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EFFECT OF MUNICIPAL WASTES MOISTURE LEVEL ON TRANSFORMATIONS OF NITROGEN FORMS IN THE COURSE OF COMPOSTING

WPŁYW UWILGOTNIENIA ODPADÓW KOMUNALNYCH NA PRZEMIANY FORM AZOTU W CZASIE KOMPOSTOWANIA

Abstract: The aim of the study was to determine the influence of municipal wastes moisture level of on the intensity of transformations of various forms of nitrogen during composting. The object of the study was fresh (heating) compost leaving the technological line of the composting plant MUT-DANO in Katowice. Composting of that material was conducted for a period of 5 months under the following conditions: variant A – pile on plastic foil, with moisture content of 0.5 kg H_2O kg^{-1} dm, variant B – perforated plastic container of ca 1 m^3 in capacity, with moisture content of 0.5 kg H_2O kg^{-1} dm, variant C – perforated plastic container of 1 m^3 in capacity, with moisture content of 0.6 kg H_2O kg^{-1} dm. The composted material was stirred at intervals of 10–15 days for aeration, moisture content of the material was determined, water deficit was replenished, and samples were taken for laboratory analyses. In collected samples the following determinations were performed: humidity, ash content, contents of different nitrogen forms: N_t – total nitrogen, N_w – water-soluble nitrogen (1:10), N-NH_4^+ and N-NO_3^- – mineral nitrogen in water extract, $N_{w\ org.}$ – organic nitrogen in water extract. Based on this results the total nitrogen losses were calculated. Obtained results shows that moisture of composted municipal wastes plays an important role in the shaping of the fertility properties of composts and determines the content of total N and the transformation of its organic and mineral forms. Composting of municipal wastes on the pile, accelerated the maturation of composts and was conducive to the obtainment of product richer in nitrogen, with a higher content of N-NO_3^-. Also higher moisture content of composted municipal wastes did not ensure their sufficient oxygenation, which led to greater losses of nitrogen, reduced the quality of compost, and did not ensure sanitary safety. Higher moisture content limited and modified the rate of biochemical transformations in composted municipal wastes.

Keywords: composting of municipal wastes, nitrogen transformation, moisture level

Low contents of nitrogen in mineral soils, at high requirements for proper growth of plants, indicate the need for supplementation of that component through application of

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mineral or organic fertilizers. Energy-consuming and costly production of nitrogen fertilizers makes it a necessity to search for cheaper nitrogen sources that may be organic waste materials. Such materials include, among other things, municipal wastes that so far are mostly kept at wastes dump [1]. Municipal solid wastes (MSW), collected selectively, contain notable amounts of organic mater and of macro- and micro-components. In view of the data given by Baran and Turski [1], the content of nitrogen in municipal wastes in Poland varies within the broad range of 3–30 g kg^{-1}.

Composting of municipal wastes permits recycling of organic and mineral components contained in them. This manner of utilization of wastes allows the creation of a valuable material that can be used for improvement of the properties of soil environment.

In the light of earlier studies by Drozd et al [9], it appears that composts produced of non-segregated municipal wastes of the agglomeration of Katowice contained nitrogen at the level of 10.9–13.0 g kg^{-1}. Composts produced from sorted municipal wastes are richer in total nitrogen (10–24 g kg^{-1}) [10, 19]. The processes of transformation of organic matter depend on the properties of the initial material and on the conditions of composting [2, 7, 8, 15, 17, 18]. Apart from the C/N ratio, another significant factor for correct composting is moisture content and oxygenation. These conditions determine the duration and intensity of the particular phases of composting, ensure biological and biochemical transformations of organic matter, and sanitary safety of composts. Temperature and duration of phases of composting play an important role in nitrogen transformations that include the processes of ammonification, nitrification and denitrification.

A consequence of composting conditions are losses of nitrogen caused by emission of NH_3, nitrogen oxides and N_2, determining the level of total nitrogen content N_t and the value of the C/N ratio [6, 14, 18].

Literature of the subject provides reports on a wide range of moisture levels (45–70 %) applied during composting [15, 17, 18]. In Poland, maturation of fresh composts produced from municipal wastes is most frequently conducted on piles, with periodic aeration and wetting, without considering the effect of those measures on the quality of the end product.

