Experimental and Analytical Principles of Improving Waste Management Technologies in the Technosphere

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1 Introduction

Biosecurity is one of the most important components of Ukraine's environmental and national security. According to the World Health Organization (WHO), the situation with diseases today is more than ever far from stable. Equilibrium in the world of microbes is violated due to population growth, rapid urbanization, intensive methods of agriculture, deterioration of the environment, etc. Opportunities for the rapid international spread of infectious diseases and their carriers are greatly increased due to aviation, which carries more than 2 billion passengers per year.

One of the most serious biosecurity challenges is H5N1, H7N9, and pork H1N1 (as well as H5N8, H7N3, H7N7) viruses, prions, SARS, MERS, Ebola, smallpox, and polio, as well as drug-resistant microorganisms (in particular tuberculosis – M (X)DRTB) and coronavirus infection COVID-19, which was first registered on December 31, 2019, in Wuhan (China). It is necessary to reorganize the economy in such a way that human industrial activity is fully integrated into the effective

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environmental infrastructure. Thus, the study of the process of transport waste management in Ukraine and the world is currently relevant.

One of the global environmental problems inherent in Kyiv like the rest of the megacities is the problem of environmental pollution with production, consumption, and transport infrastructure waste. These issues are practically not solved today, which, without a doubt, will lead to new environmental problems – pollution of groundwater with toxic waste, the formation of biogas, changes in the landscape, etc.

Problems associated with the damage of a wide variety of anthropogenically transformed substrates with microscopic fungi are becoming more urgent, extremely important, and acute in terms of city ecological issues, the neutralization of transport infrastructure waste, and the safety of human life. Microscopic fungi particularly are recognized as the main agents of bio-damage in the terrestrial environment.

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2 Statement of the Problem and Purpose of Research

Today, in Ukraine, the problem of landfills is one of the most important and relevant among the problems of environmental pollution. This issue needs to be addressed immediately, not only in Ukraine but also throughout the world. Each human dwelling produces a huge number of unnecessary materials and products, from old newspapers and magazines, empty cans, bottles, food waste, wrappers, and packages to broken dishes, worn clothes, and broken household or office appliances. Every day, we face waste: at home and on the street. Everywhere we are surrounded by papers, plastic wrappers, glass, cellophane, etc.

Garbage is formed and accumulated not only in residential premises but also in offices, administrative buildings, cinemas and theaters, shops, cafes and restaurants, kindergartens, schools, institutes, clinics and hospitals, hotels, railway stations, markets, or just on the streets.

If not in terms of standard of living, then at least in terms of the amount of household waste, Ukraine does not lag behind the average European indicator. About 10 million tons of garbage accumulate every year. According to the forecasts of both foreign and domestic experts, the environmental situation in Ukraine is approaching critical, because we are engaged in waste processing at a very low level. Official data of the Ministry of Regional Development of Ukraine shows 5500 official landfills with an area of 8500 hectares. This is 0.014% of the total area of Ukraine (60.4 million hectares).

The problem of waste disposal is relevant for Ukraine, as the country is the European leader in the amount of waste per capita. At the same time, the situation with its disposal remains at the same low level. Because the composition of domestic waste is increasingly approaching the Western one (disposable tableware, aluminum cans for drinks, plastic packaging), its volume has a steady tendency to increase annually. It especially concerns a large volume of polyethylene materials that are almost undegradable. A large amount of packaging material after one-time use is converted into waste, into the garbage.

As you know, transport is an important part of the world economy, as it is a material carrier between states. The specialization of states and their complex development is impossible without a transport system. The transport factor affects the allocation of production sites; without its consideration, it is impossible to achieve rational placement of productive forces. When allocating production sites, the need for transportation, the mass of raw materials of finished products, their transportability, the provision of transport paths, their throughput, etc. are all being considered. Depending on the impact of these components, the decision is made on the enterprises' allocation. Transport is also important in solving social and economic problems. The provision of the territory with a well-developed transport system serves as one of the important factors in attracting the population and production factors, has an important advantage for the placement of productive forces, and gives an integration effect.

Transport infrastructure includes railway, tram, and inland waterways, contact lines, roads, tunnels, overpasses, bridges, railway and bus stations, subways, airfields and airports, communication systems, navigation and vehicle traffic management, as well as others to ensure the functioning of the transport complex of the building, structures, devices, and equipment. Vehicles include aircraft, railway cars, vessels used for trade or navigation, automobiles, and electric urban passenger transport.

