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IMPROVEMENT OF THE COMPOSTING TECHNOLOGY OF FOOD COMPONENT OF MUNICIPAL SOLID WASTE

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Abstract. The work deals with solving the problem of raising the environmental safety level of the municipal solid waste landfills through the introduction of advanced composting technology of the solid waste food component with the use of mineral and microbiological additives.

Key words:landfill, food waste, environmental safety, mineral and microbiological additive, composting.

1. Introduction

Among the environmental problems, waste accumulation and waste management rank first in Ukraine. The municipal solid waste (MSW) accumulation at landfills and dumps is of particular ecological danger due to the MSW specificity among other types of waste: the genetically inherent chemical inhomogeneity, localized location and long-term negative effects on the environment [1].

The lack of mechanisms of sorting and recycling in modern conditions [2] confirms the urgency of the MSW management problem in the places of their actual storage and the definition of landfill environmental aspects in order to control and rate them.

Hundreds of thousands of tons of the MSW are accumulated annually in city dumps [3]. Location, arrangement and operating conditions of most places of waste disposal do not meet regulatory requirements, which increase the ecological danger of these objects. Typically, such landfills are now located within urban areas, occupy large areas and are called landfill sites. In Ukraine, there are about 2000 objects that were organized without projects and engineering-hydrogeological exploration. The consequence is a significant number of environmental problems, in particular groundwater pollution by filtrate (through the infiltration of contaminated waters in underground aquifers) and the migration of pollutants together with underground, terrestrial and aboveground flows [4, 5].

The analysis of the studies on the assessment of the waste disposal sites condition in Ukraine proves that environmental monitoring of the landfills impact on the environment relates only to the current state of individual components of the landfill system [6]. Landfills are functioning in the absence of an organized mechanism for their transformation into environmental protection systems, the constant waste flow eliminates the conditions for reclamation, and long-term processes of waste disposal and its metabolites remove the landfill site as an ecological disaster zone from the nature management system [7]. Thus, there is a need to improve the existing technological solutions and develop the new ones to increase the environmental safety level of the MSW landfills, which operate in modern conditions.

The results of the analysis of world and national developments in the field of environmental safety management have allowed to determine the main methodological approaches to the formation of a mechanism for the assessment of the negative impact of the MSW landfill on the environment, as well as the development of environmental safety management measures. In the case of waste disposal, biotechnology is of greatest interest [8-10]. The perspective and efficiency of the biotechnological processes application is due to their compactness and, at the same time, large-scale, high level of labor productivity. These processes are subject to control and regulation. They are implemented in "soft" conditions, under normal pressure and low ambient temperatures. They are natural and have no adverse effects on biota and the environment. They pollute the environment with waste and by-products to a lesser extent, depend little on climatic and weather conditions, do not require large land areas and do not need the use of pesticides, herbicides and other harmful agents for the environment. Therefore, biotechnology as a whole and its separate sections are among the top priority areas of scientific and technological progress and it is a striking example of "high technologies", associated with the development prospects of many industries, which determines the relevance of the research.

Since up to 40 % of the MSW is classified as easily decomposable organic waste [11], removing this part of waste from landfills by composting and turning waste into secondary material resources will substantially reduce the environmental load of actually deployed and potentially planned landfills to the environment. Composting, as a biotechnological method, is characterized by a number of advantages, the most essential of which are guaranteeing the circulation of substances in nature, increasing the ecological stability of agrocenosis and cost-efficiency of technological processes. However, nowadays, composting, as a method of MSW utilization, is not widely used in Ukraine because of the long process of implementation and the disadvantages of a technological organization.

The carried out research is devoted to the solution of the actual scientific and practical task, which involves substantiation and improvement of the composting technology of the MSW food component in order to reduce the environmental hazard level of the MSW landfills on the environmental components.

The purpose of the work is theoretical and experimental substantiation of composting technology of the MSW food component.

To achieve this goal, the following tasks have been solved:

– principles of identification and assessment of landfill functioning environmental aspects have been analyzed;

– the mechanism of the ecological danger formation of the MSW landfills has been investigated based on complex indicators system;

– an algorithm of ecological safety management of the MSW landfills has been developed with a clear definition of management objects in terms of the environmental hazard level formation;

– the technology of the MSW organic part processing through composting has been substantiated;

– the technology of composting the MSW organic part has been improved due to the intensification of natural mechanisms by adding mineral and microbiological additives;

– ecological and economic estimation of the efficiency of the developed means and methods of ecological safety management has been conducted.

2. Experimental part

To achieve the goal of the research by solving the tasks, a methodology and an algorithm of managing the ecological safety of landfill solid waste have been developed. The program of the research can be presented in the form of three complex stages. Theoretical investigations are carried out by conducting an analytical review of modern literary and patent sources on ecological safety management of the MSW landfills, which prove the need to take into account the main environmental aspects of already functioning or planned MSW landfills for making the integrated management decisions. The first stage made it possible to determine the purpose and tasks of the research on ecological safety management of the MSW landfills, on the assessment of the environmental hazard level and on the development of a set of measures aimed at reducing it.

The purpose of the second stage – experimental research – is practical implementation and confirmation of the developed theoretical provisions adequacy on environmental safety management of the MSW landfills.

The MSW landfill in the area of the Dalnytski quarries (TPV-1 landfill site "Dalnytski quarries", S = =96.2 hectare), located 9 km west of Odessa, is the main city landfill site for municipal solid waste. The nearest settlements – Dalnik, Prilimanske and Novaya Dolina – are located to the north, east and south, respectively, at a distance of 2–3 km.

A three-level scheme of experimental research has been developed for the complex estimation and forecast of the MSW landfill influence on the environmental components and for the development of the improved utilization technology of the MSW organic component. Based on the conducted studies, a system of indicators for assessing the impact of landfill on the environment was created, resulting in a comprehensive assessment for making appropriate organizational and technical decisions on the environmental safety management of landfills, that is, the improvement of the MSW composting technology.

