,65	217,00
	5/2/2	5,55	2,25	3,50	141,25	68,61	221,16
6	6/2/1	4,35	1,75	3,50	150,75	74,65	235,00
	6/2/2	4,35	1,75	3,25	141,00	85,65	236,00
7	7/2/1	3,75	1,50	3,25	155,50	78,91	242,91
	7/2/2	3,90	1,50	3,25	155,75	70,60	235,00
8	8/2/1	4,05	1,50	3,50	169,50	65,95	244,50
	8/2/2	4,35	1,50	3,00	173,00	65,15	247,00
9	9/2/1	3,75	1,25	3,00	167,50	78,00	253,50
	9/2/2	3,75	1,25	3,00	170,75	78,25	257,00
10	10/2/1	4,35	1,50	2,75	165,75	82,65	257,00
	10/2/2	4,65	1,50	2,75	166,25	74,85	250,00

Table 14.1. Average content and percentage of copper in fractions extracted with the Tessier method, stage I, series no.2.

No.	STAGE I series 2	Cu, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	I/2/1	14,25	5,25	4,13	120,75	44,63	189,00
2	I/2/2	7,73	3,38	4,38	131,25	57,53	204,25
3	I/2/3	7,65	3,00	3,75	138,00	56,35	208,75
4	I/2/4	6,75	2,50	3,25	143,13	56,63	212,25
5	I/2/5	5,33	2,25	3,50	133,88	74,13	219,08
6	I/2/6	4,35	1,75	3,38	145,88	80,15	235,50
7	I/2/7	3,83	1,50	3,25	155,63	74,75	238,95
8	I/2/8	4,20	1,50	3,25	171,25	65,55	245,75
9	I/2/9	3,75	1,25	3,00	169,13	78,13	255,25
10	I/2/10	4,50	1,50	2,75	166,00	78,75	253,50
Cu, [%]							
11	1/2	7,54	2,78	2,18	63,89	23,61	100,00
12	2/2	3,78	1,65	2,14	64,26	28,16	100,00
13	3/2	3,66	1,44	1,80	66,11	26,99	100,00
14	4/2	3,18	1,18	1,53	67,43	26,68	100,00
15	5/2	2,43	1,03	1,60	61,11	33,84	100,00
16	6/2	1,85	0,74	1,43	61,94	34,03	100,00
17	7/2	1,60	0,63	1,36	65,13	31,28	100,00
18	8/2	1,71	0,61	1,32	69,68	26,67	100,00
19	9/2	1,47	0,49	1,18	66,26	30,61	100,00
20	10/2	1,78	0,59	1,08	65,48	31,07	100,00

Table 15.1. The nickel content in the fractions extracted with the Tessier method stage I, series no.2.

No.	STAGE I series 2	Ni , [mg/kg d.m.] - two subsamples					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	1/2/1	0,90	0,50	0,50	2,50	9,60	14,00
	1/2/2	0,75	0,25	0,50	2,50	9,00	13,00
2	2/2/1	0,30	0,50	0,50	3,25	13,95	18,50
	2/2/2	0,30	0,50	0,25	3,00	13,95	18,00
3	3/2/1	0,30	0,25	0,50	3,00	11,95	16,00
	3/2/2	0,30	0,25	0,25	3,00	12,70	16,50
4	4/2/1	0,30	0,25	0,25	3,25	11,45	15,50
	4/2/2	0,30	0,25	0,25	3,25	13,45	17,50
5	5/2/1	0,15	0,25	0,25	3,00	17,35	21,00
	5/2/2	0,30	0,25	0,25	3,25	19,89	23,94
6	6/2/1	0,30	0,25	0,25	4,00	19,20	24,00
	6/2/2	0,15	0,25	0,00	3,75	20,35	24,50
7	7/2/1	0,15	0,25	0,00	4,00	10,25	14,65
	7/2/2	0,15	0,25	0,00	3,75	9,35	13,50
8	8/2/1	0,30	0,50	0,00	4,25	11,95	17,00
	8/2/2	0,15	0,50	0,00	4,50	9,85	15,00
9	9/2/1	0,15	0,50	0,00	4,50	10,35	15,50
	9/2/2	0,15	0,50	0,00	4,50	9,85	15,00
10	10/2/1	0,15	0,50	0,00	5,00	17,85	23,50
	10/2/2	0,15	0,50	0,00	5,25	14,60	20,50

Table 16.1. Average content and percentage of nickel in fractions extracted with the Tessier method, stage I, series no.2.

