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The Role of Complex Compost in Remediation of Soils in Cultivated Lands

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Abstract

The role of complicated compost on agronomic properties of ordinary chernozem affect on changes in physical, chemical and biological characteristics. Improving of abiotic properties of chernozem significantly ennobles of results of qualitative aspects of plant productivity (their growth, development of separate parts-roots, zone of tillering, forming metamers), development of various of living organisms that play an important role in maintaining the stability and functioning of upper soil layer. The functional significance these organisms is higher at the soil in 400-800 times than in aqueous systems and at complex composts their level of metabolism is higher than at the soil in 200-250 times. The increase in the number of living organisms in complex composts seriously expands of ecological niches of soils, and in the future increases of set their taxa. Living organisms in complex composts substantially exceed their content in the soil The organic matter and organic carbon in the complex compost noticeably prevails over the soil that determines the energetic material for the functioning of living organisms. Microorganisms use many different compounds and separate substances which are often inaccessible for higher taxa because boundaries of mastering life have wider and they are capable of developing in large range of temperature, pressure. pH and other extreme levels.

Keywords: microorganisms, complex compost, recultivation of soils, waste management, soil microorganisms, conditions of living.

Introduction

In field experiments, the significant differences in the physical, chemical, and biological characteristics of soil cover and the applied complex composts were determined experimentally on ordinary chernozem. Comparing the 1) mineral wastes (NP), 2) mineral (NP) and organic (semi-fusty cattle manure) wastes as well as 3) mineral wastes (NP) and complex compost comprising mineral and organic wastes clearly determined the difference of specific variants of agricultural production in soil status, performance and quality of plants. The third variant of research with the application of complex compost influenced significantly on the physical properties of soil and crop yields during 6 years after its application to soil in the autumn of 2007 for sowing winter wheat, and further until 2013. Using complex compost reduced notably the density of soil and increased its porosity, particularly in the first 4 years (by 4-5%) and at reducing this indicator down to 3.0-3.5% in the next 2 years [15, 16, 17].

Applying complex compost to the topsoil contributed to the improvement of its structure and increased the water retention indicating the volume of water absorption by soil. The topsoil density varied according to the experiment's variants from 1.15 to 1.35 g/cm^3. In the control variant with the application of NP, the indicator was 1.30-1.35. When applying the semi-fusty cattle manure, the indicator decreased from 1.20 to 1.25, and in the variant with complex compost, it constituted around 1.17-1.20 g/cm^3. Applying complex compost caused the formation of a stronger root system, especially in winter wheat and maize, which determined an increase in plants yield in all the research years (2008-2013). When complex compost was applied to the topsoil, its strong effect was observed with respect to the increasing content of organic matter, nitrogen, phosphorus, and other elements as well as to the neutralization of the soil solution medium [2, 3, 4].

Materials and Methods

Soil degradation in a number of areas requires its transfer to organic farming. An important trend consists in applying useful properties of wastes as fertilizers to produce complex composts and apply them to the topsoil. Using wastes as recyclable materials allows their removal from the soil surface, clearance of high-water beds, stream channels, river ecosystems, and in particular pastures, fields, forest strips, and meadows. Making farming organic allows for the moderate use of mineral fertilizers and pesticides. The development of methods for restoring ecological functions of soil based on improving its physical, chemical, and biological properties is a relevant issue [1, 5, 6].

Different types of wastes of various production influence on physical and chemical activity of complex compost, determine the exchange of waste cations for the cations of waste SAC solution. Complex compost affects the content of basic fertilizer elements in soil. The nitrogen content in soil was determined in the nitrate (NO_3^-) and ammonium (NH_4^+) forms, which are the most favorable to be absorbed from soil solution by plants [8, 11, 12].

The soil adsorption complex demonstrates a good retention of ammonium form, and the accumulation of nitrates in soil depends on its moisture content. Applying complex compost reduces the content of nitrates in soil that weaken nitrification. The article aims at showing the role of complex compost in recycling various wastes and its importance for remediation of soils.