In general, the methodology of experimental research is based on the application of the system analysis of the process of the MSW landfills ecological hazard formation. It allows to differentiate the general task of the study in a number of tasks for the study of individual factors – sources of negative impact on environmental objects, the mechanism of forming the negative sources impact on the objects, methods and ways of reducing the MSW landfills negative impact on the environment.

At the first level, a full-scale experiment was conducted according to the developed program, which included: a list of analyzed indicators, sampling points and periodic sampling of the air, filtrate and surface waters and soils. In addition, data on waste storage (volume, composition, time, place of storage, hazard class, etc.) are analyzed as well as climatic, soil-geological and other natural conditions of the landfill location zone.

The second level of experimental research was a block of statistical processing of the experimental research results, based both on the classical methods of statistical analysis, and on the methods of censored samples, as well as the inductive output. Identification of the sources of negative influence of the MSW landfill on the environmental objects is carried out on the basis of the analysis of all physicochemical and biochemical processes and their classification according to the degree of influence. Identification and assessment of environmental aspects was carried out by an expert (semi-quantitative) method. Due to the established mechanism of the formation of the influence of environmental aspects on the environmental objects by the method of structural-logical analysis, a general concept of environmental hazard assessment is formed. The presented methods, in combination with the analysis, are used to create an ecological safety management algorithm for the MSW landfills.

Taking into account that the sources of negative influence, environmental aspects of landfills, environmental objects which they affect constitute a single interrelated system of objects and phenomena in the natural and man-made environment, the mechanism of formation of the MSW landfills ecological danger is developed (Fig. 1).

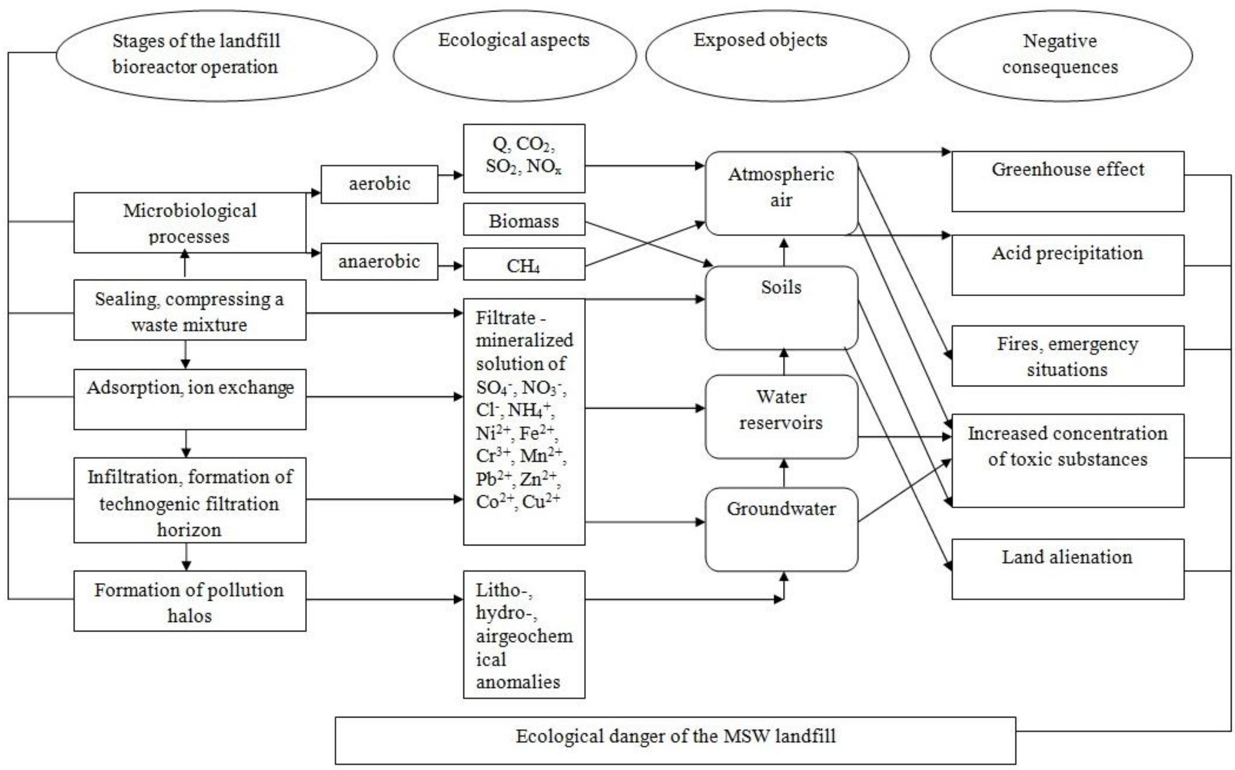

Fig. 1. Mechanism of formation of the MSW landfills' ecological danger

In order to establish the mechanism of formation of the MSW landfills ecological danger, a survey of the significance of the identified environmental aspects is carried out, and, as a consequence, the determination of priority environmental protection ways. The methodology of the assessment of the significance of the ecological aspects of the MSW landfills is based on determination of the index of influence, that is, assessment of the degree of ecological impact on the environment in points:

$$Пn = Q \cdot S \cdot E, \quad (1)$$

where Q – characterizes the quantity (volume) of influence; S – characterizes features of the influence spread; E – characterizes degree of exposure.

The expert methodology is based on the point approach, which is simple and allows us to make an acceptable general description of the MSW landfill impact on the environment. Each factor of the influence, depending on the value of these parameters, is estimated on a three-point scale. By multiplying the values of the point assessment for the three parameters, a final score, which characterizes the degree of the influence, is obtained.

