CHAPTER «ENGINEERING SCIENCES»

CAUSE-AND-EFFECT ANALYSIS OF MICROBIOLOGICAL CONTAMINATION OF MOTOR FUELS AND PROSPECTS FOR THE RATIONAL USE OF BIODEGRADATION IN THE PROCESSES OF RECYCLING WASTE FROM THE TECHNOSPHERE

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Abstract. The problem of landfills is one of the most important and urgent among the problems of environmental pollution. This issue needs an immediate solution not only in Ukraine but all over the world. Every human home accumulates a huge amount of unnecessary materials and products, from old newspapers and magazines, empty cans, bottles, food waste, wrappers and packaging, to broken dishes, worn clothes and broken appliances or office equipment. Every day we are forced to deal with waste: at home, in the environment). Everywhere we are surrounded by papers, plastic wrappers, glass, cellophane, etc. Today, taking into account the environmental factor is a necessary condition for the integration of the Ukrainian economy into world economic processes in order to ensure its competitiveness. Ukrainian enterprises face an important issue of the need to understand environmental prioritiesin the implementation of production and economic activities. That is why the introduction of new technologies, improving environmental culture, compliance with generally accepted environmental standards, the search for effective tools for environmental

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and economic management of enterprises, territories and regions is a necessary component of future sustainable development. In turn, the practical implementation of the principles of environmentally sustainable development of economic, socio-economic systems necessitates the improvement of methods, methods and tools of production organization based on the greening of the logistics management system. It has become clear that the economy needs to be reorganized so that human industrial activity is fully integrated into an efficient environmental infrastructure. Thus, the study of the process of transport waste management in Ukraine and the world is relevant today. Transport infrastructure includes railways, trams and inland waterways, contact lines, highways, tunnels, overpasses, bridges, railway stations, railway and bus stations, subways, airfields and airports, communication, navigation and traffic management facilities. vehicles, as well as other structures, devices and equipment. Vehicles include aircraft, railway rolling stock, vessels used for the purpose of merchant shipping or shipping, rolling stock of road and electric urban land passenger transport. The subject of the research is the ability of microorganisms isolated from the landfills of the transport infrastructure of Kyiv to biodegrade fuel and lubricants. Research methods: monographic, analytical methods, standard microbiological and research of physicochemical and operational properties of kerosene and diesel fuel. The purpose of research: to investigate the ability of micro-organisms isolated from the landfill of the transport infrastructure of Kyiv to the destruction / degradation of fuels. Further use of isolated microorganisms in biodegradation technologies of waste fuels and oils. Achieved results: the ability of a complex of micro-organisms isolated from the landfill of transport infrastructure of Kyiv to the destruction / degradation of fuels was studied; developed an algorithm and method for isolating a complex and pure cultures of microorganisms capable of destruction / degradation of hydrocarbons of petroleum products (diesel fuel, kerosene); developed a method of utilization of waste fuels and lubricants and solid organic (food) waste using isolated from samples taken at landfills of transport infrastructure.

1. Introduction

Property of microorganisms to metabolize hydrocarbons of solid, liquid and gaseous petroleum products was known in the early XX century. This phenomenon has become a cause of substantial problems in the field of oil producing, oil refining and petro chemistry, especially during exploitation of oil products. First documented by Miyoshi (1895), fuel biodeterioration has been well documented for more than a century [1, p. 88]. On one hand, the change of oil and oil products properties under the influence of microorganisms finds application for the special aims (waste waters cleaning of oil-processing plants, cleaning of territories and aquatoriums from contamination by oil products). On the other hand, activity of microorganisms results destruction of an oil products and the damage of materials and constructions that contact with them.

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One of the most serious consequences of fuel tanks microbiological contamination is corrosion of enforstment wing set. The funguses attach to the horizontal surfaces of fuel tanks, and multiply, forming the threaded layer. As a result, there are areas with different aeration, where corrosion is intensified. While growing fungus produce organic acids (mostly citric acid), as a result the acidity of the water at the tank bottom decreases (pH 2,5–4,5). This reduces the surface tension, increases diffusion rate at the interface between fuel and water and fungi growth is facilitated. Interweaved mycelium layer can move in the liquid volume during aircraft fuelling, leading to the clogging of filters, sensors, etc.

2. Research of microbiological pollution of fuels

Statistics of materials biological damage show that fuels and lubricants are very actively attacked by microbiological factor (Figure 1).

