Giorgi Kvesitadze *Alexander Potemkin*

Homo Sapiens
&
the Technogenic Environment

Prof. Giorgi Kvesitadze,
Georgian National Academy of Sciences

Dr. Alexander Potemkin,
Hamburg, Germany

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E d i t e d b y :
DSci, professor, academician of National Academy of Sciences of Georgia
Tinatin Sadunishvili.

A u t h o r s :

Professor Kvesitadze Giorgi,
President of National Academy of Sciences of Georgia, citizen of Georgia.
Author of above 150 publications in the field of ecological sciences:
biotechnology, microbiology, organic chemistry. Author of the book published by Springer,
Biochemical Mechanisms of Detoxification in Higher Plants.

Professor (Ph.D) Potemkin Alexander,
investor of the number of scientific and commercial projects, ecologist,
author of above 30 books and the number of critical publications, citizen of Germany.
Author of intercontinental project *EuRICAA*.

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In the new XXI century, environmental problems have become closely linked to all citizens of the planet. This creates the danger for everyone's life and determines their well-being. Millions of tons of toxic substances, mainly of anthropogenic nature, are annually produced as byproducts of different technologies, urbanization, and unpredictable growth of industry, transportation, and production of chemicals, agriculture, military action and other human activities. All these compounds are released into the environment, creating great danger for the balance of vitally important parameters determining the existence of humanity. The book provides some data on how this toxic nature compounds and products of their partial bio-transformations are concentrated with different niches of the biosphere, and how humanity has an extremely negatively effect on the environment of the entire planet.

This book has been written to provide an overview of the origin and nature of anthropogenic contaminants and a brief description of existing physical, chemical and biological environment preservation technologies. Special attention is paid to microorganisms and plants. Firstly, it has been clearly shown, that in addition to microorganisms, plants also should be admitted as main instruments for the creation ecotechnologies of global character, due to their universal distribution ability and the ability to carry out degradation of a great number of contaminants of various structures. Especially effective ecotechnology is the one that is based on the joint collaboration of these organisms.

Firstly, the book presents a rather important resource analysis of mineral sources of the planet on a world scale, which allows drawing unambiguous conclusions regarding their short lifespan. The analysis of this data is definitely convincing in terms of the need for rather careful treatment of them, as well as the principle of the necessity for the formation of a new type of human being, which treats both renewable and non-renewable substrates with care.

The book should be interesting for ecologists, biologists, chemists, politicians, sociologists, students and the people involving in environments wellbeing.

CONTENTS

PREFACE

The permanently worsening environmental contamination in the XXI century has become the number one world problem by affecting everyone's body and social existence. A notion such as national ecology does not exist, due to the universal distribution of contaminants covering the entire planet. The humankind is already facing a common world problem called ecology. There is no doubt that the main so urce of permanently increasing technogenic compounds in nature is of anthropogenic origin. In the past, when the concentration of toxic nature compounds was lower, the natural biological oxidation and members of the plant kingdom microorganisms and plants have been successfully assimilating or degrading environmental contaminants and removing them from the environment, providing the long-term protection of nature. Nowadays, the ecological situation has dramatically changed. According to some brief calculations, on a global scale, up to one billion tons of chemicals are produced for different needs, and the amount keeps increasing annually. The great majority products of chemical industry are intend for agriculture: such as pesticides, mineral and organic fertilizers, paints and varnishes, solvents and emulsifiers, etc. Some others are produced also in huge amount for different needs; monomers for synthetic polymer industry, petroleum and pharmaceutical products, explosives, etc., and according to their nature, all these products are, in different degrees, toxic and manifested by higher toxicity than comparable in function or size of molecule natural compounds. Other widely distributed and very important sources of environmental pollution are urbanization, the unpredictable growth of industry, transport, military activities, etc.