No.	STAGE I series 2	Ni, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	1/2	0,83	0,38	0,50	2,50	9,30	13,50
2	2/2	0,30	0,50	0,38	3,13	13,95	18,25
3	3/2	0,30	0,25	0,38	3,00	12,33	16,25
4	4/2	0,30	0,25	0,25	3,25	12,45	16,50
5	5/2	0,23	0,25	0,25	3,13	18,62	22,47
6	6/2	0,23	0,25	0,13	3,88	19,78	24,25
7	7/2	0,15	0,25	0,00	3,88	9,80	14,07
8	8/2	0,23	0,50	0,00	4,38	10,90	16,00
9	9/2	0,15	0,50	0,00	4,50	10,10	15,25
10	10/2	0,15	0,50	0,00	5,13	16,23	22,00
Ni, [%]							
11	1/2	6,11	2,78	3,70	18,52	68,89	100,00
12	2/2	1,64	2,74	2,05	17,12	76,44	100,00
13	3/2	1,85	1,54	2,31	18,46	75,85	100,00
14	4/2	1,82	1,52	1,52	19,70	75,45	100,00
15	5/2	1,00	1,11	1,11	13,91	82,87	100,00
16	6/2	0,93	1,03	0,52	15,98	81,55	100,00
17	7/2	1,07	1,78	0,00	27,54	69,62	100,00
18	8/2	1,41	3,13	0,00	27,34	68,13	100,00
19	9/2	0,98	3,28	0,00	29,51	66,23	100,00
20	10/2	0,68	2,27	0,00	23,30	73,75	100,00

Table 17.1. Content of humic substance and values of humification indexes in samples of composts and sludge, stage I.

No.	STAGE I	sample symbol	humic substance						C org., [g/kg s.m.]	humification index	
			specific, [g/kg d.m.]			non specific, [% d.m.]				PI, [-] (HA/FA)	HI, [%] (C_{HA}/C_{tot})100
			HA	FA	Total	lignin	cellulose	hemicell.			
1	series 1	I/1/1	174,22	81,96	256,18	18,28	9,37	15,21	398,35	2,13	43,74
2		I/1/2	159,29	51,12	210,41	30,25	10,83	11,14	373,25	3,12	42,68
3		I/1/3	164,58	39,69	204,27	29,48	14,40	7,55	374,45	4,15	43,95
4		I/1/4	162,63	45,77	208,40	34,26	11,56	12,87	372,20	3,55	43,69
5		I/1/5	174,33	60,56	234,89	22,94	10,56	8,57	372,35	2,88	46,82
6		I/1/6	176,84	57,96	234,80	29,41	11,54	10,31	364,70	3,05	48,49
7		I/1/7	173,29	56,36	229,65	24,90	8,12	9,63	364,25	3,07	47,58
8		I/1/8	183,18	44,02	227,20	27,61	10,11	3,56	380,35	4,16	48,16
9		I/1/9	188,23	40,12	228,36	30,83	11,94	2,49	369,50	4,69	50,94
10		I/1/10	174,93	49,60	224,53	29,87	10,41	0,68	356,65	3,53	49,05
11	series 2	I/2/1	164,99	69,39	234,38	25,18	11,76	5,75	387,55	2,38	42,57
12		I/2/2	160,43	63,60	224,03	27,29	11,23	9,49	373,20	2,52	42,99
13		I/2/3	148,81	45,80	194,61	30,61	13,86	10,56	373,50	3,25	39,84
14		I/2/4	150,20	48,09	198,29	27,68	11,53	9,43	367,45	3,12	40,88
15		I/2/5	152,95	50,58	203,53	26,45	13,53	16,43	351,70	3,02	43,49
16		I/2/6	159,74	39,80	199,54	31,83	10,81	4,38	359,60	4,01	44,42
17		I/2/7	172,65	29,40	202,05	32,30	8,50	5,54	347,90	5,87	49,63
18		I/2/8	174,44	43,77	218,21	26,96	6,10	4,14	354,15	3,99	49,25
19		I/2/9	176,44	27,66	204,09	26,96	5,40	2,27	347,35	6,38	50,80
20		I/2/10	185,69	34,17	219,86	26,31	5,76	2,58	340,60	5,43	54,52
21	sewage sludge		169,73	105,38	275,11	14,27	3,53	13,64	339,15	1,61	50,04

Tabela 18.2. Values of physicochemical indicators in the samples of composts and substrates in stage no. II - series no.1.