The active study of questions connected with microorganisms' development in oil fuels began from the creation of jet aviation in the USA. The work on this question in our country mainly was to determine fuels biostability in laboratory conditions. purposeful researches of fuels biostability in exploitation conditions were not conducted practically.

There were not generally accepted methods of fuels biocontamination estimation to this time. for that purpose, well-known microbiological methods were used, by which determined the presence of microorganisms in fuels, its quantitative content and specific composition were [2, p. 81; 3, p. 255].

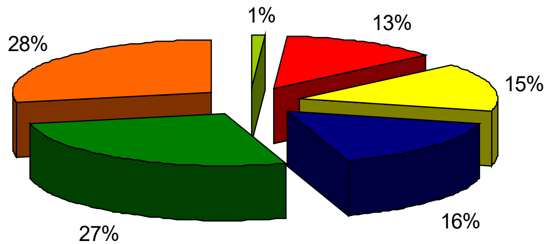


Figure 1. Statistics of materials biological damage: 27 % – fuels and lubricants; 16 % – lacquer and paint coating; 28 % – polymers; 13 % – metals and alloys; 1 % – glass; 15 % – other materials

Significant factors that assist to active the development of microorganisms are ph environments the presence of such elements as (carbon, phosphorus, potassium, nitrogen, sulphur, iron), sun energy. an ambient temperature, is also important to cells of microorganisms actively propagated themselves when the temperatures are 25-35°C, although can grow when the temperatures vary from plus 5 to 45°C. It is well-proven that the spores of many types of microorganisms remain viable for a few hours when the temperatures start from minus 40°C. there is also a necessary condition for development of microorganisms – the presence of water and nutritives in fuel. the growth and development of microorganisms is stopped in water-free fuel. however, in real exploitation conditions and fuels storage it is impossible fully to get rid of moisture. the presence in fuel of at least 0,01–0,02 % water and its tracks at the proper temperature is enough to begin the growth of microorganisms. Today it is known several sources of water ingress:

– atmospheric moisture from the air;

– rain or snow may fall into the tank through the holes for sampling, ventilation valves or unsightly fitting lid;

– transportation or storage in tankers and on the boards can cause penetration of ballast water;

– water from all listed sources accumulated at the bottom of the tank forming a water layer.

Microorganisms can penetrate to the fuel through air or water. thus, during the water layer formation colonies of microorganisms are developing.

liquid hydrocarbon fuel is an excellent source of nutrients for many types of present microorganisms. the result is microorganisms spreading at the surface of fuel and water; they begin to live in the water phase, continuing to eat fuel.

The processes of microbial oxidation of hydrocarbons are very complex, because the processes of biogenic oxidation have an influence on many factors: moisture, environment acidity (Ph), temperature, osmotic pressure, and so on. In addition to these factors, there are important physiological characteristics of most microorganisms that occur during the oxidation of individual hydrocarbons and their mixtures. microorganisms have a selective ability related to various hydrocarbons, and this ability is determined not only by the difference in the structure of substance and even the number of carbon atoms that are the part of their structure. hydrophobic of hydrocarbon molecules is important for the chemistry of microbial oxidation of these compounds, their transport in the microbial cell and dynamics of reproduction and physiology of bio destructors. the first stable products of hydrocarbons oxidation are the primary alcohols. the other is the usual biological conversion of alcohols to aldehydes and aldehyde to acid.

The general scheme of reactions [2, p. 81]:

$$R\text{-}CH_2\text{-}CH_3+[O] \rightarrow R\text{-}CH_2\text{-}CH_2OH\text{-}2H \rightarrow R\text{-}CH_2\text{-}CHO\text{-}2H+HOH \rightarrow$$
$$\rightarrow R\text{-}CH_2\text{-}COOH.$$

Reduced paraffin fuel capacity by biochemical oxidation occurs due to the removal of model systems of n-alkanes as substances which mainly consume microorganisms. physiological characteristics of each kind of microorganism depends on the orientation process of individual hydrocarbons destruction and their mixtures that have different degrees of resistance to oxidation. research of the microorganisms’ ability to oxidize specific classes of hydrocarbons within the aviation fuels allows in perspective to create biologics for specific purposes. After the damage of fuel by microorganisms in the presence of the mentioned above favorable conditions the next consequences are observed:

– change in physical and chemical properties of fuels, namely increasing of major physicalchemical parameters values as kinematic viscosity, refractive index, Ph, content of actual resins and others. Also characteristic features are the formation of sediment, turbidity fuel and peculiar odor;