What happens with this huge and highly hazardous amount of toxic compounds? The main power in decontamination of the planet from increasing toxicity is related to the nature. Such natural processes as photosynthesis, fixation of molecular nitrogen, oxidation, respiration, interrelation of organisms, etc. are directly or indirectly supporting the process of decontamination. In the past, at a low level of contamination, the ecological power of natural processes quite successfully utilized both natural and anthropogenic contaminants. Today, the amount of carbon dioxide alone overwhelms the photosynthetic potential of nature, and it is increasing annually, being one of the main reason of smog formation. Lately, the appearances of new varieties of illnesses, including viruses, are the result of the decrease of the natural immune system, as well as the air, soil and water reservoirs contamination. To avoid them, many ecological technologies have been elaborated, targeted to minimize the flow of toxic compounds to the biosphere. Despite the definite positive effect from the realization of these technologies, the intensive flow of toxic compounds to the biosphere is still more prevalent.

Another question that is becoming a global problem is as follows: what could be done to minimize and prolong humankind's existence, by providing the minimum of vitally important, drinkable water, food and clean air? Having no real chances to eliminate or decrease ecological problems created by *Worldbiome* (all organisms) by all existing measures, society should turn the attention again to nature, trying to copy and intensify natural biological processes.

Authors are making such attempts - that is why, in the presented manuscript, the naturally determined potential of microorganisms and plants to degrade foreign compounds, including those of toxic nature is described. This process is based on the action of selectively chosen active microorganisms and plants which increase the ecological power to eliminate all kind of chemical toxicity from the air, water and soil. The biotechnology has universal and global character, which presents a new eco-biological concept. The author's idea is to prolong the existing type of life for the number of decades until the *Worldbiome* grows above the planet's potential, with the hope that during this time, a technology based on a new scientific idea will be born.

The precise analysis of the planet's potential in supplying of drinkable water and the number of actively used fossils has been evaluated and the remaining time of their existence, based on the intensity of their use, has been determined. The contemporary state of health of the population and its change in time is proposed. Forecast of the Greenhouse gas emissions is calculated, based on energy production, transport, energy consumption in buildings, etc. The amount and expenses required for Domestic Animals (mainly dogs and cats) are calculated and presented to the society for discussion. Based on a wide analysis of world ecology disbalance and supply of fasil minerals, the transformation of *Homo sapiens,* already transformed into *Homo consúmens,* into new society of *Homo cosmicus*, economic in their requirements and closer related to the nature is assumed.

INTRODUCTION

Analyzing the history of the universe and, accordingly, the stages of human development since ancient and in subsequent times, it should be noted that the features of a multi-confessional, politically diverse, multilingual mentality, of completely different people had created national societies with great similarities, due to having a close relationship to nature. Nature has common canons, greatly influenced the evolution and formation of society. Despite the deep, organic connection with nature, formed of millions years of development, man, physiologically, the most complex and multifaceted (deeply thinking and analyzing) product of nature, over many centuries, acquiring over time an increasing degree of freedom and independence, has gradually began to move away from nature, creating machines, cities, various forms of cultures, different varieties of art, industry.

Moreover, what happened next to the already formed society of people?

Since the Middle Centuries and up to the modern state of the world community, consisting from the great number of countries are divided into multilingual, rich and poor, large and small, being determined by geographical location and such. According to the principles of modern classification of independent States, the determining factor in the modern world hierarchy today, in addition to politics, is the wealth of countries (most often based on natural resources) and the level of industrial development. In the international arena, big and strong countries have traditionally, been given advantages. Even today in the XXI century, such determinants still prevail. Among the reasons that determine the wealth of countries, of course, the most important factor is the availability of natural resources, and primarily petroleum products. Although the rich countries also include countries that once owned large colonies, created a solid foundation for the development of the state, military power, level of science, designed a variety of technologies – the basis for the industry are rightly among the world's leading states.

Pointing out these features of the of society, it should certainly be noted that one of the most important indexes of any country Renaissance is art, having reached an incredible perfection, relying on great historical traditions of all people. Many countries with extraordinarily beautiful churches, applied art, expressed in creation of various types of buildings, roads, bridges and other complex engineering structures were a clear example of the technological progress achieved. There is no doubt that both culture and science – the main lever for the development of society, in various degrees, become cultural property for the majority of nations. On the basis of all the victories and achievements, having absorbed all the universal values, people gained an advantage over the rest of the world, and they had a very definite opinion, characteristic of the vast majority of people, clearly expressed by the catch phrase: ***“A reasonable man is a thinking being”***.