In order to assess the environmental hazard level and to categorize the objects and sources of negative environmental impact, including landfill, in order to further take into account, a combined integrated environmental hazard index Z is proposed:

$$Z = D + iR, \quad (2)$$

where D – is the index of hazard for natural environments in the conditions of the regular work:

$$D = (d_f / 3)\,(d_s + d_w + d_a); \quad (3)$$

R – is the index of the object hazard in an emergency:

$$R = 0.5\,[(1 / N)\,Y_j + Y_{wt}]. \quad (4)$$

In order to assess the environmental safety level and the implementation of environmental measures, it is also necessary to take into account the potential danger of the MSW landfill, which can be realized in the event of a fire, the so-called emergency situation. In accordance with the adapted methodology of determining risks [14], the territorial risk of R^k_t in the Kth point of the space on the highlighted source of danger is:

$$R^k_t = P_{bij} \cdot P_{um} \cdot P_{af} \cdot P_{ck}, \quad (5)$$

where P_{bij} is the probability of a fire (accident) on the i-th source during the implementation of the j-th initiating event; P_{um} is the conditional probability of the possible consequence of the fire; P_{af} is the conditional probability of one of the possible fire types realization; P_{ck} is the conditional probability of death in the Kth point of space.

To estimate methane emissions from the MSW landfill, the first-order decay method of the second level of detail is used. The method offers an individual calculation for each category of organic waste (DOCj, kj), that are grouped according to the decomposition rate and the content of organic Carbon [12, 13].

At the third level of the experimental task, a comprehensive study was carried out on the composting process of the MSW food component, based on microbiological methods [15–16], which allowed to substantiate expediency and efficiency of the composting technology of the MSW food component with addition of microbiological and mineral additives [17–18]. Terms of the experiment are presented in a block diagram in Fig. 2.

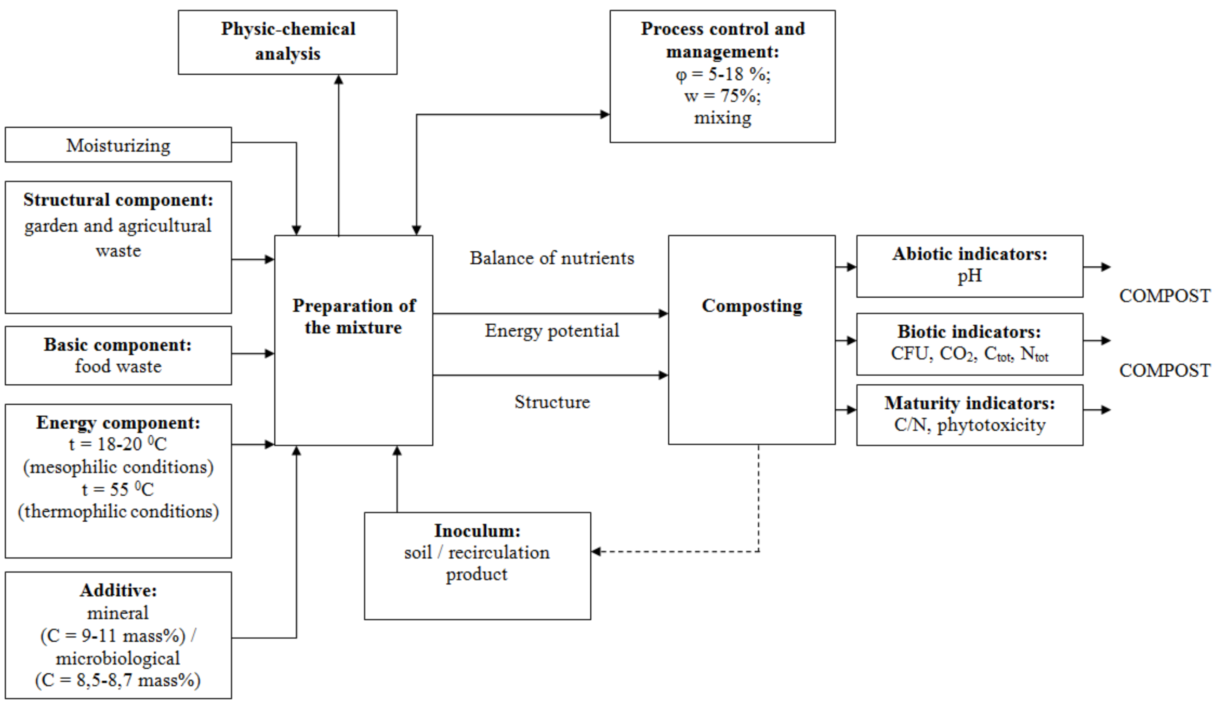

Fig. 2. Block diagram of the compost mixture preparation and composting process control

As a raw material for composting, a mixture of food (potato, squash and carrot peels, cabbage leaves), agricultural (weed) and garden (deciduous litter) waste in a weight ratio of 1:1:1 was used. Deciduous litter was used as a filler. The raw material was chopped to 10–15 mm, dried in the open air for 2 hours and loaded into the reactor. In order to increase the efficiency of the composting process and to compare the peculiarities of the processes, the extract from the soil was used as a microbiological additive; mineral salts (calcium nitrate, potassium dihydrogen phosphate and magnesium sulfate) were used as a mineral additive.

The experiment was conducted in stationary reactors of 3 dm^3 with forced aeration for 6 weeks in mesophilic (18–20 °C) and thermophilic conditions (55 °C).

A mixture for composting (CM) was introduced into each reactor in an amount of 1.2 kg (2/3 of the volume) with a humidity of about 75 % and mixed with 100 g of soil (typical for the region southern low–humus black earth soil) as an inoculum. 100 ml of distilled water was added to reactor 1 (control), and 100 ml of a microbiological additive was added to reactors 2 and 3, which is an aqueous extract of the soil obtained by incubating the soil with water under a hydro-modulus (HM) 10 for 20 minutes when stirring. In reactors 4 and 5 additional solutions of mineral salts were added in the amount of 150 g/kg of dry CM at the weight ratio $Ca(NO_3)_2{*}4H_2O:KH_2PO_4: MgSO_4{*}7H_2O = 4:2:1$

Composting lasted for 6 weeks, during which the mixture for compostingwas stirred and humidified daily to maintain the moisture level of about 70–75 %. Each week, samplings of around 10 g were selected for analyzes.