The purpose of this stage of research:

Task 1: To identify the landfills of transport infrastructure in the Kyiv and Kyiv region

Task 2: To conduct a taxonomic analysis of a complex of microorganisms isolated from landfills of transport infrastructure in Kyiv

Task 3: To highlight complexes of microorganisms capable of petroleum products hydrocarbons and solid organic waste destruction/degradation

3 Environmental Problems of Transport Infrastructure Waste

In the process of vehicles' exploitation, the particles of worn-down details are being released into the environment, which significantly pollutes it. These pollutants are formed due to the friction of material elements sliding against each other during an operational cycle.

The main sources of this type of pollution are as follows: engine and transmission parts, brake pads, and tires.

As for the wearing down of engine parts and transmission, it can be reduced by timely lubrication with high-quality oils and the use of oils recommended for this vehicle according to the frequency of oil replacement in lubrication systems.

The composition of used petroleum products includes used motor oils, transmission oils, industrial lubricants, as well as petroleum products that are used to wash machinery units.

Studies have shown that the volume of used oils and lubricants have different compositions depending on the modification of cars, their technical condition, rolling stock working conditions, and can range from 13% to 33%.

The decommissioned vehicle left in an abandoned state is a concentrated source of anthropogenic environmental pollution. Despite this, it is difficult to imagine the life of modern society without, for example, automotive or air transport constantly improving engine power, design, safety system, and comfort, and due to technical development, the morphological composition of the vehicle changes, more and more new materials are used for its production.

All those materials that were used during its manufacture remain in the decommissioned vehicle: ferrous and non-ferrous metals, petroleum products, lubricants and coolants, plastics and textiles, rubber products, glass and ceramics, cardboard, wood, etc.

For the proper handling of decommissioned vehicles and the correct selection of processes and methods of their further processing, they are systematized. All these materials can and should become secondary resources to produce new commodity products.

The aircraft consists of millions of components (parts) that must be further recycled after writing off the machine. In other words, an aircraft is a huge number of metal and composite parts that have been synchronously flying at a speed of 900 km/h (0.85 of the speed of sound; this is the typical speed of the Boeing 787 Dreamliner) at an altitude of 10 km.

Based on the situation around the world over the past decades, the use of aviation recycling and disposal processes is an alternative source for obtaining the necessary aviation spare parts and aircraft components.

4 Ways to Solve the Problem

Biotechnology for environmental protection is a low-waste technology with an environmentally friendly technical implementation of the process. Their use is aimed at cleaning the environment from various kinds of pollutants and producing environmentally friendly products with the possibility of secondary resource flows recycling. Therefore, the choice of biologically active systems (BAS) has a conceptual basis associated with the need for deep knowledge in the field of physiology and biochemical processes of growth and metabolism of biological objects, as well as the mandatory sanitary and hygienic evaluation.

Microorganisms that can be used to neutralize solid and liquid waste are very different, and their spectrum is continuously expanding. With the development of industrial processes, there is an accumulation of new types of waste that can be neutralized and converted into useful products by biotechnological methods. Biotechnological industrial areas are currently developing at a rapid pace. Taking into account the problem for Ukraine with landfills and waste in general, it is necessary to develop unconventional, in particular, biotechnological methods of their processing.

It is also worth noting that BAS of these microorganisms can be widely used in industry, medicine, and agriculture to neutralize the waste of these industries. To solve the issues of food safety, conservation, and restoration of natural resources, in particular the fertility of soils contaminated with petroleum products, it is advisable to use biotechnology that does not violate biological equilibrium in nature and contributes to the effective decomposition of pollutants without the formation of toxic and destructive products.

Various manifestations of the adaptation of organisms to stress factors are observed under the conditions of various factors. The manifestation of an active strategy for adapting microorganisms, which allows them not only to maintain viability but also to reproduce and develop in a wide range of environmental factors, is, in particular, their ability to direct their metabolic processes toward the synthesis and accumulation of individual metabolite, in the activation of nonspecific protective mechanisms, that is, to use their powerful potential – to produce important BAS.

Exopolysaccharides of microorganisms can be used as biosurfactants in the detoxification processes of soil contaminated with toxic metals and petroleum products. In recent decades, environmental measures have become widespread ways to use biological technologies that are most acceptable due to their environmental safety, low cost of work, and sufficiently high efficiency, which has been repeatedly demonstrated in solving various environmental problems. The metabolic versatility of these microorganisms plays an important role in important industrial processes as well as in the biological destruction of polluting substances.