Without any doubt we can say that this expression, according to public opinion, has fully been justified for several centuries, and it does not remain completely meaningless even today, but with some very serious deviations. Thus, having achieved serious success in science, industry, art, almost at the level of perfection, having felt himself the master of the situation, humanity, gradually, takes the path of the traditionally existing close ties with the nature that gave birth to it. As T. Heyerdahl, the famous Norwegian scientist and traveler said in 1972 in Stockholm (Sweden): “It has been five thousand years of technological progress and a continued series of victories for the human rebel, the only mutineer among the descendants of nature; nature has yielded, tree by tree, acre by acre, species by species, river by river, while man has triumphed. He has been able to advance by using the brain and the hands nature had given…”

That was continuing during centuries. Clearly seen how, through his (man’s) actions, the nature, with its colossal diverse and renewable potential, has been passing into a new stage of instability. The chosen way, through the overpopulation of the planet, extraordinary consumption and depletion of all types of non-renewable, natural resources, acute shortage of drinking water, degradation and desertification of soils (actually losing the means to subsist), greenhouse gas emissions, melting of glaciers and global warming, damage to the ecosystem of the world ocean, poisoning of agricultural lands with pesticides and mineral fertilizers, increase in all modes of transport, toxicity in all ecological niches, uncontrolled development of artificial intelligence, led the mankind to the almost full ecological catastrophe. The most serious reason leading to the creation of an extremely critical situation was the unpredictably growing population, irreversible violations of the ecological balance of the environment, mass urbanization and, as a consequence, the inevitability of a serious ecological imbalance, for the species *Homo sapiens*: whose consciousness, over time, turned out to be directed only to consumption.

It can be assumed, that somewhere at the beginning of the second half of the XX century, the multi-century stage of the existence of a reasonable man understanding his responsibility to nature, called *Homo sapiens*, came to the end of the formation. A new type, a consuming man, *Homo consúmens* i.e., a person who uses everything that has been created for the multimillion stage of its existence to satisfy his needs, has started. The incredibly growing *Worldbiome*, which is a community of all living organisms and, accordingly, their gene pool, which has become the sole and main owner of the planet, dictates new canons of existence for the formation of new forms of life, reflecting the desires of modern *Homo consúmens*. At the same time, no one cares about the problems associated with nature, with the continuation of the human race, with the physical and physiological fullness of the person himself.

Being the main part of modern civilization the ***Worldbiome*** is a community of all organisms forming an ecosystem, from the simplest – unicellular to physiologically and morphologically complex mammals, united by the principle of co-existence, in the world created by them. The *Worldbiome* unites all taxonomic groups of microorganisms, viruses, archaea, lower and higher eukaryotes, their genomes, with one habitat. *Homo sapiens* is physiologically the most complex organism created by the *Worldbiome*, and endowed with the ability of the highest thinking. The *Worldbiome* also carries out the constantly occurring evolutionary processes of all living organisms, in communion with nature. However, what is the *Worldbiome* from the point of view of philosophy? It should correspond to the *Cosmicus quanticus cerebrum* (Latin) – the universal quantum mind.

Society is increasingly beginning to realize that we live in a very complex, constantly changing world: from microparticles to immense outer spaces, in a world that we call the Universe. Everywhere there is an evolution of knowledge at all levels – genetic, atomic, molecular, and cosmic. Undoubtedly, this also refers to man, with his knowledge and intelligence. The actual ideology of life and its principles operating for thousands of years have largely rooted our ideas about the real world, which is the evolution of matter and all living things. A new goal generated by time is to identify a way out of the ideological and methodological crisis, misunderstanding of the constant evolution of the *Worldbiome*, creating a holistic view of the material world and the evolution of living matter.

Information in this case considered as a dynamic, systemic totality of the evolution of matter. The main attribute determining its state at various levels is extremely diverse, consisting of a colossal variety of substances, organisms of all kinds of hierarchies having completely different paths of evolution. Changes in the environment, respectively, lead to information changes. The consequence of this is a change in the physical state of the environment, the logical sequence of biological processes, and necessarily an indirect effect on human consciousness. The established formulations of the ongoing phenomena make it possible to give these concepts a clearer physical meaning and determine for humanity the ways of development of the integrity of the material world on a single material basis. Without these clear concepts of ways and possibilities of further evolution, the existence of the recent *Homo sapiens* is not possible. Proceeding with this thought, it should be noted that in the near future for modern civilization, because of the merciless consumer attitude, an ecological and social catastrophe are also inevitable for *Homo consúmens*.