– corrosion of storage tanks for aviation fuels. corrosion development of bottom part where accumulates water sludge, especially on verge of system distribution “fuel-water”, corrosive damage of aircraft tanks, corrosion of aircraft power constructions;

– clogging and damage of fuel filters, pumps and fuelsystems. Sedimentation of mycelium and bacteria colonies at the inner walls of the fuel systems leads to clogging pipelines, filters, pumps and fuel systems;

– threat to the safety of aircrafts flights changing the physical, chemical and exploitation properties of aviation fuels leads to early clogging of filters, pollution of regulating equipment, causing unstable operation of the fuel system, and therefore can cause a failure of the engine, and even a complete failure of the system, and as a consequence – accidents and emergency landings.

The methods for a detection of microbiological contamination of fuels are divided into longterm and express methods. The long-term methods include seeding of microorganisms in nutritive environment followed by microscopic analysis of cultivated cultures. the express methods are used at airports. they are based on indication of microorganisms by chemical compounds. one of these methods is determining microbial contamination of fuels for jet engines with a solution of ninhydrin. Ninhydrin is an organic compound belonging to the classes of ketones, alcohols and condensed carbocycles used as qualitative and quantitative reagent in the determination of primary amines and amino acids. In this area are patented detection techniques of biocontamination in aviation fuels with using two sets of microbmonitor 2, hum Bug detector, Bug alert, Bug check, electronic meter hmB Iv. for example, when using microbmonitor 2 test results are available within three days and do not require further interpretation. exploitation practice shows that in areas where the risk of getting fuel contamination are higher, the frequency of checking for microbiological contamination presence should be at least once a month.

According to the results of identification of many scientists the main representatives of microorganisms-destructors of hydrocarbons are:

1) anaerobic and aerobic bacteria – Achromobacter, Alcaligenes, Arthrobacter, Bacillus, Bacterium, Brevibacterium, Citrobacter, Clostridium, Corynebacterium, Desulfovibrio, Enterobacter, Escherichia, Flavobacterium, Metanobacterium, Micrococcus, Micromonospora,

Mycobacterium, Nicrosossus, Pseudomonas, Sarcina, Serratina, Spirillym, Vibrio, Thiobacillus;

2) fungi (or micromycetes) – Alternaria, Aspergillus niger, Aspergillus fumigatus, Hormoconis resinae, Monacus floridanus, Phialophora sp., Cephalosporium, Renicillum;

3) yeast – Candida, Debaryomyces, Endomycopsis, Hansenula, Rhodotorula, Saccharomyces, Torula, Torulopsis, Trichoderma, Trichosporon.

In relation to air, microorganisms are divided into two groups: aerobic, developing in conditions of air access, and anaerobic, capable of developing without air access. Therefore, the process of reproduction of microorganisms can occur on the surface of the oil product and its thickness.

Mushrooms isolated from fuel can be by degree growth activity can be divided into:

– active destructors;

– potential destructors;

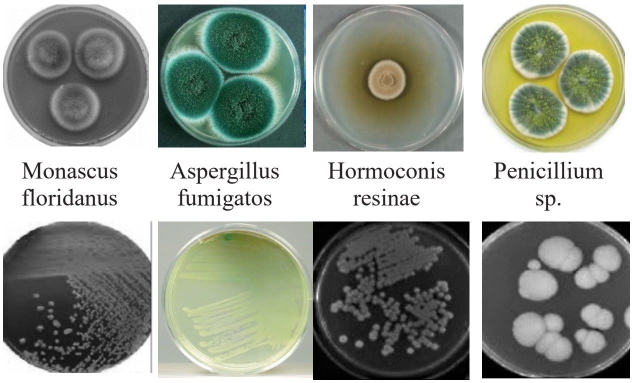
– partially adapted and random species.

An active representative of fungi, the so-called «kerosene» fungus is Hormoconis resinae. Under natural conditions, this fungus lives in the soils of the subtropical and tropical zones. «Kerosene fungi» is an active destructor. Today there is information about its presence in samples of aviation fuels from Australia, in large quantities – Brazil and California, Great Britain, Denmark, India, Syria, Nigeria, Japan, New Zealand.

In the scientific literature it is known as in other names: Hormodendrum resinae, Cladosporium resinae, Amorphotheca resinae.