Consequently, microorganisms resistant to petroleum products can be used in bioremediation processes, in treatment technology for wastewater, contaminated by petroleum products, etc. Technologies that can be used do not violate biological equilibrium in nature and allow to effectively decompose pollutants without the formation of toxic destructive products, restoring soil fertility.

It is known that most microorganisms form biofilms – more than 99% of all microorganisms on Earth coexist in such groups with different enzymatic activities and various adaptive properties. The expansion of data on the composition of biofilm groups is of great practical importance today in the use of such "biofilm" microorganisms in biotechnology.

5 Results and Discussion

During the first phase of the research, analyzing data from the Internet and using Maxar space imagery technology and scientific research, we discovered landfills containing transport infrastructure waste or the ones related to transport infrastructure (Fig. 1).

- Landfills near Boryspil International Airport (a – unauthorized, b – official)
- Landfill in Prolisky village, Boryspil district, Kyiv region
- Unauthorized landfill near the Energia garbage plant
- Waste field of military equipment on the territory of the Kyiv Armored Plant
- Waste field of cranes in the Holosiivskyi district of Kyiv on the banks of the Dnipro River
- Waste field of buses and trolleybuses KP "Kyivpastrans" in the Darnytskyi district of Kyiv
- Waste field of abandoned cars in Desnianskyi District of Kyiv
- Solid household waste landfill No5, Pidhirtsi village, Obukhiv district

We have compiled a general map of the analyzed landfills of transport infrastructure in the Kyiv and Kyiv region, which is clearly shown in Fig. 1.

For all landfills, space images were analyzed and a map was drawn up. The data and the basic OpenStreetMap were applied (https://www.openstreetmap.org). For new, unauthorized landfills that were missing from OpenStreetMap, the authors added the geometry of landfills to its database. In addition, the specified database

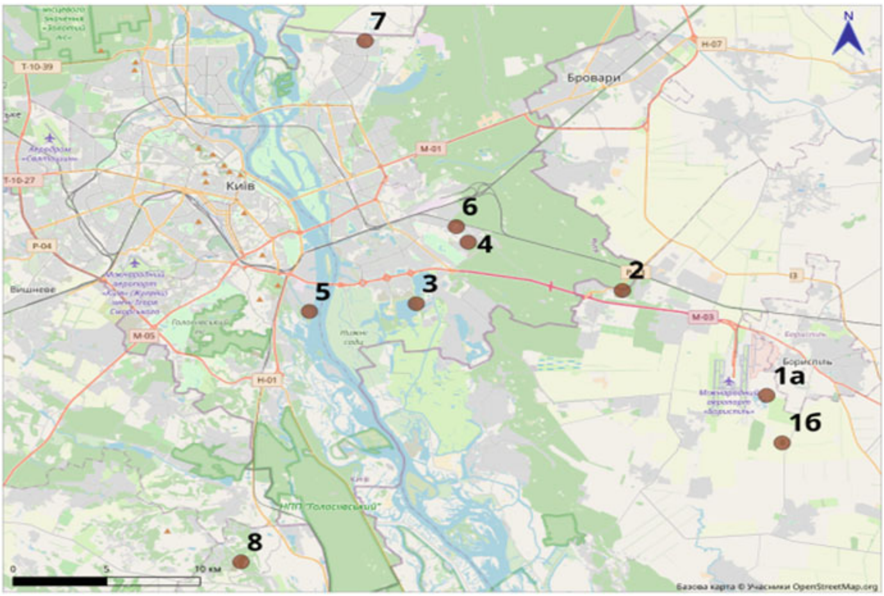

Fig. 1 Landfills of transport infrastructure of Kyiv and Kyiv region

was supplemented with information about the areas around landfills (land use, roads) obtained by decryption of space images as well as from the information on land cadastre, allowing to draw up detailed maps even for those areas that had little information in the OpenStreetMap database (first of all, it was needed for the outskirts of Boryspil International Airport and the city of Boryspil).

During the second stage of research, we took samples from the landfills of transport infrastructure (shown in Fig. 1) for the taxonomic analysis of microorganisms.