The control of the parameters of the composting process was carried out by changing the temperature, the pH and the number of microorganisms in the compostable mixture, as well as the CO_2 emissions from the reactor [19]. The maturity of the received compost was determined by the germination index [20] and the ratio of the total Carbon and Nitrogen content in the compostable mixture [21].

The temperature inside the composted mixture was measured using an alcohol thermometer which was fixed in the reactor lid, with its lower end located deep in the mixture that is being composted.

Once a week, the gas fraction was taken from the reactors using disposable plastic syringes of 50 cm^3. The syringe was attached to the gas outlet from the reactor, and then the reactor was shaken to remove the gases from the volume of the compostable mixture, and after 5 minutes the sample gas mixture in the amount of 50 cm^3 was taken. The amount of carbon dioxide in the sample was determined using a gas chromatograph "Chromatec Crystal 5000.2".

The samples of the compostable mixture at about 5 g were placed into metal boxes and dried to a constant mass to determine the moisture content, total Carbon and total Nitrogen. Brought to a constant mass the samples were chopped in a porcelain mortar. Then they were sifted through a sieve with a pore size of 0.25 mm and after then they were used to determine the total Organic Carbon by Tyurin and the total Nitrogen by Kjeldahl [18]. The wet samples weighing of 5 g were placed in 250 ml conical flasks, mixed with 50 cm^3 of distilled water, shaken in a rocker for 1 hour, and then filtered through a folded filter to determine the pH, the number of mesophilic and thermophilic microorganisms, and the germination factor.

The pH of the aqueous extract was determined using a laboratory pH meter. The number of microorganisms was determined by sowing on a solid nutrient medium in a Petri dish by the Koch method [21].

The germination rate was determined by the number of seeds of radish seedlings sprouted from ten and the lengths of seedlings in water extracts from compost compared with the control (distilled water).

The quality control of the finished product was determined by the C/N ratio and by the total Nitrogen content in the dry matter.

The numbers of bacteria in the cultivation of microorganisms' communities through the dynamics of the composting process was determined by sowing method on the MPA environment. Bacteria were recorded after 24 hours of cultivation at 28 °C. The number of myxomycetes was determined by sowing method on the Chapik dense environment (gl^{-1}): sucrose or glucose – 20.0; $NaNO_3$ – 2.0; K_2HPO_4 – 1.0; $MgSO_4x7H_2O$ – 0.5; KCl – 0.5; $CaCO_3$ – 3.0; agar – 20.0; lactic acid – 4 ml. The micromycetes were recorded after 7 days of cultivation at 28 °C. The number of bacteria and micromycetes expressed in lg CFU g^{-1} of compost.

The amount of cellulose-destroying microorganisms was determined using the boundary dilutions method [21]. Microorganisms were grown on Getchinson environment at 28 °C for 10 days. Quantitative records of microorganisms that were developed on a nutrient environment were conducted using the McCred's table, compiled based on the variation statistics methods [22].

At the third stage of the conducted research, in accordance with the management algorithm, a complex of technical and technological measures was developed to reduce the negative impact of the MSW landfills, the composting technology of the MSW food component was developed and improved, and an analysis of the effectiveness of the developed solutions implementation was performed.

3. Results and discussion

In order to substantiate the technology of waste management, an ecological hazard assessment of landfills was carried out, which was implemented through expert method (relevant tables), index calculation, environmental risk assessment and greenhouse gas emission estimation.

In this work, an estimation of the environmental hazard level of the MSW landfills on the environmental components is performed using such expert method as A, B, C – analysis, or relevant tables (or Leopold matrices). The analysis of the relevant tables can justify the removal of food and plant waste from the MSW morphological composition, as such that at all the stages of the landfill life cycle have the greatest impact on the environmental components, which is rated at 514 points, to a greater extent due to the stage of microbiological processes and the filtrate formation (274 points) This proves the need to develop technology solutions in the management of the MSW food component as a secondary resource of high potential, which will reduce the environmental hazard level.

The calculated values of the indices D = 1,78 and R = 1,27 of the complex index of ecological danger allow to classify the dump to the IV hazard group ($1<D<4$, $1<R<2$) as an object that creates a significant environmental hazard for the environment both in the regular mode of work and in the event of an emergency.

The calculation of the environmental risk level was carried out to assess the potential environmental hazard in the case of a fire on the landfill and the release of toxic substances, in particular dioxins into the air. In the case of a large long lasting fire on more than 10 hectares of the landfill site, the ecological risk is unacceptable ($R_t>10^{-5}$, $R_i>10^{-5}$).

In order to justify the possibility of reducing greenhouse gas emissions, methane emissions from the MSW landfill were estimated. The volume of methane formation at landfills depends on the storage conditions, the waste mass, the climatic features of the area and the content of biodegradable components in the MSW composition. However, the MSW composition is a key indicator in the inventory of greenhouse gas emissions, since it affects both the biodegradable Carbon content of waste and the rate of methane formation.

The comparative predictive calculation of methane formation from the landfill site on which seven categories of waste fall and the landfill site without the food component (Figure 3) indicates a significant reduction in the amount of the emitted greenhouse gases (by 21 %), thus the reduction in real and potential ecological risk levels of the MSW landfill, which can justify the expediency and effectiveness of separation the food component from the total amount of the MSW.

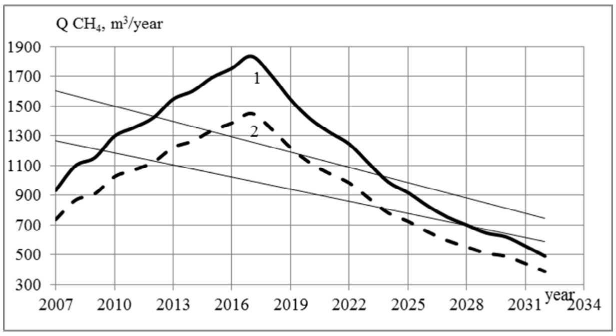

Fig. 3. Dynamics of methane emissions at the landfill TPV-1 "Dalintsky quarries" from the decomposition of the waste mass with the food component (1) and without it (2)

The conducted research on the basis of expert, index, risk and forecast estimates of the MSW landfills impact on the environmental components determines the formation of a high level of actual and potential environmental hazards and can justify ways to reduce it based on the complex of technical and technological decisions on environmental safety management.