Now ICAO is disturbed formed by the world tendency of entering of contaminated aviation fuel in airport. Many documents ICAO, IATA and Joint Inspection Group focuses on pollution fuels. ICAO issued a directive DOC 9977 “Guide to the supply of aviation fuel in civil aviation” and IATA issued EI/JIG STANDARD 1530 “Quality assurance requirements for the manufacture, storage and distribution of aviation fuels to airports”.

Active development of the fuel and the fuel systems of microscopic fungi (*Hormoconis resinae*, his types. *Penicillium, Aspergillus fumigatus, Paecilomyces variotii*, etc.) recognized the most dangerous. Fungi form a dense mycelium, the accumulation of which not only clog pipelines and fuel filters, but also create numerous localized areas of corrosion on the surfaces of fuel systems. The main strains of microorganisms-petroleum product destroyersfield in Figure 2.



Monascus floridanus | Aspergillus fumigatos | Hormoconis resinae | Penicillium sp.

Acitenobacter | Pseudomonas aeroginosa | Rhodotorula sp | Candida sp

Figure 2. The main strains of microorganisms-petroleum product destroyers

The growth of fungi in fuel at positive temperatures (in points)

Fungi	**The time of the manifestation of signs of growth, days**	**The temperature, °C**			
		9	**18**	**28**	**36**
Hormoconis resinae	7	0	0	0	0
	14	0	1	2	0
	21	1	2	3	1
Phialofora sp	7	0	0	2	0
	14	1	2	4	2
	21	2	2	4	3

0 – no signs of growth,
1 – turbidity of the water layer, the formation of precipitation,
2 – the appearance of large flakes in the water layer,
3 – mucus formation,
4 – the formation of small clots,
5 – the formation of large clots.

The risk of uncontrolled microbial contamination is generally greatest in tropical regions. However, in the absence of adequate housekeeping practices, microbial contamination problems can also occur in fuel systems located in cold climates.

There are the following features of fuel biodamage:

1. Accumulation of sludge (water with a variety of contaminants, including bacterial mucus) at the bottom of fuel tanks and reservoirs.

2. Deterioration of fuel conditioning, including stable water-oil emulsions, acidification, color and smell changes, contamination with mycelium and mucus particles.

3. Mycelium and bacteria colonies segregation on the inner walls of the fuel systems (Figure 3), tanks, pipelines and filters clogging with sediments (Figure 4).

4. Metal corrosion of the bottoms, where water sludge is accumulated, especially at the interface between fuel and water.

5. Destruction or delaminating of protective coatings under the clusters of microorganisms colonies, destruction of seals and hermetics by metabolites (Figure 5).

The ability to biodestruct classes of hydrocarbons depends on physiological properties of a particular microorganism, in particular from ability to adapt its enzymatic

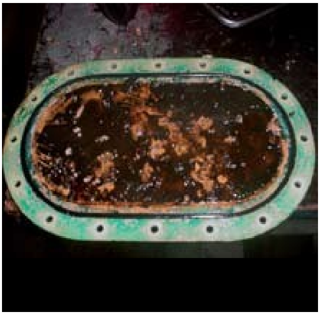


Figure 3. Microbial pollution of fuel tank

a) *b)* *c)*

Figure 4. Bacterial damage of the ground fuel filtering materials: *a, b* – damage view, *c* – the part of the filter at magnified image (10 μm)

a) *b)*

Figure 5 (*a, b*). Destruction of seals and hermetics by metabolites

apparatus to conditions environment. However, the numerous studies mentioned above allow classify hydrocarbon classes according to their ability to biodegrade.

Biodegradation of hydrocarbons occurs intracellularly and carried out due to specific oxidative enzymes of the class oxygenase. Oxygenases catalyze the use of one oxygen atom from it molecular form in the terminal methyl group of the hydrocarbon, i.e. there is a replacement of connections with weak breaking energy (C–C, C–H) connections with strong rupture energy (C–O, H–O). This method of oxidation marked for aliphatic, acyclic and aromatic hydrocarbons.

As a result of the process of biodegradation there is destruction, detoxification, utilization and mineralization of petroleum hydrocarbons, in particular aviation fuels. Because aviation fuels include a lot easily digestible components, in the process of biodegradation the fuel acts nutrient substrate (source of carbon and energy) for a number microorganisms.

Data from various studies on cell entry microorganisms, localization of hydrocarbon oxidizing enzymes indicate about the process of oxidation of hydrocarbons occurs inside the cell microorganisms. Restrictions on the oxidation of hydrocarbons by petroleum destructors are related to the solubility of hydrocarbons in water.