No.	STAGE II, series 1	data of sampling	the sample identification	d.m. %	o.m. % d.m.	C tot., % d.m.	N tot., % d.m.	P tot., % d.m.	C/N
1	compost (4-1-1)	24-Oct. 2018	II/1/1	35,2	85,2	42,85	2,30	1,25	19
2		31-Oct.	II/1/2	36,4	89,6	42,09	2,38	0,71	18
3		Nov.-06.	II/1/3	33,3	84,6	40,54	2,8	1,54	14
4		Nov.-13.	II/1/4	33,6	77,5	38,39	2,93	1,57	13
5		Nov.-20.	II/1/5	38,5	75,9	38,46	3,36	1,7	11
6		Dec.-04.	II/1/6	36,6	73,8	36,59	3,61	2,02	10
7		Dec.-18.	II/1/7	40,5	76	37,03	3,73	1,73	10
8		Jan.-02.	II/1/8	40,8	75,2	37,90	3,89	1,88	10
9		Jan.-21.	II/1/9	42,6	73,5	34,76	3,74	1,93	9
10		Feb.-12	II/1/10	42,2	73,2	36,77	3,92	2,43	9
11		05- march.	II/1/11	47,6	74	37,76	3,8	1,47	10
12	sewage sludge	24-Oct. 2018	os.	15,6	78,2	40,4	7,54	2,85	5
13	straw	24-Oct. 2018	sł.	62,0	94	45,5	0,71	-	64
14	wood chips	24-Oct. 2018	zrę.	34,0	87	44,4	1,18	-	38

Table 19.2. Values of physicochemical indicators in the samples of composts and substrates in stage no. II - series no.2.

No.	STAGE II, series 2	data of sampling	the sample identification	d.m. %	o.m. % d.m.	C tot., % d.m.	N tot., % d.m.	P tot., % d.m.	C/N
1	compostt (8-1-2)	24-Oct. 2018	II/2/1	30,9	80,700	39,40	4,270	1,96	9
2		31-Oct.	II/2/2	32,1	83,2	40,05	2,44	1,28	16
3		Nov.-06.	II/2/3	33,5	79,2	38,25	2,76	1,57	14
4		Nov.-13.	II/2/4	25,7	73,3	37,50	2,91	1,93	13
5		Nov.-20.	II/2/5	27,9	73,2	36,50	3,96	1,98	9
6		Dec.-04.	II/2/6	27,5	71,3	36,60	3,2	2,06	11
7		Dec.-18.	II/2/7	31,3	74	36,80	3,35	2,31	11
8		Jan.-02.	II/2/8	31,4	71,6	37,27	3,33	2,54	11
9		Jan.-21.	II/2/9	31,2	69,9	36,88	3,56	2,47	10
10		Feb.-12	II/2/10	32,9	71,9	37,35	3,39	2,43	11
11		05- march.	II/2/11	35,9	70,1	36,02	3,54	2,53	10

Table 20.2. The content of heavy metals in samples of compost and sewage sludge in stage II - series no.1.