The samples of ordinary chernozem selected under the winter wheat and maize crops served as the research material in different experimental variants (soil + NP, soil + manure + NP, soil + NP + complex compost). The population of organisms was estimated by seeding soil dilutions on solid and liquid nutrient mediums (Ashby-Hutchinson and Capek). Bacteria and actinomyces were identified based on their physiological and biochemical characteristics using common identifiers [43]. Streptomyces were identified by using an actinomyces Gauze determinant, and micromyces—by using the determinants of domestic [31] and foreign authors [50]. The total abundance of microorganisms was estimated in CFU/g of complex compost. Actinomyces were distinguished due to a great variety thereof. They are crucial for circulation of organic and mineral elements affecting the nitrogen balance of soil, synthesis and decomposition of humic substances that transform various compounds.

Results and Discussion

Complex compost and waste recycling

Various industrial and agricultural wastes are processed into recyclable materials. In Russia, unfortunately, wastes are continually stocked, which will undoubtedly lead to a general deterioration in the environmental situation of certain regions. Waste recycling is a technological process intended to transform the physical, chemical, and biological status of wastes, which is focused on the neutralization and safe removal of wastes from the population. The recycling of different wastes is based on the mechanical, chemical, and biochemical processes with the active participation of different ecological groups of soil microorganisms [6, 10, 13].

Living organisms, such as bacteria, fungi, actinomyces, unicellular algae, micro-and mesofauna, play a significant role in the formation and maturation of complex composts by maintaining their stability and functioning at their subsequent application to the topsoil. The functional role of these organisms on land is approximately 700-800 times greater than in aqueous systems, while in complex composts, the level of their metabolism, according to our estimates, is 400-500 times higher than that in soil. It is very important to evaluate the mass reproduction of living organisms in the formation of complex composts because it is the indicator, through which the terms of applying complex composts to soil can be determined. The microorganisms (bacteria, microscopic fungi, algae, protozoa), being characteristic of soil and organic wastes, constitute a considerable part of the complex compost biomass. An increase in the number of living organisms in complex composts expands the ecological niches of soils. In the long term, a species diversity of higher organisms (plants and animals) is determined within this system [22, 23, 24, 25].

The abundance of living organisms in complex composts exceeds significantly their soil pool. The amount of organic matters, carbon, and nitrogen in the complex compost greatly exceeds their content in soil and they are energetic materials for the vital functions of numerous living organisms. In complex composts, the biogeochemical and physiological activity of the soil living organisms exceeds the same of plants and terrestrial animals. This is due to a high ratio of their surface area to the mass volume as well as a greater mobility of their metabolism (for example, the respiration rate of aerobic bacteria per 1 g of biomass is hundreds of times higher than in humans, and in a layer of 0-15 cm per 1 ha of fertile soil, it is equivalent to the metabolism of thousands of people). Microorganisms use different compounds and substances that are not available to the organisms of higher taxa [24, 25].

In small living organisms, the borders for life development are much broader than in large ones. They are capable of functioning within a wide range of temperatures (from-13°C to +110°C), osmotic pressure (from the double-distilled water to the concentrated salt brines), pH level (1 to 13), humidity (-20 to +90%), and in other extreme conditions [20, 21,].

Complex compost is a good medium for the development of different kinds of small bottom litter species of living organisms that produce hydrocarbons, enzymes, vitamins, amino acids, and other active ingredients. According to their chemical and physical properties, complex composts are the heterogeneous and polydisperse temporal systems. They are a rich complex substrate that provides a diverse set of living organisms with food resources. They actively use animal wastes, sewage sludge, organic secretions of germinating seeds and spores of higher and lower plants [23, 24]. The development of various living organisms in the complex compost increases the variety of chemical reactions between the organic and mineral wastes and then accelerates their transformation into a single biogeochemical system. Microorganisms in complex composts are the main regulators for the formation of major greenhouse gases therein, such as methane, nitrogen oxides, carbon dioxide, and others. Using complex composts to improve the topsoil (0-20 cm) contributes to its long-term (up to 5-6 years) enrichment with organic, nitrogen-phosphorus, and calcium-sulfur compounds. At this level, they preserve concentrations of the mineral compounds sesquioxides that contribute to the efficient consumption of nutritional substances [6, 7, 8, 11].