Getting a nutrient substrate into the cell is possible from the state true solution or during direct contact with it.

From the physiological characteristics of each genus of microorganisms depends on the direction of the process of destruction of individual hydrocarbons and them mixtures that have different degrees of resistance to oxidation. Difficulties in uptake of hydrocarbons by microorganisms is associated with their insolubility in water. To activate destructive enzymes need as much as possible hydrocarbon-water phase separation surface.

Hydrocarbons can be broken down by microorganisms fairly quickly anaerobic conditions and extremely slowly – under anaerobic.

Nutrients enter the cells of microorganisms or oil destructors through the surface of the semipermeable cell wall and cytoplasmic membrane.

There are the following types of transport of hydrocarbons into cells microorganisms:

– passive transport:

a) passive diffusion – non-specific entry of substances into the cell, in which various compounds enter the cell without interacting with any carrier, and the driving force of this process is the gradient nutrient concentrations, ie the difference between their concentrations inside the cell of the microorganism and the external environment. Consumption the cell of the microorganism nutrients occurs before their alignment concentrations beyond the cell membrane and in the environment, ie by laws of osmosis. Passive diffusion occurs without energy consumption the speed is low. Water is the main substance that enters the cell and released from it by passive diffusion;

b) facilitated diffusion is a specific process in which the nutrient – the substance is transferred to the cell only with the participation of the carrier protein (permease) and depends on the nutrient concentration gradient.

Permeases have substrate specificity, is transfer specific nutrients inside the cell of the microorganism. At the same time speed the supply of substances depends on their concentration.

The exchange of products of metabolism of the microorganism occurs by through this process.

– active transport – the substance enters the cell regardless of the gradient of the concentration of nutrients in the environment; the process needs energy consumption ($C_{10}H_{16}N_5O_{13}P_3$) – adenosine triphosphate or adenosine triphosphate is a universal source of energy for – biochemical processes) and occurs with the help of specific carrier proteins (permease). During this process, the speed of hit substances to the cell may be maximal at low concentrations nutrients in the environment.

All reactions of microbiological conversion of hydrocarbons are available redox. Maximum reproducibility of these substances makes the presence of oxygen necessary for their oxidation.

The hydrophobicity of a hydrocarbon molecule is of great importance for chemistry their microbiological oxidation and their transport into the cell of the microorganism oil destructor. The hydrophobic nature of the molecule is the reason that oxidation processes are carried out by oxygenase's, in contrast to oxidation more hydrophilic substances, which occurs under the action of dehydrogenases.

Hydrophobicity of hydrocarbon substrates and their poor solubility in water determine the ways in which substances enter the cell. It should be noted that a characteristic feature of the assimilation process Hydrocarbons as carbon sources are the accumulation of intermediates. The biodegradation of aliphatic hydrocarbons is influenced not only by them physicochemical properties such as solubility in water, the ability to – emulsification and the value of surface tension, but also biological factors – enzymatic activity of microorganisms, the reactivity of the substrate.

According to many studies, paraffins are the most unstable to microbiological damage by a class of hydrocarbons, especially paraffins of normal structure. According to scientists, the process of enzymatic oxidation is subject hydrocarbons with a medium chain length (C_5 – C_{15}), in turn, light nalkans are able to absorb only some species of bacteria (eg, Pseudomonas), since they dissolve the lipids of bacterial cells and cause dissolution of the cytoplasmic membrane.

In the vast majority of cases of primary enzymatic attack n-paraffin molecules are oxidized by the terminal atom hydrocarbon. Many scientists present the reactions of biological oxidation of paraffins as follows:

$$R\text{-}CH_2\text{-}CH_3 + [O_2] \rightarrow R\text{-}CH_2\text{-}CH_2OH\text{-}2H \rightarrow R\text{-}CH_2\text{-}CHO\text{-}2H + HOH \rightarrow$$
$$\rightarrow R\text{-}CH_2\text{-}COOH.$$

The first stable oxidation products of hydrocarbons are primary alcohols. The next step is the usual biological transformations of alcohol in aldehyde and aldehyde in acid. The most common and described way of oxidation of n-alkane by microorganisms includes three main stages [4, p. 193]:

1) primary oxidation of n-alkane, which leads to sequential the formation of the corresponding alcohol, aldehyde and carboxylic acids of the fatty series;

2) beta-oxidation of these acids with the formation as the main acetyl-CoA intermediate;

3) oxidation of acetate in the cycle of tricarboxylic acids.