To obtain the accumulative crops of microorganisms, samples were placed on the surface of agarized media: malt extract agar, malt agar (IEA, MA produced by Merck KGaA, Germany), nutrient agar (NA, Sigma), trypticase-soybean agar (TSA), Chapek-Dox agar, and potato glucose agar (KHA or PDA – potato dextrose agar) (HiMedia Laboratories). The release of pure crops of microorganisms from cumulative crops was carried out using standard microbiological cultivation methods on appropriate agarized nutrient media (IEA, PDA, Chapek-Docks).

Isolated pure cultures of microscopic fungi were identified with the help of determinants of domestic and foreign authors. The taxonomic analysis was carried out according to the IX edition of the "Dictionary of Fungi" (www.Speciesfungorum).

As a result of the study, microorganisms capable of growth in the presence of diesel fuel were found in most of the samples studied. However, stable consortiums, microorganisms of which were capable of increasing biomass during five probations, were found in samples taken at a waste dump near the Boryspil airport. With the help of a microscopic study, it was found that consortiums were formed by static and active rod-like bacteria.

The static forms were located in the middle of a drop of diesel fuel, while the active forms either adhered to the outer part of the membrane or moved freely in the liquid between droplets of diesel fuel. We can assume that in sample 2PT, there are pleomorphic bacteria, and in samples 3PT, 4PT, and 5PT, there are capsule-forming, non-spore-forming bacteria that are capable of diesel fuel oxidation. In samples of 3VRZ, 4B, and 5B for 30–40 days of cultivation in the presence of diesel fuel, compact biofilms were formed, resembling a bacterial mat in structure. Bacterial mats are highly integrated microbial ecosystems with significant physicochemical gradients, which resemble the result of the metabolic activity of microorganisms.

During the cultivation of bacteria consortiums of samples 2PT,3PT, 4 PT, and 5PT on the solid Tauson's medium (Fig. 2), which contained 100 mkl of diesel fuel, the formation of a powerful bacterial culture in all the samples studied after 24 hours of cultivation at 28 °C was observed. Ten bacteria isolates were obtained from a bacterial consortium of sample 2PT. Their ability to assimilate diesel fuel in monoculture was tested. It was found that five of them could grow during cultivation on Tauson's liquid medium, which contained 2–4% diesel fuel, which was confirmed by phase-contrast microscopy data and Gould's sowing results on the R2A medium (Fig. 3).

According to morphological (Fig. 4) and tinctorial (Fig. 5) signs of the bacterium strain, 1–2 can be attributed to the group of corinomorphic bacteria, bacteria of other strains represented by gram-negative sticks. During the study of the ability of

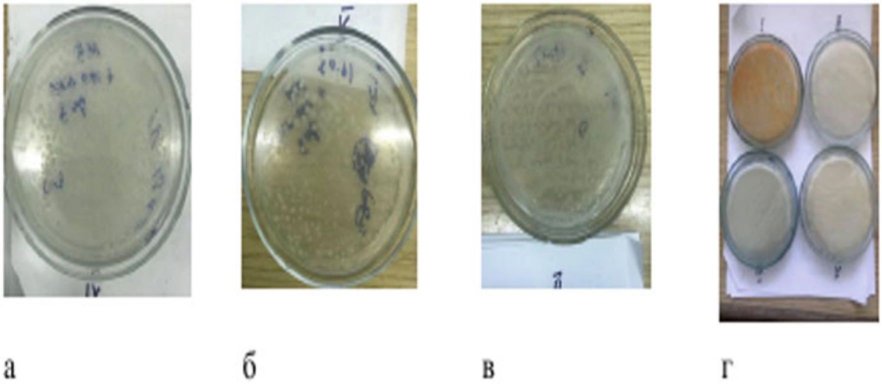

Fig. 2 Cultivation of bacteria of consortiums 2–4PT on the agarized Tauson's medium in the presence of diesel fuel (explanation in the text)