The aim of the study was to determine the influence of municipal wastes moisture level on the intensity of transformations of various forms of nitrogen during composting.

Material and methods

The object of the study was fresh (heating) compost leaving the technological line of the composting plant MUT-DANO in Katowice. Composting of that material was conducted for a period of 5 months under the following conditions:

– variant A – pile on plastic foil, with moisture content of 0.5 kg H_2O kg^{-1} dm on the day of aeration, with variation of 0.44–0.524 kg kg^{-1},

– variant B – perforated plastic container of ca 1 m^3 in capacity, with moisture content of 0.5 kg H_2O kg^{-1} dm on the day of aeration, with variations of 0.462–0.534 kg kg^{-1},

– variant C – perforated plastic container of 1 m^3 in capacity, with moisture content of 0.6 kg H_2O kg^{-1} dm on the day of aeration, with variation of 0.469–0.6 kg kg^{-1}.

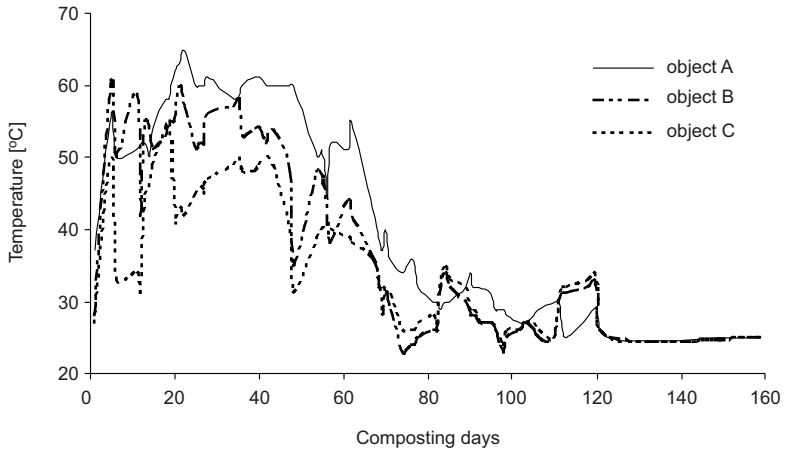

Fig. 1. Changes of the temperature during composting

The composted material was stirred at intervals of 10–15 days for aeration, moisture content of the material was determined, water deficit was replenished, and samples were taken for laboratory analyses, point-wise from 20 points, and mixed together to create averaged samples. In the course of the experiment, temperature of composted material was measured at intervals of 2–3 days (Fig. 1). Samples taken at various times of composting (after 11, 22, 36, 54, 68, 82, 95, 112, 126, 143 and 159 days) were used for the following determinations:

– moisture content – with the oven-dry method,

– ash content after combusting a weighed portion in an oven at temperature of 550 ^oC,

– N_t and N_w – total nitrogen and water-soluble nitrogen (1:10), with the Kjeldahl method,

– $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ – in water extract, using Braun Luebbe analyser,

– $N_{w\ org.}$ – organic nitrogen in water extract, from the difference of N_w – ($N\text{-}NH_4^+$ + + $N\text{-}NO_3^-$).

Results presented in this paper are average from two repeats.

Based on the obtained results, calculations were made of losses in total nitrogen content, on the basis of the initial (X_1) and final (X_2) levels of ash and initial (N_{t1}) and final (N_{t2}) nitrogen contents according to the formula: N_{losses} (%) = 100 – – $100(X_1 \cdot N_{t2})/(X_2 \cdot N_{t1})$ [4]. Obtained results were statistically verified at significance level $\alpha = 0.05$.

Results

The study showed that moisture played an important role in shaping the values of total nitrogen content N_t and of the content of its soluble forms in the particular phases of composting (Figs. 2–6). In the course of composting there was an increase in the total nitrogen content N_t in all the experimental variants. Composts maturing on the pile (variant A) displayed, over the whole period of composting, a gradual increase of N_t and, at the same time, a lower content of total nitrogen compared with the other experimental objects. Likewise, in the maturation of composts with moisture content of