Understanding the species composition of microbiological contamination and the patterns of its development creates conditions for their rational use, the choice of effective ways and means to prevent or eliminate their occurrence in petroleum products.

It is established that the spread of microorganisms in nature is due to their biological features:

– rate of reproduction: under favorable conditions, the cells of many bacteria divide every 20 to 30 minutes;

– relatively high resistance to various physical and chemical – factors – high and low temperatures, the effects of various types of radiation, drying, high osmotic pressure, lack of moisture, etc.;

– extremely easy adaptability to environmental conditions – environment;

– extremely large variety of physiological properties, – so they can be used for food or reception energy is almost all natural compounds, live and multiply where others living beings cannot live.

Assessment or analysis of risk is a process for identifying hazards, assessing the probability of an event and its consequences. The ratio of risk objects and risky events makes it possible to determine the link between the biological risk in the field of the use of aviation fuel with technogenic and economic risks. Technogenic risk is a complex indicator of reliability of elements of technical means of operation. It expresses the probability of an accident or disaster during the operation of machines and mechanisms, in particular vehicles, and the implementation of technological processes. The source of Technogenic risk is the violation of the rules of operation of technical systems, the untimely conduct of preventive inspections. Economic risk is determined by the ratio of benefits and harm that society receives from a particular activity [5, p. 560; 6, p. 222; 7, p. 42].

3. The risks and consequences of microbial damage of aviation fuels

The authors of this work identified and systematized the consequences and the risks of microbiological contamination, for example, of aviation fuel (Figure 6).

Risk reduction is an action to reduce the likelihood of a negative event or mitigate the consequences of this event if it occurs.

The aim of the work is to study, analyze and establish the causes and consequences of biodegradation of petroleum products with the help of microorganisms. Formation of practical recommendations for their rational use.

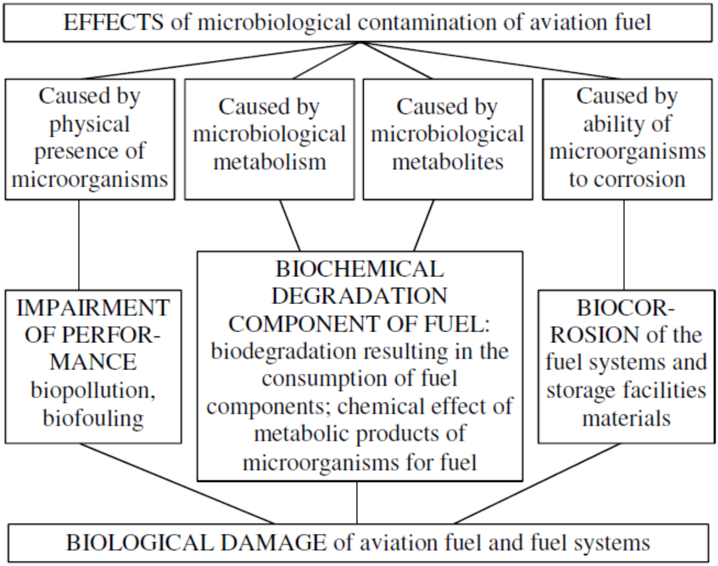


Figure 6. The risks and consequences of microbial damage of aviation fuels

The task of the study is to study and identify sources of turbulence, causes, influencing factors. Establish the relationship and interdependence, patterns of biodegradation in order to justify the choice and determine the current technical solutions (tools).

The object of research is the process of biodegradation of petroleum fuels.

The subject of the study is the relationship and interdependence of the biodegradation process from the sources, causes, factors that most affect the intensity. Justification of the most effective tool depending on the factors of influence.

The method of this study was chosen causal analysis by the method of «Ishikawa Diagram», a graphical method of research and determination of the most significant causal relationships between factors (factors) and the consequences of microorganism and the result of biodegradation.

Isikawa's method, which is presented in the form of cause-and-effect relations, was used to study the problem of microbiological damage and biodegradation, to identify and study the influence of a set of causes, factors, sources, and their consequences. The algorithm for constructing a cause-and-effect relationship diagram involved formulating a problem to solve it. In Figure 7 presents the set of factors influencing the process of microbiological damage and biodegradation.

The idea of microbiological damage of aviation fuels is developed as a process consisting of three successive interdependent stages: interaction (adhesion) of microorganisms with fuels – the development of microorganisms in fuel hydrocarbon environment – change in fuel properties. Brought irreversible change in the quality of aviation fuels due to microbiological lesions [8, p. 435; 9, p. 83].