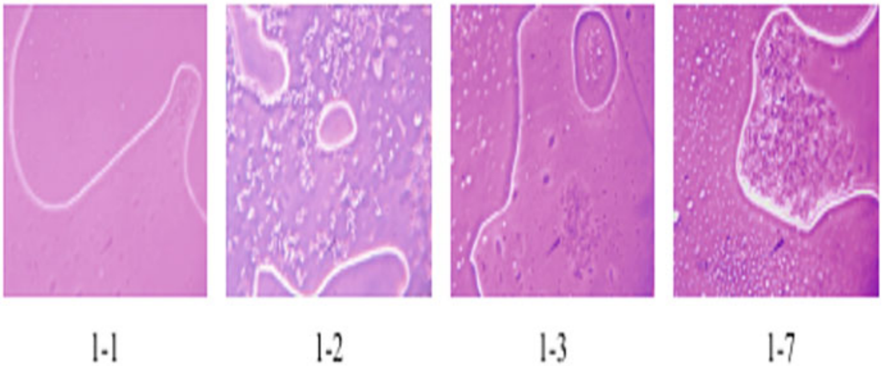

Fig. 3 Interaction of monocultures of 2PT bacteria consortium with drops of diesel fuel for 4 days of cultivation at a temperature of 28 °C. Phase-contrascopy microscopy, increase in Ch1600

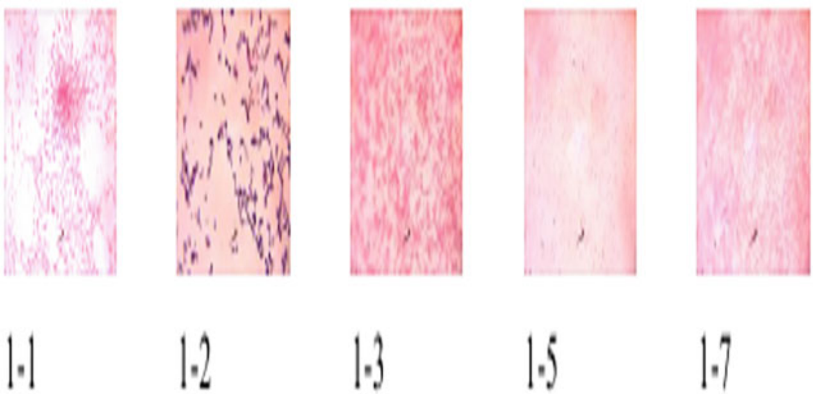

Fig. 4 Morphological and tinctorial features of monocultures of bacteria isolated from the 2PT sample. R2A cultivation environment, 48 hours, 28 °C. Coloring by gram, light microscopy, magnification H1600

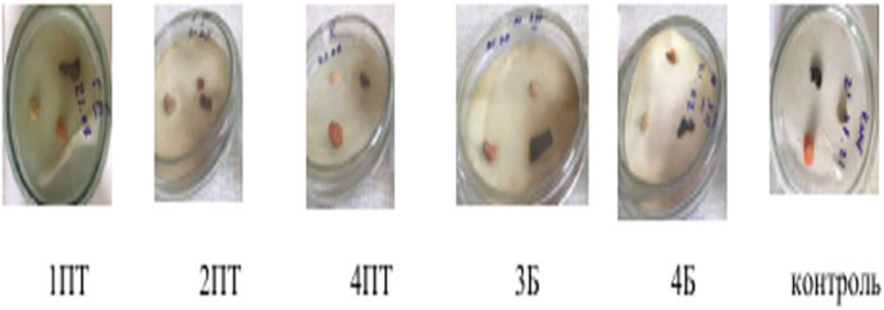

Fig. 5 Maceration of plant and fungal tissue by consortiums of microorganisms from transport waste dumps near the Boryspil airport and Boryspil Auto Plant

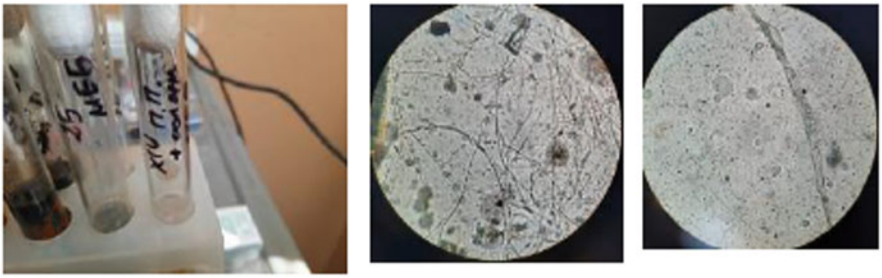

Fig. 6 Microorganisms (microscopic fungi of *Cladosporium* and *Fusarium* genera) in sample No4B (XIV) (residue of spent motor oil from the landfill of Boryspil Auto Plant)