Due to the accumulation of large amounts of organic matters, complex compost is markedly surpassing in a set of species of living organisms and the abundance of individual populations within the surrounding systems. Over time, the topsoil is numerically incremented by living organisms, which enhances the exchange of energy and substances between various components of land, atmosphere, and hydrosphere, significantly expanding their ecological niches [4, 14, 15, 16].

The effect of complex compost on the topsoil

The ordinary chernozem soil in our experimental plots exposed to the study is the heavy loam soil with a high share of dust, silt, and fine dust components. The fraction of medium dust and sand occupies a small part. When applying complex compost, the physical clay fraction in soil increases insignificantly. In the second and the following years after the application of complex compost, the physical clay content increases from 6.0% up to 6.5% as compared to the control plots (53-55%); the silt fraction in the control plot was 25-26%, and increased by 2.0-2.5% upon the complex compost application. When applying complex compost, an increase in the fine particles was observed as compared to the control plot.

Complex compost improves the index of soil structure, which improves its aggregation. Applying complex compost enhances the soil aggregation index by 6.0-7.5% as compared to the control plot and demonstrates a high level of its micro-aggregation and water stability of micro-aggregates. Complex compost improves the soil structure coefficient and the level of the valuable for agronomy aggregates distinguished by the fine-crumbling condition of their macrostructure and determining good water and air modes for plants and the development of soil microfauna.

Using wastes of different origin to form complex compost and its application to the ordinary chernozem contributes to the accumulation of moisture in soil and its gradual consumption, which is favorable for the conditions of plants growth, prolongation of the vegetation season, increase in yields, and provision of a good water regime.

Applying complex compost to soil significantly affects the response of the soil environment and the share of labile phosphorus, total and ammonium nitrogen. Complex compost increased the content of labile phosphorus by 40.0-42.0% as compared to the control plot, while the application of semi-fusty cattle manure raises the level of phosphorus by 18.2% only. The amount of total nitrogen at the application of complex compost grew by 0.03-0.05%, and by 2.0-3.2% at the application of the ammonium one. Applying complex compost affected the content of nutritional substances throughout the period of farming rotation—6 years (Table 1).

Table 1: The content of organic matter and nitrogen compounds in the field experiment.

2007-2013					
Year	Variant of experiment	Contents OM, %	N_{total}	NH_4, mg/kg	NO_3, mg/kg
2007	Control plot	3.42	0.20±0.01	5.32±1.05	4.36±0.76
	Complexcompost	3.60	0.34±0.01	8.37±0.17	5.27±1.10
2013	Control plot	3.15	0.23±0.01	4.30±1.05	3.68±0.10
	Complexcompost	4.07	0.37±0.01	12.15±0.17	5.84±1.10

The differences in the total nitrogen content at applying complex compost increased significantly due to the conservation of nitrogen in ammonium form and its usage by the soil microflora. For a prolonged period in summer, ammonium nitrogen is better preserved in the complex compost as well as in a mixed variant of topsoil and complex compost. Using complex compost in soil dissociates calcium sulphate, in the solution of which the SO.r acid residue reacts with ammonium ion to form ammonium sulfate that contributes to the conservation of nitrogen in the ammonium form and limits the denitrification process. Phosphogypsum is involved in changing its cations to the cations of the soil adsorption complex (SAC) solution and contributes to the formation of the complex compost, in which its basis as compared to soil is more porous and easily retains most of the nutritional substances.

Nitrogen is of paramount importance for the life of living organisms. The circulation of nitrogen is provided by soil microorganisms, especially by ammonifiers that mineralize organic matters, which enrich soil with the ammonium nitrogen and perform the sanitary function for purifying soil and the ecosystem as a whole from the organic substrate contributing to their decomposition. A major work is related to the transformation of nitrogen into nitrates oxidizing ammonium to simple nitrogen compounds available for plants. Nitrates formation increases the denitrification, reduces the nitrogen content in soil, while plants accumulate high levels of their mineral compounds. Using mineral fertilizers contributes to the development of nitrification. Applying complex compost reduces the titer of nitrifiers down to 10^{-4} (Table 2).

Table 2: The dynamics of the abundance of ecological and trophic groups of microorganisms within a farming rotation on ordinary chernozem.