No.	STAGE II series 1	sample symbol	Zn, mg/kg d.m.	Cu, mg/kg d.m.	Cr, mg/kg d.m.	Cd, mg/kg d.m.	Pb, mg/kg d.m.	Ni, mg/kg d.m.	Hg, mg/kg d.m.
1	compost (4-1-1)	II/1/1	312,00	106,00	125,25	0,25	5,75	38,75	0,166
2		II/1/2	134,00	61,75	37,75	0,25	3,75	12,75	0,113
3		II/1/3	300,00	137,00	27,25	0,25	7,50	10,00	0,194
4		II/1/4	334,75	158,25	40,00	0,50	8,75	13,75	0,255
5		II/1/5	359,00	175,00	63,75	0,75	10,50	21,25	0,289
6		II/1/6	423,75	207,00	74,00	0,00	16,00	24,00	0,376
7		II/1/7	372,50	176,00	66,00	0,25	11,50	21,00	0,343
8		II/1/8	417,25	199,50	76,75	0,50	13,50	24,25	0,371
9		II/1/9	427,50	205,25	72,00	0,25	22,25	22,50	0,321
10		II/1/10	478,00	217,50	107,75	0,75	16,00	33,25	0,369
11		II/1/11	312,25	184,75	63,75	0,00	12,75	19,75	0,423
12	sewage sludge		497,25	252,25	27,00	0,50	8,75	11,75	0,463

Table 21.2. Average content and percentage of zinc in fractions extracted with the Tessier method in stage II, series 1.

No.	STAGE II series 1	Zn, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	II/1/1	8,78	73,38	57,50	40,63	131,73	312,00
2	II/1/2	9,15	56,63	38,13	25,63	4,47	134,00
3	II/1/3	9,83	72,75	88,13	71,13	58,18	300,00
4	II/1/4	9,75	61,50	117,13	109,47	36,91	334,75
5	II/1/5	10,58	58,38	134,00	114,38	41,68	359,00
6	II/1/6	11,10	67,38	147,38	146,38	51,53	423,75
7	II/1/7	8,70	57,75	129,63	134,25	42,18	372,50
8	II/1/8	7,95	64,63	150,00	140,13	54,55	417,25
9	II/1/9	11,25	71,00	138,50	150,25	56,50	427,50
10	II/1/10	13,88	86,50	159,88	165,75	52,00	478,00
11	II/1/11	8,40	61,63	125,38	136,28	65,33	397,00
12	sludge	12,60	98,25	174,50	157,50	30,65	473,50
Zn, [%]							
13	II/1/1	2,81	23,52	18,43	13,02	42,22	100,00
14	II/1/2	6,83	42,26	28,45	19,12	3,34	100,00
15	II/1/3	3,28	24,25	29,38	23,71	19,39	100,00
16	II/1/4	2,91	18,37	34,99	32,70	11,02	100,00
17	II/1/5	2,95	16,26	37,33	31,86	11,61	100,00
18	II/1/6	2,62	15,90	34,78	34,54	12,16	100,00
19	II/1/7	2,34	15,50	34,80	36,04	11,32	100,00
20	II/1/8	1,91	15,49	35,95	33,58	13,07	100,00
21	II/1/9	2,63	16,61	32,40	35,15	13,22	100,00
22	II/1/10	2,90	18,10	33,45	34,68	10,88	100,00
23	II/1/11	2,12	15,52	31,58	34,33	16,45	100,00
24	sludge	2,66	20,75	36,85	33,26	6,47	100,00

Table 22.2. Average content and percentage of copper in fractions extracted with the Tessier method in stage II, series 1.

No.	STAGE II series 1	Cu, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	II/1/1	10,20	3,50	1,63	66,25	24,43	106,00
2	II/1/2	7,80	2,63	1,13	42,13	8,08	61,75
3	II/1/3	7,80	2,88	2,25	89,88	34,20	137,00
4	II/1/4	5,10	1,63	2,63	122,86	26,05	158,25
5	II/1/5	5,78	1,88	3,38	135,13	28,85	175,00
6	II/1/6	5,33	2,38	3,25	166,88	29,18	207,00
7	II/1/7	3,68	2,13	2,75	146,25	21,20	176,00
8	II/1/8	3,45	2,25	3,25	156,75	33,80	199,50
9	II/1/9	4,13	2,50	2,88	159,50	36,25	205,25
10	II/1/10	4,13	2,63	2,75	173,63	34,38	217,50
11	II/1/11	3,38	2,38	3,00	145,69	30,31	184,75
12	sludge	40,65	7,25	3,25	174,75	13,60	239,50
		Cu, [%]					
13	II/1/1	9,62	3,30	1,53	62,50	23,04	100,00
14	II/1/2	12,63	4,25	1,82	68,22	13,08	100,00
15	II/1/3	5,69	2,10	1,64	65,60	24,96	100,00
16	II/1/4	3,22	1,03	1,66	77,63	16,46	100,00
17	II/1/5	3,30	1,07	1,93	77,21	16,49	100,00
18	II/1/6	2,57	1,15	1,57	80,62	14,09	100,00
19	II/1/7	2,09	1,21	1,56	83,10	12,05	100,00
20	II/1/8	1,73	1,13	1,63	78,57	16,94	100,00
21	II/1/9	2,01	1,22	1,40	77,71	17,66	100,00
22	II/1/10	1,90	1,21	1,26	79,83	15,80	100,00
23	II/1/11	1,83	1,29	1,62	78,86	16,41	100,00
24	sludge	16,97	3,03	1,36	72,96	5,68	100,00