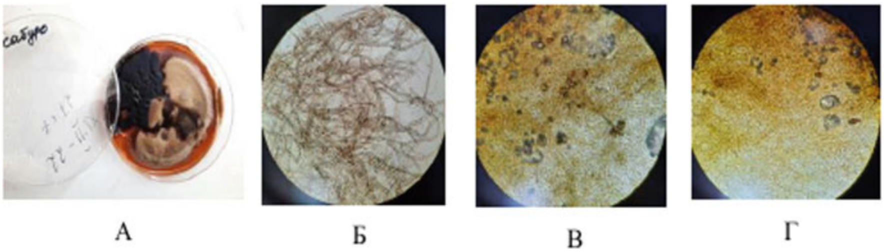

Fig. 7 Microscopic fungi of the genus *Aureobasidium pullulans* (B) and *Alternaria* cf *chlamydospore* (B, D) in sample No. 2B (XVII) (soil sample taken in the decomposition of automotive plastic parts from the landfill of Boryspil automobile plant). A – fungi cultures on the Saburo medium, B–G – increase × 400

microbial consortiums to macerate fungal and plant tissue, stable consortiums of bacteria were found in samples selected at the landfills of transport waste near the Boryspil airport and Boryspil Auto Plant. As you can see, hbceyre microorganisms participating in the iron cycle were found in most samples of a landfill of transport waste near the Boryspil airport and the landfill of the central railway station in Kyiv.

Microscopic fungi were identified with the help of the relevant determinants of domestic and foreign authors (Figs. 6 and 7). The taxonomic analysis was carried out according to the ninth edition of the "Dictionary of Fungi." This slide shows the families of fungi we have selected. These fungi can actively produce high-molecular-weight extracellular polysaccharides and important enzymes (amylase, xylanase, pectinase), which are widely used in biotechnology.

The analysis of the obtained results shows that microscopic fungi belonging to the following taxonomic groups were found in the samples: groups of the *Zygomycota phyla* (species of the genus *Mucor* and *Rhizopus*), *Basidiomycota phyla* (yeast fungi of the genus *Rhodotorula*), and *Ascomycota phyla* (species of genera *Eurotium*, *Monascus*, *Talaromyces*, etc., in particular substrate-specific fungus *Amorphotheca resinae* (modern synonym *Hormoconis (Cladosporium) resinae*). Representatives of the informal group anamorphic fungi, as well as the group of oomycetes (species of the genus *Phoma*), were also found in the studied samples (species of genera *Acremonium*, *Alternaria*, *Aspergillus*, *Aureobasidium*, *Cladosporium*, *Fusarium*, *Geomyces*, *Gliocladium*, *Exophiala*, *Penicillium*, *Trichoderma*, *Stemphylium*, *Ulocladium*, etc.)

During the third stage of research, we have improved the technological scheme of the process at the bio-remediation site of transport infrastructure waste landfills (Fig. 8).

We have investigated the landfill waste of the transport infrastructure of Kyiv and selected microorganisms, which we recommend to use for the treatment of landfills of transport infrastructure to implement the patented method.

For the destruction of diesel fuel, kerosene, and used oils: bacteria *Rhodococcus erythropolis*; fungi *Fusarium* sp. and their consortium; bacteria *Acinetobacter* sp.;

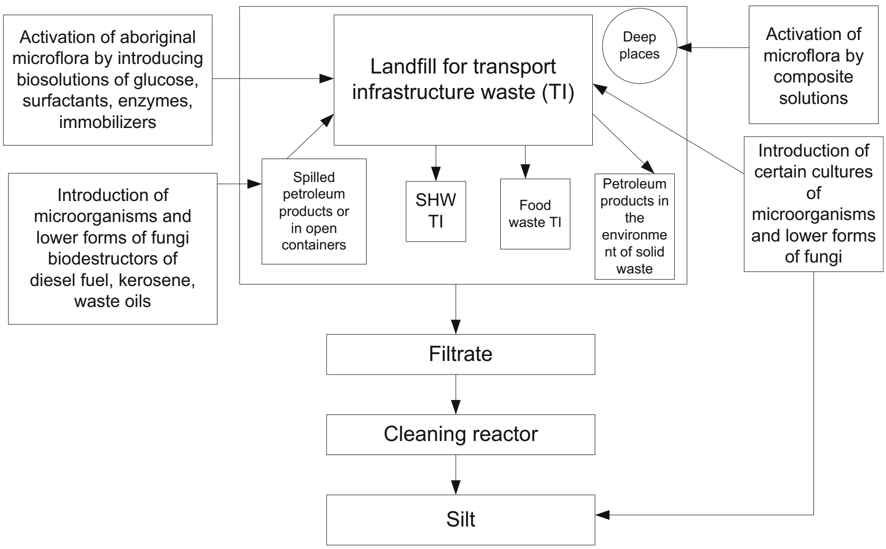

Fig. 8 Technological scheme of the process at the bio-remediation site of transport infrastructure waste landfills

yeast *Candida maltosa*, bacteria *Dietzia maris,* and their consortium; and aboriginal forms of microorganisms.