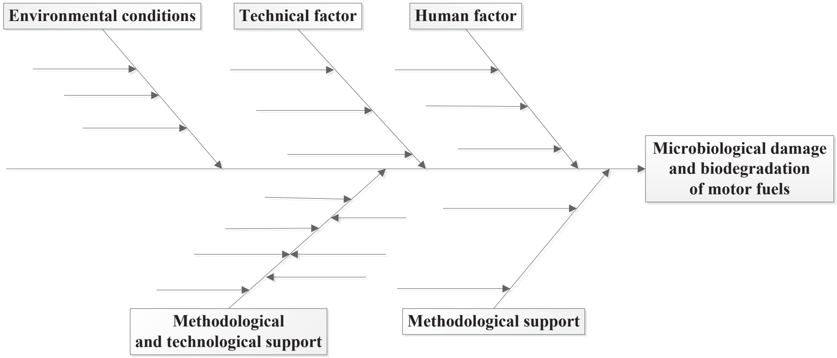


Figure 7. Simplified scheme of systematization of factors of microbiological damage and biodegradation of motor fuels according to Isikawa

Instrumental physicochemical studies have determined the change in acidity (an increase of 1.5-70.0 times), corrosion activity, the content of actual resins (increase of 2.6-4.2 times), thermal oxidative stability (reduction 1.3–3.5 times), heat of combustion (reduction by 1–5%), temperature onset of crystallization (increase by 2–15%), kinematic viscosity (increase by 2–4%) of modern aviation fuels under the influence microbiological contamination.

Theoretical idea of further development has received microbiological stability of motor fuels. Given the different destructive activity of cultures of microorganisms and hydrocarbon composition, investigated fuels are ranked according to microbiological stability (in ascending order) in the following order: *motor gasoline – fuel for jet engines – diesel fuel – aviation gasoline*. Higher level resistance to damage in aviation gasoline is due to the presence of it composition of thermal power plants, which has a toxic effect on living organisms [10, p. 94].

It was first discovered that the presence of biocomponents (ethyl esters fatty acids) accelerates the development of the microbiological phase in the composition aviation fuels due to the availability of esters for microorganisms and weak chemical bonds in the molecules of biocomponents, which contributes to the active reproduction of microorganisms. Reformulated jet fuels (blended, containing FAME) are more sensitive to microbiological damage due to them increased hygroscopicity and content of ethyl / methyl fatty esters acids. Ease of oxidation and ability to biodegrade this fuel justifies the mandatory use of biocides for blended fuels.

The factors that contribute to the emergence and development are systematized micro-biological pollution in aircraft fuel systems.

ASTM D6469 «Standard Guide for Microbial Contamination in Fuels and Fuel Systems» this guide provides information addressing the conditions that lead to fuel microbial contamination and biodegradation and the general characteristics of and strategies for controlling microbial contamination. It compliments and amplifies information provided in Practice D4418 on handling gas-turbine fuels.

The other side of the problem indicates that microorganisms can also perform a positive function. Thus, the oxidation of hydrocarbons by microorganisms is a leading factor in the natural process of degradation of oil and oil products. The composition of crude oils includes thousands of compounds of various chemical nature, among which such large groups of substances as hydrocarbons, resins and asphaltenes are distinguished. Over the past decades of studying the biodegradation of oil, the utilization of linear and branched hydrocarbons (especially with low and medium molecular weight), as well as aromatic hydrocarbons with five or less aromatic rings in the molecule, has been well studied.

By comparing the experimental data with the literature, we proposed a strategy for the search and selection of oil-degrading microorganisms for use in bioremediation in places subject to constant pollution by oil and oil products in the technosphere.

Some microorganisms can metabolize only a limited number of hydrocarbon substrates. A set of different microorganisms with all possible enzymatic pathways can more efficiently break down a complex mixture of hydrocarbons in soil, fresh and sea water than single microorganism can.

Possibility of microbial growth on hydrocarbon medium is provided by combination of two factors: biochemical complementarity of organism and resistance to hydrocarbon toxic action. It is obvious these two factors should be optimal. Considering polycomponent character of petroleum pollution, microorganism (association of microorganisms) should be able to grow on most components of pollutant and be resistant to their toxic action for complete mineralization of oil products.