Table 23.2. Average content and percentage of nickel in fractions extracted with the Tessier method in stage II, series 1.

No.	STAGE II series 1	Ni, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	II/1/1	0,30	0,00	0,00	2,25	36,20	38,75
2	II/1/2	0,15	0,00	0,00	1,00	11,60	12,75
3	II/1/3	0,23	0,00	0,00	2,00	7,78	10,00
4	II/1/4	0,23	0,00	0,00	2,50	11,03	13,75
5	II/1/5	0,30	0,00	0,00	3,00	17,95	21,25
6	II/1/6	0,00	0,50	0,00	3,50	20,00	24,00
7	II/1/7	0,08	0,50	0,00	3,25	17,18	21,00
8	II/1/8	0,15	0,25	0,00	3,50	20,35	24,25
9	II/1/9	0,15	0,50	0,00	3,50	18,35	22,50
10	II/1/10	0,08	0,50	0,25	3,75	28,68	33,25
11	II/1/11	0,15	1,00	0,25	3,50	14,85	19,75
12	sludge	1,50	0,75	0,50	2,50	5,75	11,00
		Ni, [%]					
13	II/1/1	0,77	0,00	0,00	5,81	93,42	100,00
14	II/1/2	1,18	0,00	0,00	7,84	90,98	100,00
15	II/1/3	2,25	0,00	0,00	20,00	77,75	100,00
16	II/1/4	1,64	0,00	0,00	18,18	80,18	100,00
17	II/1/5	1,41	0,00	0,00	14,12	84,47	100,00
18	II/1/6	0,00	2,08	0,00	14,58	83,33	100,00
19	II/1/7	0,36	2,38	0,00	15,48	81,79	100,00
20	II/1/8	0,62	1,03	0,00	14,43	83,92	100,00
21	II/1/9	0,67	2,22	0,00	15,56	81,56	100,00
22	II/1/10	0,23	1,50	0,75	11,28	86,24	100,00
23	II/1/11	0,76	5,06	1,27	17,72	75,19	100,00
24	sludge	13,64	6,82	4,55	22,73	52,27	100,00

Table 24.2. he content of heavy metals in samples of compost and sewage sludge in stage II - series no.2.

No.	STAGE II series 1	sample symbol	Zn, mg/kg d.m.	Cu, mg/kg d.m.	Cr, mg/kg d.m.	Cd, mg/kg d.m.	Pb, mg/kg d.m.	Ni, mg/kg d.m.	Hg, mg/kg d.m.
1	compost (8-1-2)	II/2/1	372,50	174,75	42,50	0,75	7,00	13,00	0,438
2		II/2/2	245,50	112,25	84,75	0,00	3,75	24,25	0,169
3		II/2/3	307,50	135,25	58,00	0,50	6,00	16,50	0,375
4		II/2/4	413,00	196,75	55,00	0,75	18,00	16,50	0,363
5		II/2/5	406,50	195,00	98,00	1,00	9,25	28,50	0,349
6		II/2/6	442,50	214,50	87,75	0,50	9,75	26,75	0,395
7		II/2/7	423,25	198,50	87,75	0,75	8,50	26,00	0,409
8		II/2/8	477,75	223,00	88,25	1,00	9,75	26,25	0,386
9		II/2/9	487,25	229,25	68,50	1,00	13,25	20,50	0,487
10		II/2/10	450,25	212,50	111,00	1,00	10,50	32,75	0,414
11		II/2/11	459,50	220,00	46,50	0,75	9,75	14,50	0,413
12	sewage sludge		497,25	252,25	27,00	0,50	8,75	11,75	0,463

Table 25.2. Average content and percentage of zinc in fractions extracted with the Tessier method in stage II, series 2.