To improve the composting technology of the MSW food component, it is substantiated that the introduction of mineral or microbiological additives into the compost mixture will lead to the activation of microbial activity in the initial stages of the process.

In general, the completion of the composting process is characterized by two concepts – "stability" and "maturity" of compost, which, in spite of their conceptual differences, are simultaneously used to determine the degree of organic matter decomposition during the composting process. In this work, parameters which allow us to estimate the intensity of organic matter decomposition (temperature, organic matter content, soluble organic carbon and ammonium nitrogen) and its stability (respiratory activity and cellulosolytic activity, number of bacteria and micromycetes) and maturity (pH, phytotoxicity) were investigated.

To obtain a highly effective method of composting the MSW organic part, in particular the food component, the uncontrolled fermentation of which has the highest potential for methane formation, the possibility of acceleration the composting process of organic waste through the application of microbiological and mineral additives has been tested. The results of the research on the change in the pH of the composite mixture with mineral and microbiological additives are presented in Fig. 4.

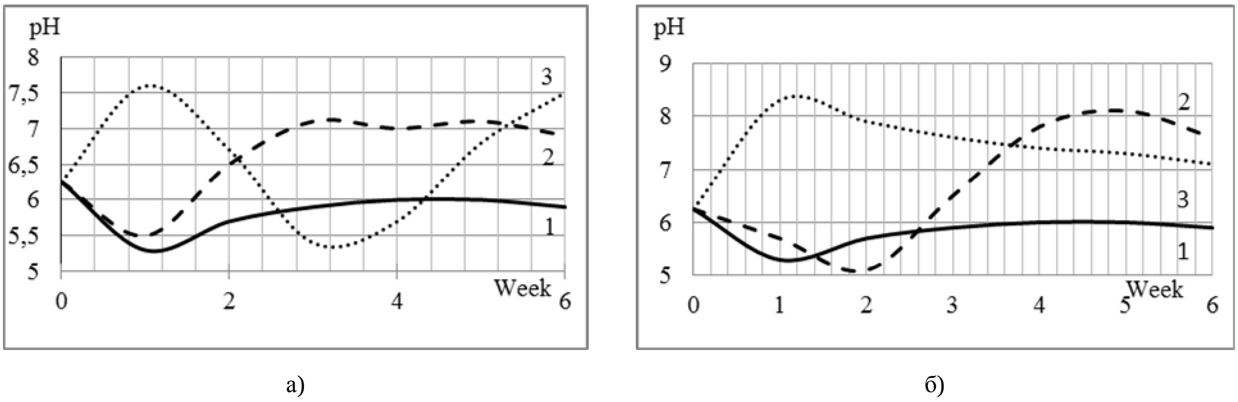

Fig. 4. Dynamics of changes in the pH of the compost mixture with mineral (a) and microbiological (b) additives in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample (1)

From the data obtained from the study it can be concluded that the pH values observed in the mesophilic and thermophilic regimes when introducing mineral and microbiological additives are optimal for plant cultivation and meet the requirements for mature compost. Stabilization and even a certain decrease in the pH level which was noted during the last week of composting is likely to result from the formation of humus-like substances, as indicated indirectly by the stabilization of the content of organic matter and soluble organic carbon during this period.

Fig. 5–7 show the study of biotic indicators of the composting process. Thus, a widely distributed parameter for assessing the stability of compost is respiration, which is estimated by the release of CO_2, the change in which is presented in Fig. 6.

The dependence of the change in the CO_2 concentration released in the reactor on the duration of the biodegradation process demonstrates the changes in the microorganisms' colonies activity during composting. The microorganisms' activity is much higher in mesophilic conditions when introducing both mineral and microbiological additives but in the second case, the percentage of CO_2 release during the second week is 2.5 times the level of respiratory activity when adding a mineral additive, which can be explained by the increased number of colonies of microorganisms in compost.

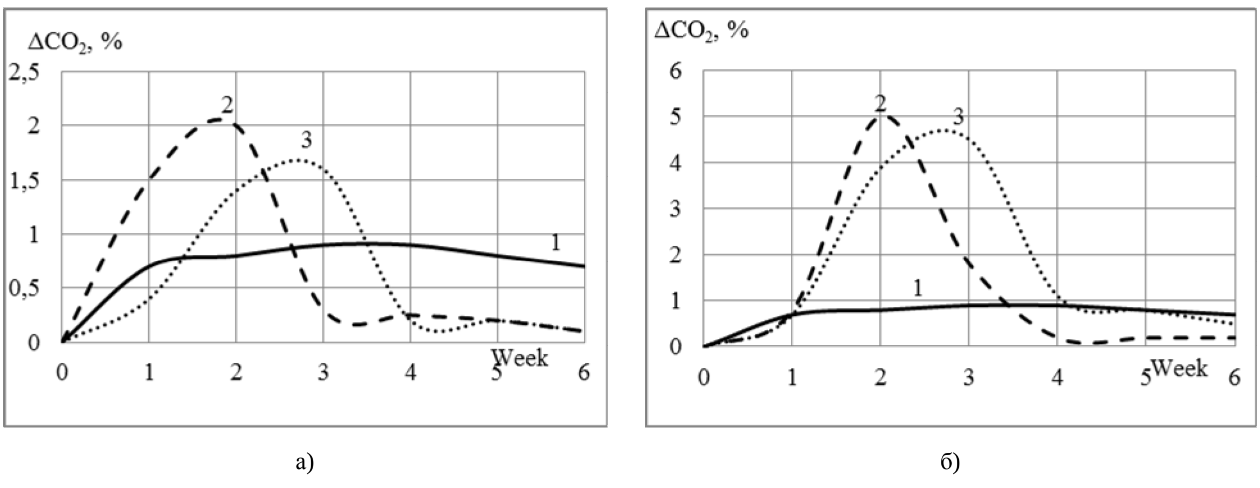

Fig. 5. Change in CO_2 emissions during the composting process with mineral (a) and microbiological (b) additives in the mesophilic (2) and thermophilic regimes (3) as compared to the control sample (1)