Nature does not care what social structure governs a country, region, and continent, its only requirement is, the people living on the planet, is to ensure that the economic development must be managed by ecology. The modern world is interdependent than ever before. There is nowhere to hide from the impending ecological catastrophe. Due to the exhaustion of all minimal life opportunities (food, energy, and ecology), the inevitability of the concept of a new civilization, which requires to be defined, as *Homo cosmicus*, definitely appears. The goal of this civilization is to create a multifaceted human *Homo cosmicus*, able to reach other celestial bodies, and unlike *Homo consúmens*, able to live a different, much more economical life. In order to survive on the planet, humanity needs to modify itself into *Homo cosmicus*. It should make people abandon their characteristic waywardness, renounce uncontrolled consumption and subordinate their minds to one all-consuming idea – their own epigenetic improvement into an all-planetary citizen.

Analyzing the history of life existence, one would conclude, that the main influence on the evolutionary formation of organisms, their living mode and physiology, in the past, was exerted only by natural factors. Such factors as climatic changes, volcanic emissions of large, high-temperature underground massifs, natural processes of decay, influencing climatic changes leading to enriching the environment with a wide spectrum of chemical compounds. For millions of years, nature – our progenitor *Worldbiome*– has created a living world based on geological, chemical, and biological potential, acceptable for the coexistence of a wide variety of completely different forms of life. In terms of the scale and nature of their impact on natural processes, in reality, anthropogenic factors significantly exceed all natural sources of environmental contamination with carcinogenic toxic compounds.

The main tasks presented in this book are:

- Analysis of a new innovative, nature-friendly global, ecological biotechnology presented by the authors, based on the ability of specially selected species of microorganisms and plants, both individually and jointly, symbiotically, degrade toxic compounds from all ecological niches, the global or large-scale use of which will significantly (for many decades) would avoid the impending ecological catastrophe. Friendly-to-nature biological technologies based on natural transformations are much more efficient and extensive than all known modern classical chemical and physical ecological technologies [1];
- Transformation of *Homo sapiens* society, which has already been overwhelmingly transformed into *Homo consúmens* (a person consuming), into a new type of person – *Homo cosmicus*, who has the ability to explore new planets and at the same time constantly cares about the increasing environmental problems of the planet. Each representative of *Homo cosmicus* is extremely frugal about all kinds of expenses (food produced by traditional and non-traditional technologies, extremely careful about the use of water, energy and consumer goods, etc.).

Having intuitively refused to choose a path that is truly friendly and quite comparable with nature and its values, the all of humanity, thereby have preferred self-affirmation, our dominance. It is interesting that, apart from the last decades, already in anticipation of a threatening environmental disaster, no one has ever even tried to change our logic and philosophy of life in order to direct it to milder forms of environmental management. Obviously, we like to repeat the expression that has become a universal motto: **"Everything for man!"**

Despite the almost complete non-recognition of the thrift of modern society, the activities of some citizens of the planet should be especially noted, correctly assessing, by many indicators, the critical limits of human existence that have already been achieved and creating technologies of the future. Among such a few people should certainly be mentioned outstanding engineer, Elon Musk, owner of Tesla plants, developing and sponsoring the most advanced environmental technologies, such as carbon capture technology, studying climate change problems, developing technologies for the efficient use of solar energy (LED lighting), economical use of metals in the industry. Creation of reusable transport spacecraft Space X, Space Shuttle and Crew Dragon. Development of very important low-waste technologies, saving water when washing cars and much more. Unfortunately, there are no other such examples or there are only a few of them.