No.	STAGE II series 2	Zn, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	II/2/1	16,25	105,00	116,75	91,75	42,75	372,50
2	II/2/2	12,75	67,75	101,75	51,75	11,50	245,50
3	II/2/3	13,50	77,25	111,25	77,75	27,75	307,50
4	II/2/4	13,25	87,50	156,75	111,50	44,00	413,00
5	II/2/5	13,25	87,75	142,00	126,25	37,25	406,50
6	II/2/6	11,25	87,25	174,00	134,00	36,00	442,50
7	II/2/7	10,00	80,75	157,75	13,25	161,50	423,25
8	II/2/8	8,50	86,50	173,50	155,75	53,50	477,75
9	II/2/9	8,75	78,50	174,00	163,00	63,00	487,25
10	II/2/10	7,50	76,00	171,25	139,00	56,50	450,25
11	II/2/11	7,00	77,25	162,00	158,00	55,25	459,50
12	sludge	21,75	141,75	193,75	136,25	3,75	497,25
		Zn, [%]					
13	II/2/1	4,36	28,19	31,34	24,63	11,48	100,00
14	II/2/2	5,19	27,60	41,45	21,08	4,68	100,00
15	II/2/3	4,39	25,12	36,18	25,28	9,02	100,00
16	II/2/4	3,21	21,19	37,95	27,00	10,65	100,00
17	II/2/5	3,26	21,59	34,93	31,06	9,16	100,00
18	II/2/6	2,54	19,72	39,32	30,28	8,14	100,00
19	II/2/7	2,36	19,08	37,27	3,13	38,16	100,00
20	II/2/8	1,78	18,11	36,32	32,60	11,20	100,00
21	II/2/9	1,80	16,11	35,71	33,45	12,93	100,00
22	II/2/10	1,67	16,88	38,03	30,87	12,55	100,00
23	II/2/11	1,52	16,81	35,26	34,39	12,02	100,00
24	sludge	4,37	28,51	38,96	27,40	0,75	100,00

Table 26.2. Average content and percentage of copper in fractions extracted with the Tessier method in stage II, series 2.

No.	STAGE II series 2	Cu, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	II/2/1	24,75	4,25	4,25	100,50	41,00	174,75
2	II/2/2	9,75	2,00	3,25	69,75	27,50	112,25
3	II/2/3	9,00	2,00	3,25	93,00	28,00	135,25
4	II/2/4	7,50	1,75	4,50	137,25	45,75	196,75
5	II/2/5	9,25	2,00	4,50	141,75	37,50	195,00
6	II/2/6	6,50	1,50	5,00	155,00	46,50	214,50
7	II/2/7	6,25	1,25	4,25	141,50	45,25	198,50
8	II/2/8	5,75	1,50	5,25	158,00	52,50	223,00
9	II/2/9	5,50	1,50	4,25	162,00	56,00	229,25
10	II/2/10	5,00	1,25	4,75	146,75	54,75	212,50
11	II/2/11	5,00	1,25	4,75	184,75	24,25	220,00
12	sludge	55,50	8,00	7,00	163,25	18,50	252,25
		Cu, [%]					
13	II/2/1	14,16	2,43	2,43	57,51	23,46	100,00
14	II/2/2	8,69	1,78	2,90	62,14	24,50	100,00
15	II/2/3	6,65	1,48	2,40	68,76	20,70	100,00
16	II/2/4	3,81	0,89	2,29	69,76	23,25	100,00
17	II/2/5	4,74	1,03	2,31	72,69	19,23	100,00
18	II/2/6	3,03	0,70	2,33	72,26	21,68	100,00
19	II/2/7	3,15	0,63	2,14	71,28	22,80	100,00
20	II/2/8	2,58	0,67	2,35	70,85	23,54	100,00
21	II/2/9	2,40	0,65	1,85	70,67	24,43	100,00
22	II/2/10	2,35	0,59	2,24	69,06	25,76	100,00
23	II/2/11	2,27	0,57	2,16	83,98	11,02	100,00
24	sludge	22,00	3,17	2,78	64,72	7,33	100,00

Tabela 27.2. Average content and percentage of nickel in fractions extracted with the Tessier method in stage II, series 2.