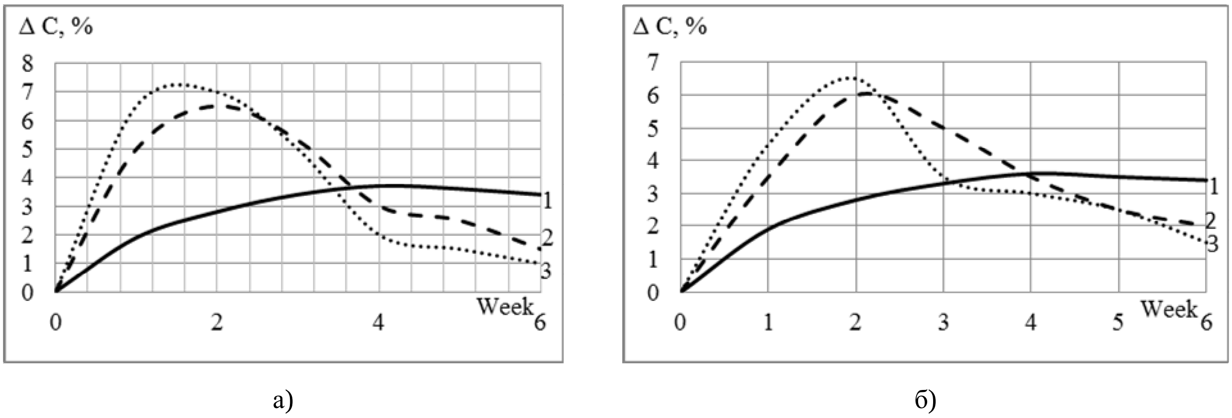

Fig. 6. Change in the total Carbon during the composting process with mineral (a) and microbiological (b) additives in mesophilic (2) and thermophilic modes (3) as compared to the control sample (1)

Traditionally, during composting, there is a decrease in the organic matter content with the release of CO_2. In the composting process, the organic matter decomposition occurs, which leads to a decrease in the content of the total Carbon and Nitrogen. The nature of these parameters change depends on the chemical composition of the compost mixture and the level of microorganisms' activity in it.

The nature of the dependence of the change in the total Carbon number on the duration of composting, shown in Fig. 6, is approximately the same for all reactors and has a classical character.

As it is evident from the data obtained, the introduction of mineral and microbiological supplements stimulates the increase in the activity of the microorganisms' community at the initial stages of composting – during the first three weeks, which indicates that the destruction of the compost mixture organic matter is actively taking place during these terms.

In the process of composting with a microbiological additive, the maximum consumption of Nitrogen (Fig. 7) in thermophilic conditions is observed after the first week of composting (3.6), and in mesophilic conditions it is observed during the second week (3.5 g/kg). This shows the greatest efficiency of composting with the addition of the microbiological additive, and higher costs of the total Nitrogen when added with the mineral additive due to an increase in its content in the initial mixture.

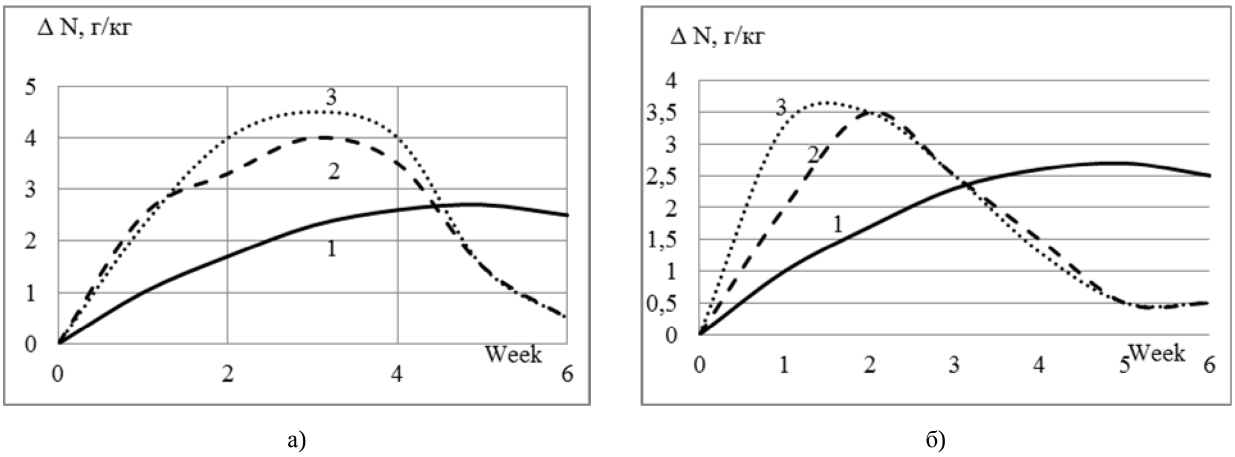

Fig. 7. Change in the total Nitrogen during the composting process with mineral (a) and microbiological (b) additives in mesophilic (2) and thermophilic modes (3) as compared to the control sample (1)

Presented in Fig. 8–9 dynamics of compost maturity reflects the degree of compost mixtures stability and maturation at the end of composting. The compost maturity is estimated by the mass ratio of total Carbon and total Nitrogen (C/N) in it. According to international standards, the C/N quality compost value should not exceed 25.

Presented in Fig. 8 dependencies of the change in C/N rates on the duration of composting with mineral and microbiological additives, show a high degree of the compost maturation in both regimes, as evidenced by C/N at a level of less than 22, while in the control sample this parameter reaches the value of 29.6.