I. THE ECOLOGICAL HETEROGENEITY OF THE PLANET BEING AT THE EDGE OF PHYSICAL LIMITS

1.1 Environmental problems of the planet

Uncontrolled, unpredictable population growth is changing the reality of the planet; natural ecosystems are being displaced by megalopolises, transport, agricultural, energy and other industrial facilities; oil extraction and refining are causing especially great harm to the environment. All of them lead to colossal pollution of the environment, loss of biological diversity, reduction of agricultural plantations, deterioration of living conditions of the population of the whole planet. Environmental pollution has an extremely negative impact on the health of its inhabitants. Every year, more than 1.8 million people die, as a result of non-infectious lung diseases; 9 out of 10 inhabitants of the planet breathe polluted air; more than 70% of deaths from stroke, widespread lung cancer and respiratory diseases are caused by high levels of air pollution [2]. It seems, that in the XXI century, the most important international problem concerns the field of ecology – namely, keeping the acceptable environmental balance in conditions of extremely increased and still increasing worldwide population and highly developed industry. To date, the picture of the most polluted countries in the world by the content of PM2.5 is as follows: Bangladesh – 77.10, Pakistan – 59.00, India – 51.90, Mongolia – 46.60, Afghanistan – 46.50, Oman – 44.40, Qatar – 44.30, Nepal – 39.20. It should be noted that the causes of environmental problems in all these countries are different [3].

Pakistan's environmental problems are associated with the depletion of natural resources and prolonged military operations. Qatar is a country rich in natural resources – gas and oil, but their processing enterprises emit critically large amounts of toxic compounds into the atmosphere. The environmental situation in Afghanistan is related to almost permanent military operations that have been going on for several decades. Bangladesh mainly suffers from natural causes – floods and landslides. Deforestation and forest fires significantly worsen the ecology in Mongolia. This list can be continued, but it should be noted that the causes of environmental pollution might be not only oil and gas production, but also other factors.

On September 25, 2015, the UN adopted a set of measures consisting of 17 SDG (Sustainable Development Goals) and 196 tasks ensuring balanced development of all continents. Of these goals, three are directly related to ecology:

Goal 13 (out of 17, UN): Take urgent action to combat climate change and its impacts;

Goal 14: Conserve and sustainably use the oceans, seas and marine resources;

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

It cannot be said that all these recommendations are strictly being implemented, but there is no doubt that they have already had their effect in practice.

Already at the beginning of the XXI century, humanity faced unprecedented environmental problems: the unpredictably growing population of the planet, global climate change, the melting of large masses of ice, a huge increase in the volume of industry and transport, the formation of a large number of megalopolises and many others. On the basis of intensive agriculture, soils are becoming increasingly depleted in terms of their content of organic carbon and nitrogen and degraded as a result of the action of great amount of techno-genic stable compounds. In this amazingly fast-changing world, achieving a sustainable ecological balance and providing food resources to the world's population has never been such a difficult and important task. It is simply impossible to describe all the variety of environmental problems of the planet within the framework of this monograph; therefore, the main factors causing the ecological imbalance typical for different regions of the planet will be discussed.

One of the most important components of the ecosystem is the soil, which is diverse in structure, chemical composition, often containing different structure toxic compounds. Being a non-renewable natural resource for a long time, the soil underlies the production of agricultural products, feed, fibers, fuel, cleans tens of thousands of cubic kilometers of drinking water, so important for all humanity, per year. It serves as the main reservoir for the storage and use of bound carbon and fixation of molecular nitrogen, significantly reduces emissions of carbon dioxide and other greenhouse gases in the atmosphere. The soil provides more than 95% of food and is the basis for solving the problems of poverty eradication, providing food for all humanity.

The required characteristics to ensure the normal level of all soils are:

1. The minimum level of erosion caused by a shortage of water and wind.

2. The soil should not be degraded and provide a stable physical environment for the movement of air, water and heat, as well as the growth of the roots of herbaceous, shrubby and large trees.

3. A surface cover (formed by growing herbaceous plants) is required to protect the soil.

4. A stable supply of soil organic matter is required, corresponding to the optimal level of the local environment.

5. The soil should ensure the accessibility of sufficient nutrients for assimilation by all plant species.

6. An important characteristic of the soil is the minimum level of salinization and alkalization.

7. The soil should contain the required amount of water provided by precipitation, artificial irrigation and additional water sources.