Year	Variant	Ammonifiers, 10^{-5} CFU/g	Amylolytic bacteria, 10^{-6} CFU/g	Oligotrophic bacteria 10^{-5} CFU/g	Nitrifiers, titer
2008	Control plot	95±4.5	40±2.3	70±3.8	10^{-6}
	Complexcompost	187±9.6	82±4.1	82±4.1	10^{-5}
2013	Control plot	89±4.2	37±2.1	71±3.1	10^{-6}
	Complexcompost	182±9.5	82±4.1	85±4.5	10^{-4}

The amylolytic group of soil microorganisms performs relatively late stages of organic matter decays. During the development of plants, ammonifiers are equal to the amylolytic group in terms of their activity. When complex compost is applied, the group of amylolytic microorganisms was a level lower than ammonifiers. With the application of complex compost, the amylolytic organisms totaled to 80×10^6 CFU/g, and 43×10^6 CFU/g in the control plot. A strong increase in the actinomyces is observed when applying complex compost that comprised up to 60% of the oligotrophic group.

Complex compost and organic matter stability

Microbiocenoses in complex compost, especially during the initial period of its development, are quite diverse and distinguished through the differences in vegetation conditions. They can both destroy and stabilize organic matter. In the biomass of living organisms, the concentration of organic matter reaches up to 10-14% or more, and the period of organic carbon and nitrogen circulation is about 6 years. If the share of clay fraction in complex compost is significant, the activity and protection of living organisms is higher, and the duration of their development is enhanced considerably [5, 7, 9, 10, 14].

The decomposition of organic matter by living organisms in the complex compost depends on the activity of enzymes functioning for a relatively short time (up to several days). The extracellular enzymes using the free energy within the system are adsorbed by the solid phase and contribute to the decomposition of organic matter in the vicinity of their source (up to 30-50 µm). While mixing the complex compost, the activity of living organisms is reduced. However, an organic matter is also retained as a whole since the effect of extracellular enzymes thereon is not available [15, 17, 18, 30, 32].

The clay minerals in complex composts have different ways of binding metabolites and weakening growth of living organisms, but do not cause dehydration of their cells. The diameter of bacteria ranges from 0.15 to 4.0 µm, and fungal hyphae—from 3 to 8 µm. The fungal hyphae are rarely found in micropores, whereas bacteria colonize them and thus are reliably protected from a number of carnivores. Fungi as compared to bacteria are better protected from carnivores due to close interaction with clay minerals and soil aggregates [12, 13, 14, 19].

The fungal hyphae contribute to the formation of bridges between the inner and surface layers of various wastes and are less dependent on their positional application. The mobility of the majority of living organisms in the complex compost is subject to organic matters and their secretions, and is used by the closely applied wastes. Fungi produce various forms of enzymes (e.g., peroxidases) that reduce the lignin complexes. Monomers (derivatives of lignin polymers) compose an integral part of the humic new growths. They are preserved in complex compost for a significantly long time and strongly enough. Later, they are also retained in soil—in the walls of fungal cells containing melanin and chitin. The metabolism in phospholipids is quite active, which is caused by the conformity of organic carbon accumulation to the growth of organic matter [7, 8, 23, 25, 32].

Mycorrhizal fungi are of much significance for the stabilization of organic carbon in complex composts because they are the obligate symbionts. This allows for the development by plants of a large soil volume, which affects the accumulation of organic carbon in the biomass of mycorrhizal fungi (they contain about 1,000 kg of carbon per 1 ha). Mycorrhizal fungi contain organic carbon in the form of a decay-resistant glycoprotein (glomalin). By using their hyphae, the mycorrhizal fungi together with small plant roots form a kind of net in the complex composts, which entangles and weaves the soil particles and contributes to the stability of organic matter in the form of aggregates [13, 29, 30, 32].