To destruct various organic synthesis products: bacteria *Bacillus subtilis*; bacteria *Pseudomonas putida*, *Pseudomonas* sp., *Pseudomonas pseudoalcaligenes*, and *Pseudomonas aeruginosa*; a consortium of bacteria of the genera *Marinobacter*, *Halomonas,* and *Idiomarina*; bacteria *Halomonas* sp.; bacteria *Pseudonocardia dioxanivorans*; bacteria *Acinetobacter calcoaceticus* and *Achromobacter xylosoxidans*; bacteria of the genera *Bacillus*, *Pseudomonas*, *Kocuria*, *Stenotrophomonas*, *Proteus*, and *Staphylococcus*; and yeast *Geotrichum* sp.

For the processing of solid food waste: bacteria *Bacillus cereus*; fungi of the genera *Aspergillus*, *Mucor*, *Penicillium*, and *Neurospora*; and fungi *Trametes versicolor*.

Processing of transport infrastructure landfills (by analogy, it is also possible for urban landfills) by microorganisms is recommended to be carried out once a season during the warm period.

The method in Fig. 8 is implemented as follows. First, aboriginal microflora is activated by bringing components to the landfill with the basic media – solutions of surfactants, glucose, and enzymes, creating an optimal environment for the development of microorganisms.

At the same time, mechanical fringing and injections to the soil of the landfill are carried out in separate deep places of composite solutions with the ability to provide an aerobic environment in closed layers. Next, a complex of certain cultures of microorganisms and lower forms of fungi is added to the body of the landfill. If there are large spots of spilled petroleum products (diesel fuel, kerosene, or used motor and transmission oils) at landfills, or if soil is saturated with petroleum products, contribute a complex of microorganisms and lower forms of petroleum products destructor fungi separately for these places, followed by soil slicing to a depth of 5–10 cm. In addition, certain cultures of microorganisms and lower forms of fungi are added to sediment silt.

6 Conclusion

Waste from landfills of transport infrastructure of Kyiv is investigated, and microorganisms, which we recommend using to neutralize petroleum products and solid organic waste, are separated.

For the destruction of diesel fuel, kerosene, and used oils: *Rhodococcus erythropolis* bacteria; *Fusarium* sp. fungi and their consortium; *Acinetobacter* sp.; *Candida maltosa*, *Dietzia maris* bacteria, and their consortium; and organic forms of microorganisms.

For the destruction of various organic synthesis products: bacteria *Bacillus subtilis*; bacteria *Pseudomonas putida*, *Pseudomonas* sp., *Pseudomonas pseudoalcaligenes*, and *Pseudomonas aeruginosa*; consortium of *Marinobacter*, *Halomonas*, and *Idiomarina* bacteria; bacteria *Halomonas* sp. and bacteria

Pseudonocardia dioxanivorans; bacteria *Acinetobacter calcoaceticus* and *Achromobacter xylosoxidans*; bacteria of the genera *Bacillus*, *Pseudomonas*, *Kocuria*, *Stenotrophomonas*, *Proteus*, and *Staphylococcus*; and yeast *Geotrichum* sp.

For the processing of solid food waste: bacteria *Bacillus cereus*; fungi of the genera *Aspergillus*, *Mucor*, *Penicillium,* and *Neurospora*; and *Trametes versicolor* fungi.

We have established that it is necessary to select strains/bacteria consortiums for the treatment of certain types of waste. From the microorganisms selected at the landfills of the transport infrastructure of Kyiv, those that are best suited for the destruction of petroleum products, products of organic synthesis, and processing of solid household waste are allocated. In general, it is impossible to establish any patterns; microorganisms need to be selected separately for each particular case. The information obtained will be useful in the selection of microorganisms for the processing of petroleum products, solid industrial, and food waste.

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