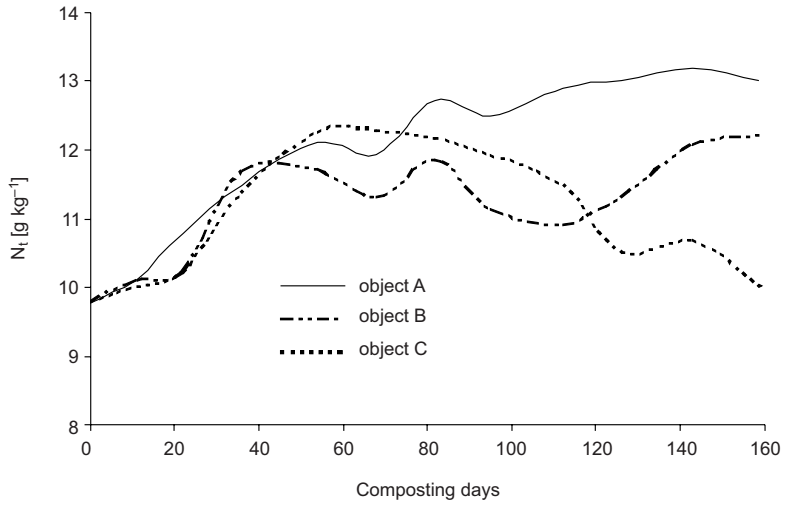

Fig. 2. Changes of total nitrogen (N_t) contents during composting

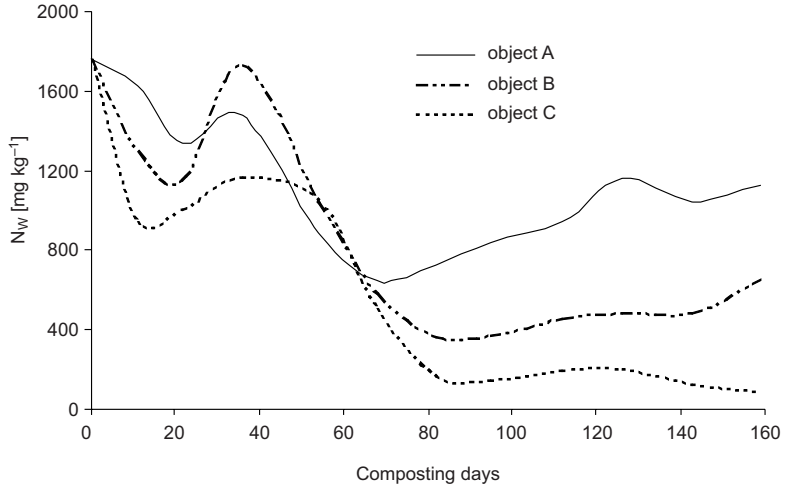

Fig. 3. Changes of water – soluble nitrogen (N_w) contents during composting

0.5 kg H_2O kg^{-1} dm (variant B), the content of N_t increased, and its level after 159 days was higher by ca 2.5 g kg^{-1} dm in comparison with the initial material. The application of higher moisture level in the experiment (0.6 kg H_2O kg^{-1} dm, variant C) was not conducive to the formation of compost rich in nitrogen. In the analysed variant C, increase in the level of nitrogen continued until day 68 (Fig. 2), and subsequently its content gradually decreased and on day 159 of composting was higher by 0.24 g kg^{-1} dm than in the initial material. These data indicate that in the process of composting at moisture level of 0.6 kg H_2O kg^{-1} dm there occurred, in the final phase, considerable losses of nitrogen. This finds support in the level of water-soluble forms of nitrogen and in the calculated losses of N_t (Fig. 3–7). During the composting, in all the experimental variants the level of water-soluble forms of nitrogen (N_w) displayed a general decreasing trend, with observable variations. In the mesophilic phase, around days 20–25 of composting, there occurred the first rapid drop in the content of water-soluble forms N_w, most pronounced in variant C, and the least in variant A. In the thermophilic phase, around days 35–40 of composting, a notable increase was observed in the level of N_w, followed by a strong decrease. The lowest (642 mg kg^{-1}) were recorded on day 68 in treatment A, in treatment B on day 82 (359 mg kg^{-1}) and in treatment C on day 95 of composting (142 mg kg^{-1}). In subsequent periods of maturation of the composts the content of water-soluble forms of nitrogen increased again. The increase was more intense in composts maturing on the pile, somewhat slower at moisture level of 0.5 kg H_2O kg^{-1} dm (variant B), and only slight at moisture level of 0.6 kg H_2O kg^{-1} dm. This differentiation in the content of water-soluble forms of nitrogen and their level after 159 days of composting indicate that the higher level of moisture in the composted material inhibited the rate of oxygen transformations of nitrogen. This is supported by the contents of water-soluble forms: $N_{w\ org.}$, $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ (Fig. 4–6).