Bacteria also prove to be rather essential for the transformation of organic matter in complex compost. For example, an autotroph fixation by CO_2 bacteria reaches 5% of the soil respiration level, while the carbon fixed from the atmosphere is accumulated mainly in the mass of bacteria. In complex composts, living organisms are used as a source of nutrition for organic carbon, which serves as the primary biotic agent for the transformation of organic matter, and the biomass of living organisms is a basis for its renewal in soil. The organic matters and living organisms in complex composts transform many compounds into more simple ones. They are used or exposed to the chemical and physical-chemical processing mainly with the microbial metabolites [7, 16, 20, 29, 33].

The variation of forms and taxa of living organisms in complex composts is determined mainly by the C:N (21:1) ratio of organic carbon and available nitrogen. Complex compost is dominated by small living organisms (bacteria, fungi, actinomyces, etc.), which are characterized by a high rate of reproduction per a short period of term and are actively increasing their population composition. The population of living organisms in complex compost as compared to air, water and soil is significantly higher (the number of cells in 1 g of complex compost reaches several billions, the length of fungal hyphae makes thousands of meters, and their total biomass totals to 20-30 thousands of tons per

1 ha of soil). The circulation of all ash constituents and especially of organic carbon and nitrogen (27:1) passes throughout the entire system of the complex compost development. The C:N ratio in complex compost is higher than the 23:1 ratio that is dominated by fungi, which indicates their substantial nitrogen security [3, 21, 22, 34].

The complex compost is formed from a mixture of various organic and mineral wastes. At a narrow C:N ratio (20:1 and less), complex compost is dominated by prokaryotes (bacteria), which are backed mainly by the nitrogen fixation, tariffing, denitrification, oxidation of sulfur and metals, formation and use of methane as well as sulfur and sulfate respiration. The circulation of sulfur and nitrogen in the complex compost is largely controlled by prokaryotes, which support the movement of these elements and preserve the biosphere. Eukaryotes cannot cope with such a task because they specialize mainly on photosynthesis as well as on the development of aerobic conditions for the existence and opposition of prokaryotes [23, 24, 28, 31].

When applying complex compost to soil, eukaryotes and prokaryotes differ in the consumption of organic carbon, application and sustainability of their forms as well as the specific features of metabolism in their accumulation of biomass. At a high efficiency of the organic carbon consumption (increase in biomass), it is less spent on breathing, less transmitted to the atmospheric air in the form of CO_2, and better retained in the salt variant of complex compost. At nitrogen deficiency, the growth of living organisms (prokaryotes and eukaryotes) in complex compost makes only about 20-30% of the norm, while at its increasing amount, the growth of living organisms increases 20-25% more on account of ammonium sulphate [2, 4, 7, 25, 26].

Complex compost and its composition

Mature complex compost is a soil-like formation enriched with organic matter (up to 20% and more) with a neutral solution reaction (pH 6.8-7.2), with the inclusion of a large amount of sesquioxides that are actively binding together various mineral and organic particles. The system of complex compost actively involves many living organisms, wherein their waste products are used as a cementing agent to bind together a large number of fine particles. Numerous species of bacteria, unicellular algae, fungi and actinomyces form peptide and carbohydrate gums and together with clay particles form relatively small, but water-resistant formations [27, 30, 32].

The microscopic fungi and certain species of unicellular algae have a dominant role in the formation of water-resistant particles, which affect significantly the aggregation of complex compost through the isolation of polysaccharides that bind various organic and mineral particles fixing them mechanically with their hyphae and filamentous thalli [14, 18. 35, 36]. The main part of this work is performed in the topsoil from 0 to 15-20 cm in depth with periodic mixing and irrigation of complex compost every 20-25 days during the summer, which accelerates the formation of the soil-like composition under the active development of fungi and unicellular algae [2, 5, 12, 37, 38].

Forming the soil-like composition in complex compost is performed by small unicellular algae on acid substrates (such as phosphogypsum, etc.), which produce mucous substances that combine the upper part of the organic-mineral nature. By using thalli, they bind and condense these combinations, enhancing their resistance to water. Some living organisms produce rather active substances that destroy the fine-crumbling condition of the complex compost structure and do not contribute to its strengthening. Complex composts are the main repository for various species of living organisms, representing a wide spectrum of their communities. Sampling various communities makes it possible to isolate averaged parts out of the 5-6 replication of the complex compost and to study the most valuable species of microorganisms, such as bacteria, fungi, and algae, to compare them with the nature-made objects, for example, the undisturbed territories [7, 38, 39, 41].