8. A characteristic feature of the soil should be a very low level of toxic pollutants.

9. The soil is responsible for the existing biodiversity and the full range of chemical compounds characteristic of nature.

10. To achieve the above-mentioned goals, it is necessary to provide all agricultural areas with modern soil management technologies. At the same time, the tendency of a constant increase in the mankind captured territories from nature for the creation of megalopolises, factories, buildings, communications, landfills, should be noted.

In order to implement appropriate remediation environmental measures, it is necessary to identify the current main characteristic problems as the consequences of the influence of human activity on the environment, manifested primarily in:

- atmospheric air pollution;
- depletion of potable water resources;
- contamination of the soil cover with mainly toxic nature – substances and wastes from production and consumption;
- violation of the logically permissible territorial relationship between non-agrarian industrial, agricultural and free ecological territories – forests, meadows, pastures, lakes, rivers, which determine the ecological balance of large regions.

Environmental problems of nowadays are associated with the world sustainable development. Constant, comprehensive attention to environmental problems has already become a global problem.

Describing the existing ecological situation it should be noted that, if specific measures are not taken, the further development of society might become unpromising. In particular, all developed technologies should be evaluated through the prism of ecology. Urgent environmental measures are needed to remediate the environment, including legislative, organizational, technical issues, as well as the development of innovative, environmentally friendly agricultural technologies. It is necessary to pay more attention to the problem of cleaning contaminated soils. For this purpose, in a number of developed countries – the USA, Canada, Western European countries, Japan, South Korea, China, etc. – state organizations have been created that carefully study the condition and fertility of the soil.

Despite the colossal ability of environmental pollution, the problems associated with the extraction, processing and use of oil and petroleum products, one of the most important minerals, are the subject of special discussion. On the surface of the earth, oil and its processing wastes are particularly large in scale and highly toxic. Individual components, like toxic hydrocarbons, have an exceptionally high migration capacity. The location of the organic mass, the precursor of petroleum products, for thousands of years was in anaerobic conditions based on reductive reactions of organic compounds, where the transformations characteristic of geochemical processes in an oxygen-free environment occurred very slowly – for thousands of years. It should be taken into account that during the extraction and transportation of oil, due to intensive contact with oxygen, the characteristics of the oil and petroleum products themselves change as a result of rapidly occurring oxidative processes.

One of the most difficult global problems of the modern community is the shortage of fresh water. Fresh water, being an absolutely necessary component to ensure minimum vital conditions for all organisms inhabiting the planet, has already become acutely deficient in at least 40 countries around the world. The total territory of these countries is almost 60% of the area of the entire planet. It is estimated that humanity uses at least 10 million tons of potable water per day, and this figure, with the growth of the world's population, has a constant tendency to increase significantly. Considering the critical importance of desalinated, clean water, and taking into account that the planet's population uses approximately 4 trillion m^3 of water a year, various anthropogenic pollutants are of great danger on a global scale, which spread quickly enough over large areas, causing pollution of all ecological niches [4].

Unpredictable population growth, the existence of large cities, urban agglomerations and megalopolises with appropriate infrastructure are certainly one of the main causes of environmental pollution. The environmental situation has become so complicated that in the European Union, where carbon dioxide emitted by cars accounts for 12% of the total amount of techno-genic exhaust gases, car manufacturers have strict requirements. The purpose of these requirements is that the intensity of exhaust gases containing carcinogenic benz[a]anthracene, benz[a]pyrene, carbon monoxide, would become very insignificant and as close as possible to zero, and spontaneously formed carbon dioxide, converted into organic compounds by photosynthesis.