The level of water-soluble organic nitrogen ($N_{w\ org.}$) decreased in the process of maturation of the composts (Fig. 6). This was observable especially in the mesophilic

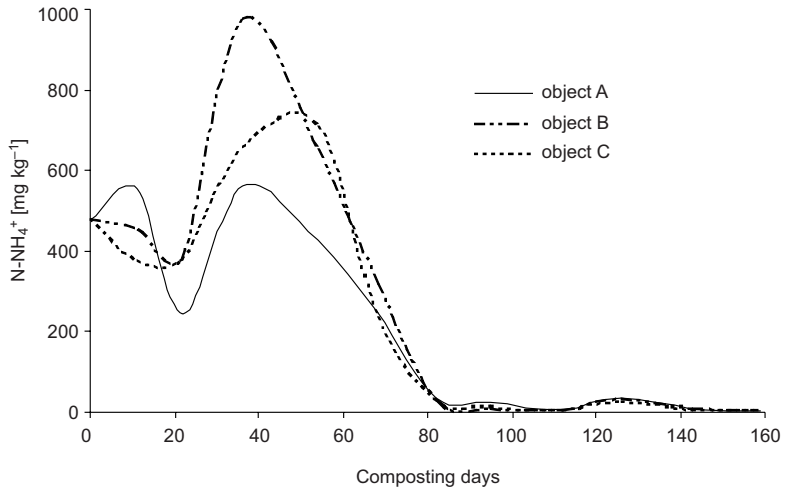

Fig. 4. Changes of $N\text{-}NH_4^+$ contents during composting

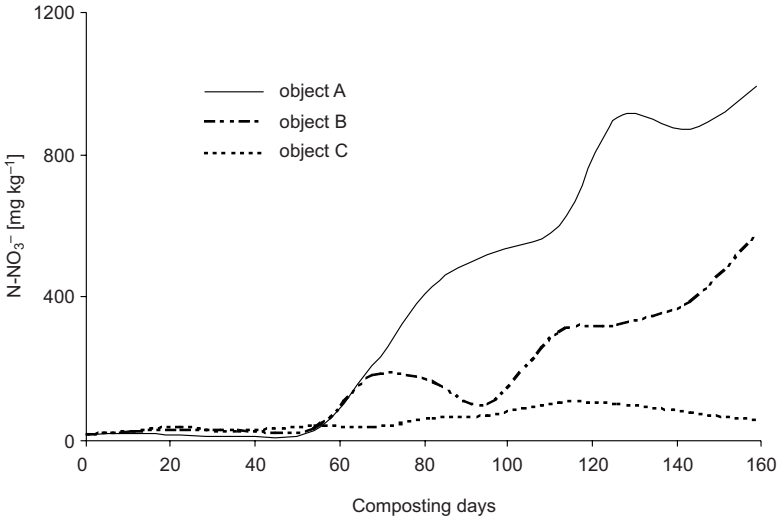

Fig. 5. Changes of $N\text{-}NO_3^-$ contents during composting

and thermophilic phases of composting. A slightly higher content of water-soluble forms of organic nitrogen was found in the compost maturing on the pile, remaining under somewhat more favorable oxygenation conditions. The lowest level of that form of nitrogen was found at moisture content of 0.6 kg H_2O kg^{-1} dm (variant C).

The amounts of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ indicate that the processes of ammonification take place at a higher rate in the thermophilic phase of composting, and those of nitrification in the phase of cooling and maturity of composts (Fig. 4–5). Composting conditions affected on $N\text{-}NH_4^+$ content in thermophilic composting phase. Notably