Transforming the nutritional substances and developing the redox processes at the formation of the complex compost may be carried out by microorganisms and particularly by bacteria and microfungi. Living organisms affect the underlying layers of complex compost through organic matters. They are the result of the decomposition of plant residues and minerals due to the extraction of phosphorus, silicon, iron, manganese, sulfur, calcium, and other elements therefrom [16, 17, 40, 42].

In complex compost including a variety of microorganisms, plants, and animals, as well as the natural materials of biological formations, the organic carbon and nitrogen as well as sulfur, phosphorus, potassium, and calcium are primarily released during the decomposition of organic matter, and the nutritional substances that are the most valuable for the development of living organisms are accumulated. The rhizoplane microorganisms are of great importance. They are concentrated in soil on the surface of living roots and transmit the readily available macronutrients and many active substances, including enzymes, auxins, vitamins, and other compounds in the composition of complex compost. In living organisms (e.g., bacteria), the content of nitrogen is higher than in complex compost, and it exists in the form of structural organic matters that are decaying and consumed by other systems relatively slow [19, 21, 43].

The complex compost is an important source of the molecular nitrogen fixation by prokaryotic organisms after its application to the topsoil. Since the provision of plants with nitrogen is of systemic importance, the biological role of complex compost proves to be rather essential. In complex compost, the nitrogen-fixing bacteria (symbiotic and nonsymbiotic) are formed with a varying intensity. Nonsymbiotic bacteria are associated with complex wastes, since they produce available organic carbon and are of core importance for the fixation of nitrogen [7, 20, 34].

The eukaryotic organisms, including fungi, form mycorrhiza on the roots of plants and are capable of utilizing the hardly accessible compounds of phosphorus and providing plants with this element. The plants that do not form mycorrhiza are supplied with this element less. When complex compost is applied, the mycorrhizal fungi supply not only calcium and phosphorus to plants from the soil, but also nitrogen, sulfur, potassium, and many trace elements, such as manganese, copper, zinc, and cobalt. Thus, the microorganisms of complex compost diversify the "diet" of nutritional substances in the topsoil [19, 28, 44, 46].

Complex compost and organic pollutants

Vitamins, enzymes, growth stimulators, and other biologically active substances influence the development of living organisms in complex compost. At frequent cultivation of certain crops (e.g., potatoes, sunflower, etc.), the same field often suffers from toxicosis, which is determined by the accumulation of toxin-producing fungi referred to saprotrophs. Mycotoxins are produced by microfungi at the development of organic wastes, which are in general dangerous for living organisms and humans. Applying complex compost to soil as a fertilizer smoothens the action of mycotoxins or even neutralizes them completely [7, 26, 47, 49].

Within the system of complex compost, fungi often demonstrate their toxicity through inhibiting seeds germination. Phytohormones playing an active role at low concentrations in complex compost affect the regulation of certain physiological processes (for example, the growth of bacteria, fungi, actinomyces). Such substances can include ethylene produced by yeast fungi. The microscopic eukaryotes, as the sources of organic carbon, are important producers of ethylene in media with humates and fulvic acids. Saprotrophs can also produce other gaseous substances, which have a toxic impact on plants and their microbial communities.

Some fungi and bacteria dominating in complex compost form auxins, the main producer of which is the azotobacter that causes growth reduction in some organisms. Individual mycorrhizal fungi and bacteria produce phytohormones cytokinins that inhibit cells aging and contribute to the regulation of their growth [2, 19, 45, 48].

Applying complex compost to soil enhances the development of microbial communities that start interacting during the seeds germination in certain plant species, the development of microorganisms spores, the growth of higher plants roots, and during other processes that depend on the temperature, water, air, and nutritional conditions of vegetation. The effect of soil and complex compost on these processes in plant life is achieved through the interaction of living organisms of both media. The effect on the plants development is manifested in the formation of complex consortia and merger of the bio-inert systems. Mycotrophic organisms are well adaptable. The correlations are observed often between the growth and development of plants and their mycorrhizas associated with the water-and-air regime of soil, which enriches them with nutritional substances [1, 22, 48].