No.	STAGE II series 2	Ni, [mg/kg d.m.]					
		fr. I	fr. II	fr. III	fr. IV	fr. V	Total
1	II/2/1	0,75	0,00	0,25	2,00	10,00	13,00
2	II/2/2	0,25	0,00	0,25	1,75	22,00	24,25
3	II/2/3	0,00	0,00	0,00	2,00	14,50	16,50
4	II/2/4	0,25	0,00	0,25	2,75	13,25	16,50
5	II/2/5	0,25	0,25	0,25	3,00	24,75	28,50
6	II/2/6	0,00	0,00	0,25	3,25	23,25	26,75
7	II/2/7	0,00	0,00	0,25	3,25	22,50	26,00
8	II/2/8	0,00	0,00	0,25	3,50	22,50	26,25
9	II/2/9	0,00	0,00	0,25	3,75	16,50	20,50
10	II/2/10	0,00	0,00	0,25	3,50	29,00	32,75
11	II/2/11	0,00	0,00	0,25	4,00	10,25	14,50
12	sludge	2,75	0,25	0,75	2,00	6,00	11,75
		Ni, [%]					
13	II/2/1	5,77	0,00	1,92	15,38	76,92	100,00
14	II/2/2	1,03	0,00	1,03	7,22	90,72	100,00
15	II/2/3	0,00	0,00	0,00	12,12	87,88	100,00
16	II/2/4	1,52	0,00	1,52	16,67	80,30	100,00
17	II/2/5	0,88	0,88	0,88	10,53	86,84	100,00
18	II/2/6	0,00	0,00	0,93	12,15	86,92	100,00
19	II/2/7	0,00	0,00	0,96	12,50	86,54	100,00
20	II/2/8	0,00	0,00	0,95	13,33	85,71	100,00
21	II/2/9	0,00	0,00	1,22	18,29	80,49	100,00
22	II/2/10	0,00	0,00	0,76	10,69	88,55	100,00
23	II/2/11	0,00	0,00	1,72	27,59	70,69	100,00
24	sludge	23,40	2,13	6,38	17,02	51,06	100,00

Table 28.2. Content of humic substances and values of humification indices in s

compost and sludge, stage II.

No.	STAGE II	sample symbol	specific humic substance [g/kg d.m.]			C org., [g/kg d.m.]	humifi
			HA	FA	Total		PI, [-] (HA/FA)
1	series 1	II/1/1	133,25	34,37	167,62	428,50	3,88
2		II/1/2	137,73	43,33	181,05	420,90	3,18
3		II/1/3	132,46	45,32	177,78	405,40	2,92
4		II/1/4	136,29	37,28	173,57	383,90	3,66
5		II/1/5	148,86	96,38	245,24	384,60	1,54
6		II/1/6	149,19	34,27	183,45	365,90	4,35
7		II/1/7	138,71	86,56	225,27	370,30	1,60
8		II/1/8	138,38	47,48	185,87	379,00	2,91
9		II/1/9	139,61	44,52	184,12	347,60	3,14
10		II/1/10	136,09	60,47	196,56	367,70	2,25
11		II/1/11	142,20	42,80	185,00	377,60	3,32
12	series 2	II/2/1	128,69	80,16	208,85	390,40	1,61
13		II/2/2	156,48	30,33	186,80	400,50	5,16
14		II/2/3	135,40	41,70	177,10	382,50	3,25
15		II/2/4	134,94	59,30	194,23	375,00	2,28
16		II/2/5	133,08	41,82	174,90	365,00	3,18
17		II/2/6	145,78	17,20	162,98	366,00	8,48
18		II/2/7	141,90	43,86	185,76	368,00	3,24
19		II/2/8	135,06	45,22	180,28	372,70	2,99
20		II/2/9	128,64	28,54	157,18	368,80	4,51
21		II/2/10	101,68	57,02	158,70	373,50	1,78
22		II/2/11	132,43	38,56	170,99	360,20	3,43
23	sewage sludge		148,82	60,94	209,76	404,00	2,44