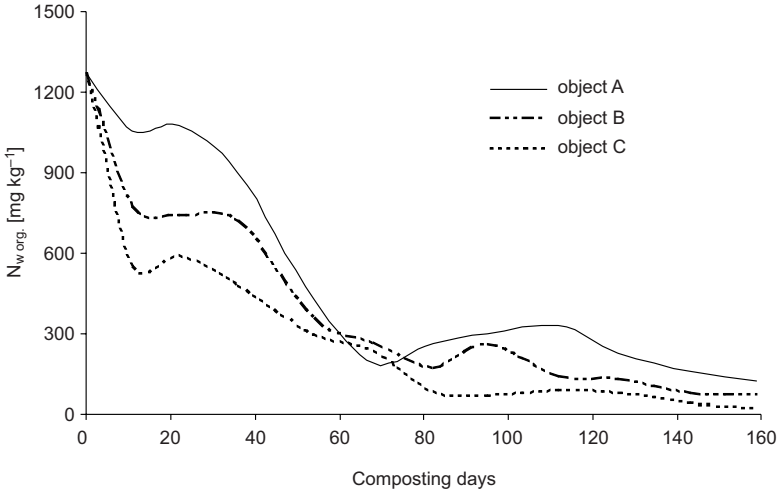

Fig. 6. Changes of $N_{w\ org}$ contents during composting

greater levels of $N\text{-}NH_4^+$ was recorded in composts maturing at the moisture contents of 0.5 kg H_2O kg^{-1} dm (variant B) and 0.6 kg H_2O kg^{-1} dm (variant C), than on the pile. In the phase of cooling, the content of $N\text{-}NH_4^+$ decreased rapidly in all the treatments.

On day 82 of composting it was only 5–7 %, and in mature composts did not exceed 1 % of the initial levels.

The composting conditions determined also the content of $N\text{-}NO_3^-$ in the course of the composting process. Very low and similar levels of that form on nitrogen were observed in water extracts from all the treatments in the mesophilic and thermophilic phases of composting. In the cooling and maturation phases the level of that form of nitrogen increased rapidly in composts maturing on the pile, more slowly in the container at moisture content of 0.5 kg H_2O kg^{-1} dm, and only slightly in variant C, at moisture level of 0.6 kg H_2O kg^{-1} dm.

The above analysis indicates that moisture level of composted mass and its oxygenation play an important role in the process of maturation of composts and determine their fertilizer value, expressed in the content of total nitrogen and its mineral forms.

In the light of the results obtained, the content of total nitrogen N_t in mature composts is determined mainly by the level of losses that were notably higher in composting at the higher moisture content (Fig. 7).

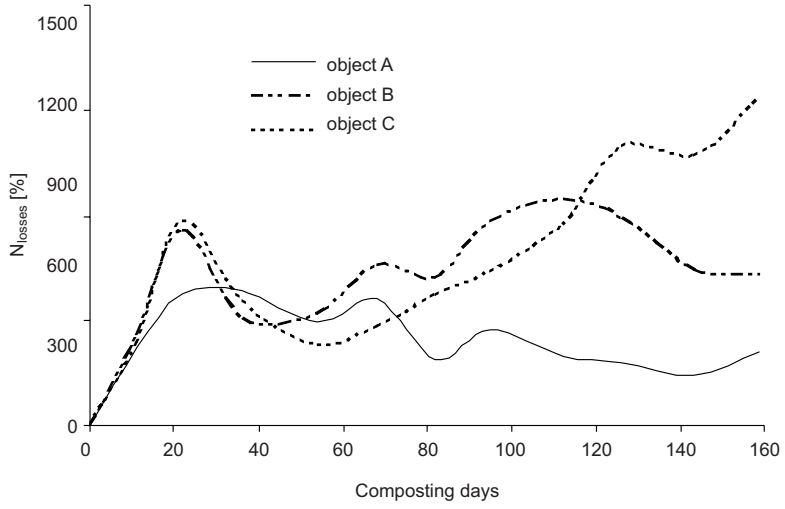

Fig. 7. Losses of nitrogen ($N_{loss.}$) during composting

Losses of total nitrogen took place over the whole period of composting, at various rates. In composts maturing on the pile (treatment A) they were observed mainly in the thermophilic phase of composting. However, quantitatively the greatest losses of nitrogen in composting were recorded at the moisture level of 0.6 kg H_2O kg^{-1} dm. Intensive losses of N in that treatment took place between days 11 and 36 in the thermophilic phase of composting, and very intensive – in further phase of composting.

These data indicate that nitrogen losses in the course of composting could have been caused by nitrogen volatilization in the form of ammonia in the thermophilic phase of composting, and in other gaseous forms in the process of nitrification, in the cooling phase.