An important factor in the development of complex composts is the temperature level during the spring and autumn seasons. In the spring, their formation is accelerated through the development of living organism populations, and in the autumn, they demonstrate a significant decrease. Increasing the populations of living organisms and their activity during the spring season runs parallel with the increase in temperature of the complex compost and its humidifying and strengthening of a nutrient status capacity. In the autumn season, the development of the living organisms populations is caused by an increase in the amount of plant wastes (sugar beet, sunflower, immature seeds, etc.), on the one hand, and by moistening and retention of many not yet washed by rain biological secretions from wet wastes (vegetables, cabbage, tomatoes, fruit, etc.), on the other hand. The large in population prokaryotic and eukaryotic living organisms further increase their abundance within the complex compost that develops during this period, which contributes to the conservation of their nitrogen and carbon component [7, 8, 17].

Populations of the living organisms species within complex compost are associated with changes in some of their characteristics: ethylene and cytokinins fluctuations, concentration of toxic compounds, etc. The availability of phosphorus, sulfides, iron oxides, silica, and a number of sesquioxides in phosphogypsum contributes to the mineralization of dead organisms [10, 12]. Living organisms prove to be essential in solving problems related to the transformation of wastes in the topsoil of cultivated lands.

Using complex composts as a technique for treating soil against heavy metals, oil pollutions, etc. is an effective method to protect landscape systems. Humification of wastes involves using the living organisms in the complex composts that accelerate their maturation, increase their content of nitrogen, phosphorus, calcium, potassium, sulfur, magnesium, and organic compounds. When complex compost is applied to topsoil, organo-mineral fertilizers are simultaneously delivered to the soil as well as a variety of living organisms contributing to the restoration of soil fertility, the inhibition of pathogenic organisms development, the increase in agricultural yields, and the ability of crops to endure adverse conditions [23, 25, 48. 49].

Upon the addition of relatively fresh plant wastes (forage remains, sweepings after grain cleaning, etc.) and mineral wastes (chalk, phosphogypsum, etc.) to complex compost, the microorganisms quickly transform them with achieving an equilibrium level. This process passes intensively. The development of complex compost includes a variety of wastes that can transform the received additional organic matters, especially pollutants. The more diverse the range of living organisms in complex compost is, the higher its ability to convert various incoming pollutants is. Biochemical processes in complex compost are backed up by several species of living organisms, while their species and population composition contributes to the fulfillment of important functions within the emerging agricultural system, such as the purification from organic pollutants [15, 16, 18].

In complex compost, an important function of living organisms is to destroy the received organic pollutants, which is mostly performed by soil prokaryotes. The function of transforming substances in the complex compost belongs to the living organisms and needs to be studied seriously. For the last 20-30 years, dozens of new substances (oil and plastics, heavy metals and herbicides, soot and dust, gaseous emissions, etc.) were added to wastes. A problem in the organization of complex composts is that it could be possible to create favorable conditions for the development of high-quality substrate in future [32, 33, 49].

The normal functioning of complex compost at its application to topsoil depends on the transformation of main wastes at minimum effort, which will provide an important solution for recycling used organic and mineral substances. Preparing complex compost for these purposes is an important technique for using a wide range of industrial wastes that contribute to the preservation of nutritional substances during their decomposition, to the formation of new compounds, to the availability of nutritional elements within plants, and to the development of new ecological niches [13, 14].

A biological fixation of nitrogen when applying complex compost to soil improves and accelerates the neutralization of pollutants. This conclusion is based on the living abilities of individual strains of the living organisms to decompose or absorb many organic pollutants within their biomass. The biological neutralization causes a secondary air pollution with the decomposition products of the soil organic matter, such as ammonia, ammonium, and hydrogen sulfide. To neutralize organic toxic agents and heavy metals in the complex compost, the biological treatment is used as well as the impact of nitrogen and phosphorus compounds with the enhancement of their biological degradation and placement of pollutants within the soil layers [21, 23, 25].