Oil at low concentrations has a stimulating effect for soil biota because it is an energy substrate for a large group of microorganisms. Significant petroleum soil pollution, which occurs at emergency spills, is accompanied by acute toxic oil effects on organisms. Microorganisms' reaction to the effect of any toxic substance depends on the toxic agent nature, its concentration, contact time, perceiving system properties, state and other properties of the organisms exposed. The toxic effect of oil is shown through the transformation of microorganisms' environment by physical, chemical, agronomic and other characteristics of contaminated soils.

Light oil fractions partially inhibit heterotrophic microorganisms but act also as a substrate for hydrocarbon degrading microorganisms. Heavier fractions are less toxic to microorganisms, but they are not actively metabolized.

Petroleum hydrocarbons are characterized by strong antibacterial effect and can cause cell lysis. However, some bacteria show a high resistance to these substances. Toxicity of hydrocarbons is mainly determined by their ability to damage the membrane of microorganisms. The interaction of oil hydrocar- bons with cell membranes occurs at the level of lipid-lipid and lipid-protein interactions. The thickness of a phospholipid bilayer, its fluidity, asymmetric distribution of membrane com- ponents, activity of enzymes and proteins transport in the membrane are changed as a result. These changes, in turn, lead to membrane barrier properties disruption, protons and other intracellular ions passive flux increasing across membranes. All of this leads to a decrease cell viabilitying.

The ability to oxidize petroleum hydrocarbons has been found in numerous species of bacteria and fungi belonging to the following genera: bacteria – Acinetobacter, Acremonium, Arthrobacter, Acaligenes, Aeromonas, Bacillus, Bacterium, Brevibacterium, Beijerinckia, Burholderia, Citrobacter, Chromobacterium, Clostridium, Comamonas, Corynebacterium, Flavobacterium, Holobacterium, Gliocladium, Gluconobacter, Gordona, Klebsiella, Leucothrix, Micrococcus, Micromonospora, Mycobacterium, Nocardia, Proteus, Pseudomonas, Rhodococcus, Streptomyces, Serratia, Spirillum, Sphaerotilus, Xanthomonas; and mushrooms – Aspergillus, Aureobasidium, Debaryomyces, Candida, Metcshnikova, Penicillum, Trichoderma, Gliocladium, Rhodotorula, Torulopsis, Trichosporon, Cryptococcus, Sporobolomyces and some others.

Since the natural process of oil mineralization is sufficient long, there is a need for events that could speed up this process. Therefore, soil reclamation should consist in the intensification of the processes of natural soil cleansing, activation of the regeneration of the most productive biocenoses, which is achieved by carrying out a phased reclamation of oil-contaminated soils:

Stage I – Technical: agrotechnical methods that improve aeration soil (loosening, plowing, disking), regulation of the water regime and alkaline acid conditions;

Stage II – Biological:

Bioremediation is a method of soil cleaning using biological agents: microorganisms, fungi, worms and other organisms.

The application of the bioremediation method by the second approach is carried out by adding cultures of microorganisms-destructors of oil hydrocarbons to natural association of microorganisms. As active strains of destructors of oil and oil products for the creation of biological products on their basis used microbes isolated from the probable areas of their distribution – oil-contaminated soils selected from various climatic districts.

Cultures of microorganisms from the studied samples were isolated by the method of accumulative culture using conventional methods of general and soil microbiology. Isolation of hydrocarbon-oxidizing bacteria was performed on Tawson's medium, g / l: Ca (NO_3) 2 · $4H_2O$ 1.0; KNO_3 0.25; $MgSO_4 \cdot 7H_2O$ 0.25; $FeSO_4 \cdot 7H_2O$ 0.005; distilled water 1000.0; pH – 7.0; sterilized by autoclaving at 121°C for 15 minutes.

4. Conclusions

We conducted a taxonomic analysis of microorganisms, investigated their ability to assimilate (destroy) diesel fuel and kerosene, figured out how to accelerate the process at different temperatures. The ability of microalgae to absorb nutrients from wastewater was also investigated.

Achieved results: the ability of a complex of micro-organisms isolated from the landfill of transport infrastructure of Kyiv to the destruction / degradation of fuels was studied; developed an algorithm and method for isolating a complex and pure cultures of microorganisms capable of destruction / degradation of hydrocarbons of petroleum products (diesel fuel, kerosene); developed a method of utilization of waste fuels and lubricants and solid organic (food) waste using isolated from samples taken at landfills of transport infrastructure.

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