Discussion

Composting, commonly defined as a process of bio-oxidation of heterogeneous organic matter, is an effect of living dynamic succession of microorganisms [3]. In the process of composting, deep transformations take place in organic matter and in mineral compounds, including nitrogen. The aim of composting is the obtainment of fertilisers with high effectiveness and rich in nitrogen, among other things. Composting conditions have a significant effect on transformation of nitrogen, presence of water-soluble forms, nitrogen losses, and its content in the end product.

In literature [6, 12, 14] it is emphasized that nitrogen losses are determined by temperature, pH and quality of composted material. They are low when composting wastes rich in lignincelluloses, and increase under interaction of higher temperature and pH in the thermophilic phase of composting. In the experiment presented here, the run of temperatures in the process of composting had an effect on the rate of nitrogen transformations and on the level of its losses. The more favorable aeration conditions in the pile, at moisture level of 0.5 kg H_2O kg^{-1} dm, were conducive to intensive growth of thermophilic bacteria, which led to increase in temperature of the composted material.

The temperature in the pile in the initial two weeks of composting was within the range of 37–56 ^oC (Fig. 1), most frequently assuming values around 50 ^oC, and in the thermophilic phase increased to 60–65 ^oC. In the light of data reported by Pragans et al [12], such a run of temperatures in the thermophilic phase of composting ensures sanitation of composts, at the same time reducing the level of nitrogen losses in the form of ammonia. The above supposition finds confirmation in the intensive increase of N_t and $N_{w\ org.}$ in comparison with the other variants. At the same time, the higher rate of decrease in the content of $N\text{-}NH_4^+$ indicates its rapid immobilisation by microorganisms and its incorporation into structures of specific humus compounds [8].

In the subsequent phases of maturation of composts on the pile the losses of nitrogen decreased (Fig. 7), and its total content slowly increased (Fig. 2). On day 159 of maturing on the pile, the compost was characterised by the highest content of N_t compared with the other variants. This resulted, among other things, from low losses of nitrogen than on day 159 amounted to ca 7 % at LSD only 0.7.

In the analyzed period, the content of $N\text{-}NH_4^+$ in water extracts decreased, and that of $N\text{-}NO_3^-$ increased, and intensive processes of nitrification took place especially when the temperature dropped below 40 ^oC [14].

The more favorable composting conditions on the pile, at moisture level of 0.5 kg H_2O kg^1 dm, determined also faster maturation process of the compost. It is accepted after Pare et al [11] that the ratio of $N\text{-}NH_4^+/N\text{-}NO_3^-$ informs about the intensity of processes of biological decomposition. Its value below 0.16 is, according to Bernal et al [5] one of the indicators of compost maturity. On this basis we can assume that the compost produced on the pile reached maturity after 82 days of composting.

Whereas, at the moisture level of 0.5 kg H_2O kg^{-1} dm (variant B), already in the first week of composting the temperature exceeded 55 ^oC. This caused increase in the level of nitrogen losses that, throughout the whole period of composting, were at a higher level than on the pile. The effect of this was a reduction in the content of N_t in the final product. Among the mineral forms of nitrogen, in the thermophilic phase of composting the content of $N\text{-}NH_4^+$ increased nearly twofold relative to the initial level (Fig. 4). This indicates an intensive process of desamination of organic matter, leading to volatilization of ammonium nitrogen. Under such conditions, the forms $N\text{-}NH_4^+$ were subject to limited immobilization and incorporation into the structures of humus compounds [8], which is confirmed by the high losses of nitrogen between days 20 and 40 of composting (Fig. 7). The index of compost maturity, calculated on the basis of the content of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$, assumed a value below 0.16 in the third month of compost maturation.

In variant C, in which the content of water was maintained at 0.6 kg kg^{-1} dm, the processes of nitrogen transformation showed a different run, and the dynamics of temperature (Fig. 1) did not ensure sanitary safety of the compost. In that treatment, in the initial two months, the content of N_t and $N\text{-}NH_4^+$ in water extracts increased, and in further periods of compost maturation their content decrease. Losses of nitrogen increased at a high rate from day 82 of composting, and after five months attained the level of 31 % in relation to the content of nitrogen in the initial material.