When transforming certain types of wastes, harmful substances with a high degree of toxicity are generated. Much attention is paid to the decontamination of soil from various pollutants, including heavy metals, oil contamination of certain organic wastes, and other substances. Living organisms are of essential importance for decreasing the volume and toxicity of organic pollutants. Living organisms (bacteria, fungi, actinomyces, and unicellular algae) fulfill a great function of the complex composts subject to the participation of individual substances of nitrogen, carbon, calcium, sulfur, and phosphorus within a cycle [19, 20, 21].

The decomposition of organic pollutants is caused by sufficiently high temperature and humidity and is used each time when the microbial community preserved its viability as well as species and population diversity. This process is accompanied by the application of complex compost, which develops slowly, but at the same time with a high degree of efficiency. On the contaminated fields, legumes, sorghum, forage peas, alfalfa, clover, barley, oats, amaranth, rape, and other field crops are cultivated to check the level of soil contamination [23 25 28].

To activate the functioning of living organisms (microorganisms and soil animals) in the complex compost, it is required to periodically apply carbon and nitrogen at a high C:N ratio and mechanically mix and water wastes. A condition for propagation of microorganisms in wastes is to maintain an optimal level of temperature and humidity within the mixture. The effect of microbiological degradation of the environment polluting substances in wastes is achieved by activating the emerging simple agricultural systems. Applying complex compost to soil is a prerequisite for the biological treatment of soil against organic pollutants. A neutral medium in the main part of wastes is the most suitable medium for their biological decomposition [1, 24].

The introduction of certain species of microorganisms and acclimatization of soil living organisms creates favorable conditions for the transformation and decomposition of organic wastes, which underlies the development of anaerobic technologies for their disposal. The results of these studies confirm the possibility of using complex composts with a wide range of emerging microbiocenosis and faunal systems [29].

The production of complex composts by using mineral and organic compounds therein as well as their acidic and alkaline properties contributes to the decay of toxic compounds (for example, the effect of sulfuric and other acids on the decay of surfactants, oil wastes, etc.) and enhances the self-purifying capacity of soil. The inability of soil to purify itself due to its overload with pollutants (such as heavy metals or oil contaminations) without applying complex composts transforms such territories into man-made deserts. An unfocused program on soil advancement is one of the main reasons for non-acceptance of the proposed measures and becomes a mere waste of money and time [1, 2].

Soil-like structures and complex compost

Mature complex compost is a soil-like formation enriched with organic matter with the inclusion of a large amount of sesquioxides that are actively binding together various mineral and organic particles. Living organisms are actively involved in the creation of such soil formation within the system of complex compost, wherein their waste products are used as a cementing agent to bind together a plurality of fine heterogeneous particles. Many bacteria, unicellular algae, fungi, and actinomyces together with clay particles produce water-resistant formations [11, 12].

The microscopic fungi and certain species of unicellular algae have a dominant role in the formation of complex compost, affecting the substrate composition through the isolation of polysaccharides that bind various organic and mineral particles fixing them mechanically with their hyphae and filamentous thalli [4, 8, 12].

When decomposing organic matters, the biological formations within the complex compost (microorganisms, plants and animals) release primarily the organic carbon and nitrogen followed by sulfur, phosphorus and calcine, thereby carrying out a very important systemic function — the accumulation of the most valuable nutritional substances that are fundamental for the formation of living organisms. Rhizoplane microorganisms are of special importance. They are concentrated on the surface of living roots and transmit the readily available macronutrients and many active substances, including enzymes, auxins, vitamins, and other compounds. Complex compost, especially its humus, contains less nitrogen than the living organisms (for example, bacteria), wherein the nitrogen is contained in the form of structural organic matters that are decayed and consumed relatively slow [17, 20].

Conclusion

Complex compost, which is a three-phase system of mineral compounds, is capable of transforming into a habitat (the solid, liquid and gaseous phases) as well as the vitally important fourth phase of living organisms representing a rather diverse composition (microorganisms, meso-and microfauna) of different biota groups, including the growing space for living systems, and unifying the three previous abiotic phases. Developing the main substrate of complex compost is generally carried out in a way similar to the topsoil and at the same time differs in the specificity of the development and conditions for passing certain phenological phases for individual living representatives of biota that form their microcolonies, as well as in the development of physical and chemical processes that seriously transform the system of mineral compounds formation.

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