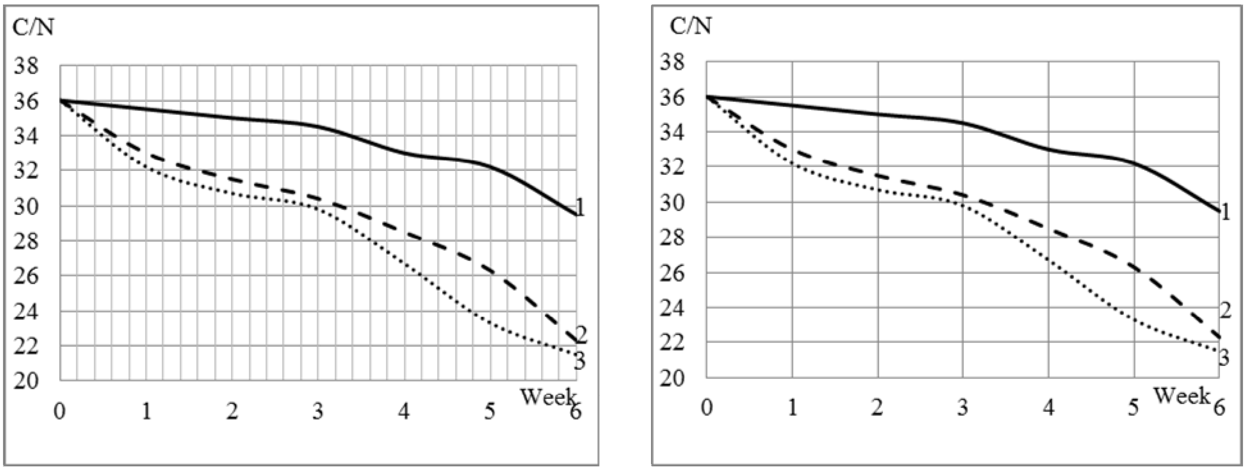

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Fig. 8. Dynamics of change in C/N during composting with mineral (a) and microbiological (b) additives in mesophilic (2) and thermophilic modes (3) as compared to the control sample (1)

Fig. 9 shows the dynamics of the change in the germination index as an indicator of the level of the compost phytotoxicity.

It is known that the germination index of mature compost is more than 80 %. After 6 weeks of composting the composts with the introduction of mineral and microbiological additives in the mesophilic and thermophilic modes are characterized by a germination index of more than 100 %, indicating that they are not only free from phytotoxins, but also have a stimulating effect on germination. The greatest values of the germination index are observed in the thermophilic regime when introducing a microbiological additive, which determines the greater degree of the compost maturity in composting conditions, precisely with the microbiological additive. The process of the compost maturation when applied to the mineral additive is accelerated by 2.2 times under the thermophilic conditions and by 1.4 times under the mesophilic ones, and the process of the compost maturation when applied to the microbiological additive is accelerated by 3.3 times under the thermophilic conditions and by 2.1 times – under the mesophilic ones.

The improved technological scheme of the compost production (Fig. 10–11) includes the following basic operations: mixing the compost mixture after the delivery to the landfill and stage separation, introducing structural components and additives, balancing the mixture, forming bursts and obtaining the final product.

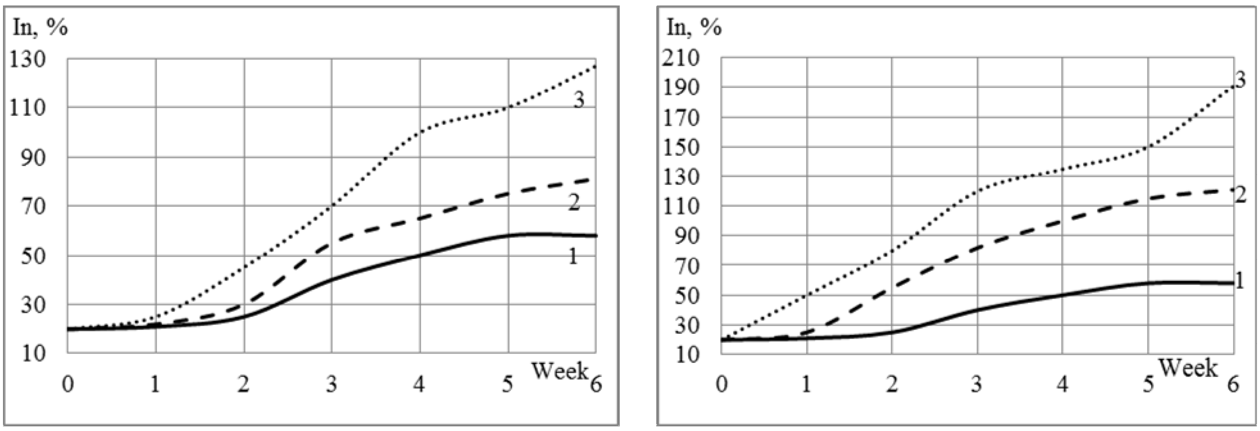

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Fig. 9. Dynamics of changes in the germination index during composting with mineral (a) and microbiological (b) additives in the mesophilic (2) and thermophilic modes (3) as compared with the control sample (1)