Analyzing the dynamics of changes in the content of water-soluble forms of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ during composting of wastes (Fig. 4–5), we can assume a strong effect of denitrification process on the level of losses of N_t at higher moisture levels. The moisture level range of 0.46–0.6 kg H_2O kg^{-1} dm and changes in aeration conditions at intervals of 10–15 days when the composted material was stirred, could have determined the processes of nitrification and denitrification. This is evidenced in the low content of $N\text{-}NO_3^-$ in the composts of the variant in question, compared with the content of $N\text{-}NO_3^-$ in the composts on the pile.

The results of the above observations indicate that during composting of MSW the processes of ammonia volatilization, immobilization, nitrification and denitrification take place at various rates.

The results obtained indicate also that modification of the parameters of composting, such as moisture level, temperature and content of oxygen [2, 8, 16, 18] has an significant effect on the properties of the final products of composting.

Conclusions

1. The level of moisture content of composted municipal wastes plays an important role in the shaping of the utility properties of composts and determines the content of total N and the transformation of its organic and mineral forms.

2. Composting of municipal wastes on the pile, at moisture level of 0.5 kg H_2O kg^{-1} dm, accelerated the maturation of composts and was conducive to the obtainment of product richer in nitrogen, with a higher content of $N\text{-}NO_3^-$.

3. Higher moisture content of composted municipal wastes (0.6 kg H_2O kg^{-1} dm) did not ensure their sufficient oxygenation, which led to greater losses of nitrogen, reduced the quality of compost, and did not ensure sanitary safety.

4. Higher moisture content (0.6 kg H_2O kg^{-1} dm) limited and modified the rate of biochemical transformations in composted municipal wastes and caused intensification of transformation of nitrogen compounds.

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WPŁYW UWILGOTNIENIA ODPADÓW KOMUNALNYCH NA PRZEMIANY FORM AZOTU W CZASIE KOMPOSTOWANIA

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Abstrakt: Analizowano wpływ uwilgotnienia komunalnych odpadów miejskich na szybkość przemian różnych form azotu w czasie kompostowania.

Kompostowanie materiału grzejnego opuszczającego linię technologiczną kompostowni MUT-DANO prowadzono przez okres 5 miesięcy w następujących warunkach: A – na pryźmie przy uwilgotnieniu 0,5 kg $H_2O \cdot kg^{-1}$ s.m., B – w pojemnikach ażurowych przy uwilgotnieniu 0,5 kg $H_2O \cdot kg^{-1}$ s.m., C – w pojemnikach ażurowych przy uwilgotnieniu 0,6 kg $H_2O \cdot kg^{-1}$ s.m. w dniach napowietrzania. Materiał mieszano w odstępach 10–15-dniowych, uzupełniano ubytki wody i pobierano próbki do badań. Oznaczono w nich: wilgotność aktualną, zawartość popiołu oraz różnych form azotu: N-ogółem, N – w wyciągu wodnym (1:10), $N\text{-}NH_4^+$ i $N\text{-}NO_3^-$ w wyciągu wodnym. Na podstawie uzyskanych wyników obliczono straty azotu ogółem.

Uzyskane wyniki badań wskazują, że poziom uwilgotnienia kompostowanych odpadów komunalnych odgrywa ważną rolę w kształtowaniu wartości nawozowej kompostów i decyduje o zawartości N-ogółem oraz transformacji jego form organicznych i mineralnych. Kompostowanie odpadów komunalnych na pryźmie ograniczało straty azotu, sprzyjało powstawaniu kompostów bardziej zasobnych w azot, o wyższej zawartości $N\text{-}NO_3^-$, gwarantowało ich pełne bezpieczeństwo sanitarne oraz decydowało o szybszym ich dojrzewaniu. Większe uwilgotnienie ograniczało i modyfikowało tempo przemian biochemicznych w kompostowanych odpadach komunalnych i zmieniało kierunek transformacji związków azotu. Zauważono, iż wyższa wilgotność kompostowanych odpadów komunalnych przyczyniała się do gorszego ich natlenienia i prowadziła do większych strat azotu, co obniżało wartość nawozową kompostu i nie gwarantowało bezpieczeństwa sanitarnego.

Słowa kluczowe: kompostowanie odpadów komunalnych, transformacja azotu, poziom uwilgotnienia