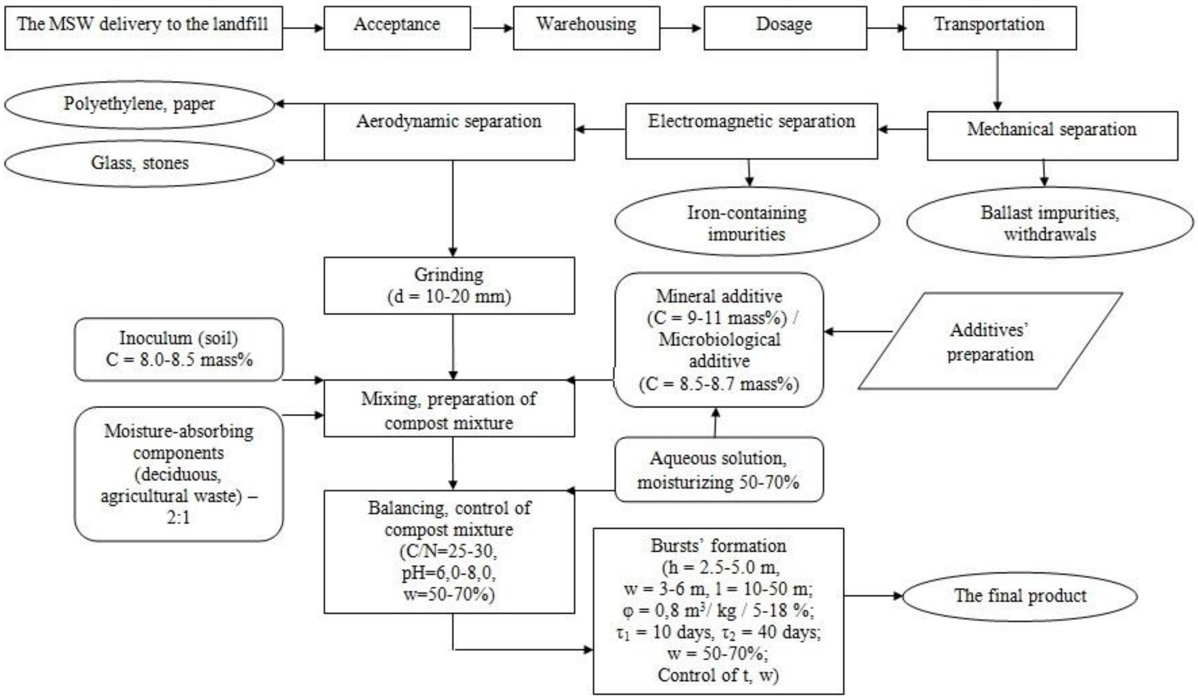

Fig. 10. The general technological scheme of composting of the MSW food component at the landfill

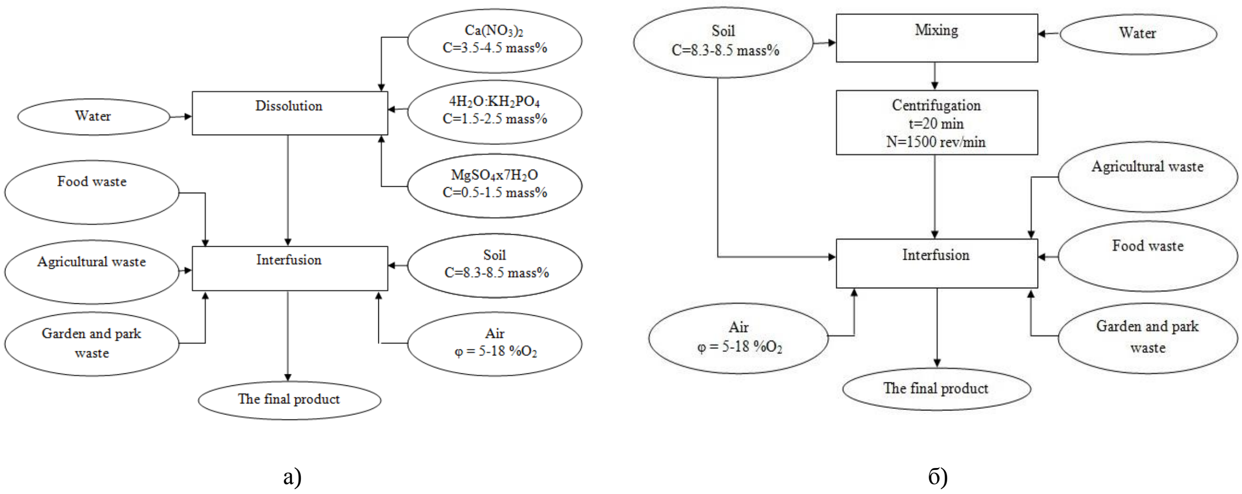

Fig. 11. Technological scheme of composting of the MSW food component with the addition of mineral (a) and microbiological (b) additives

The improved composting technology of the MSW food component is environmentally safe and economically feasible as evidenced by the performed ecological and economic assessment of waste disposal technologies. Payback of the introduced technology is 6–10 years, the cost of the received compost is 76 UAH per ton, which is 4 times less than the market value. The implementation of the improved technology will allow to preserve the natural resource potential of soils and ensure stable high ecological and economic efficiency indicators by reducing the MSW amount, greenhouse gas emissions, raising the environmental safety level in the region and obtaining a quality product.

Conclusions

The actual scientific and practical tasks are solved, such as providing ecological safety of the MSW landfills by introducing a complex of technical and technological measures for ecological safety management which include an advanced composting technology of the MSW food component, methodological approaches to integrated assessment and prediction of the MSW landfills impact on the environmental components.

The conducted studies allowed to get the following scientific and practical results:

1. The mechanism of the ecological hazard formation of the MSW landfills is grounded on the basis of identification and evaluation of input, output and risk ecological aspects.
2. An assessment of the environmental hazard level is conducted, based on the system of complex indicators characterizing the occurrence probability and the environmental hazard degree of the MSW landfill, and it allows to classify the object in accordance with the negative impact degree.
3. An ecological safety management system for the MSW landfill was developed, where the management object is the MSW food ingredient. The system is based on the improvement of the composting technology of the MSW food component, which reduces the negative impact intensity of the MSW landfill on the environmental components.
4. It was established that the introduction of advanced composting technology allows to reduce the volume of discharged methane by 21 %.
5. Experimental methods of the composting intensification of the MSW food component through the introduction of mineral or microbiological additives have been substantiated. It was established that the introduction of a mineral additive accelerates the compost maturation period by 2.2 times in the thermophilic conditions and by 1.4 times in the mesophilic, the application of the microbiological additive accelerates it by 3.3 times in the thermophilic conditions and by 2.1 times in the mesophilic ones.
6. The environmental friendliness of the proposed technology is confirmed by an increase in the level of environmental safety, the efficiency is confirmed by investment attractiveness, and social value is confirmed by reducing the product cost.

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