A serious environmental document is a report presented by the United Nations Environment Program (UNEP, 2009) as a response to the 2008 global crisis concerning food, fuel and finance. The document discusses a number of policy actions aimed at stimulating the economy and simultaneously improving the stability of the global economy. The Global Green New Deal (GGND) advises governments to allocate special funding to the green sector in three areas: (1) economic recovery; (2) poverty eradication; (3) reduction of carbon emissions and ecosystem degradation; implementation of a framework program to stimulate green programs and thus support local and international environmental policies. [5]

The European Green Deal, approved in 2020, is a set of policy initiatives of the European Commission, the main goal of which is to turn the European Union (EU) into climate neutral by 2050 (to decrease the emission of toxic compounds to zero level). In modern conditions, climate change and environmental degradation are an existential threat both for Europe and for the whole world. The implementation of the Green Pact will transform the European Union into an environmentally stable, resource-efficient and competitive economy, ensuring:

- no greenhouse gas emissions, later than 2050;
- achieving economic growth of countries that are not connected or minimally dependent on the use of natural energy resources, the main purpose of which is to eliminate harmful emissions.

1.2 Factors negatively affecting the environment

An important place in the complex of solving global and regional environmental problems is held by natural phenomena and factors of an economic (anthropogenic factors), biological, social and political nature that negatively affect the environment. The analysis of long-term observations allows concluding that in created conditions of the world economy; these factors are changing, often leading to their negative or extremely negative ecological safety.

The factors polluting the environment, obviously, should be divided into three main groups [126,127] (Fig.1).

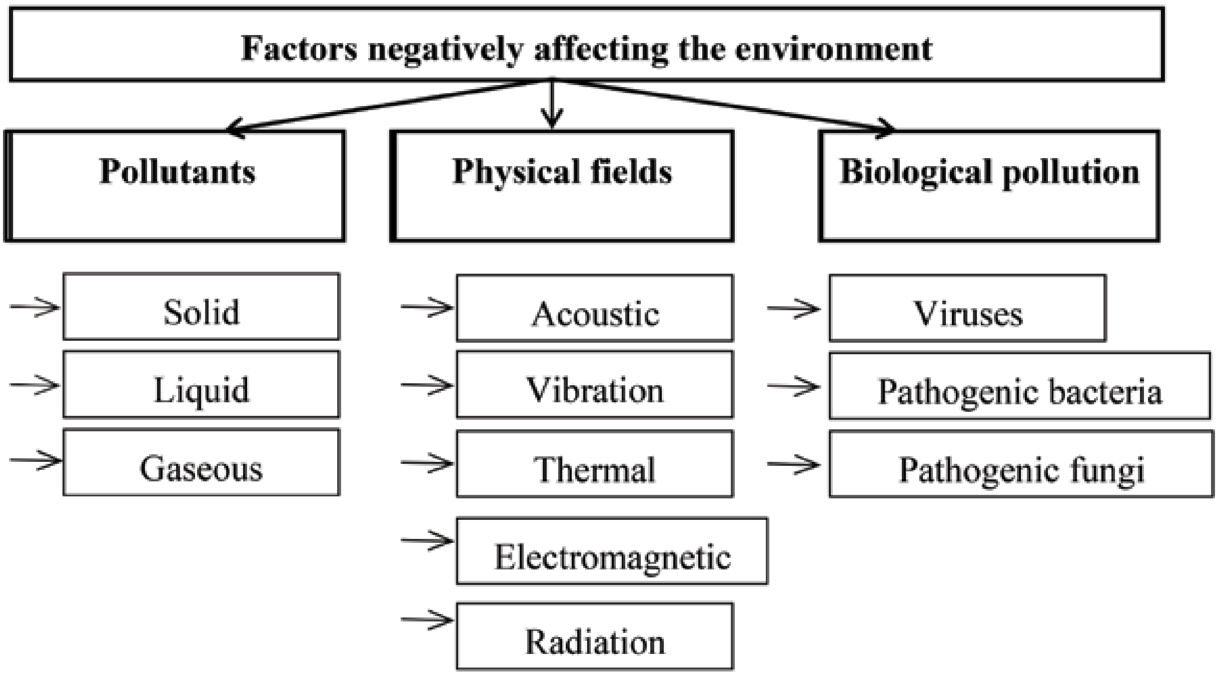


Fig. 1. Factors globally and regionally affecting the state of the environment

The first group includes pollutants by the nature of mechanical contamination, which depending on the aggregate state can be solid, liquid and gaseous. In addition to well-known and well-characterized sources: gaseous and liquid aggressive mixtures, the elimination of a huge amount of plastic-like materials obtained by chemical synthesis have recently become a serious subject for discussion. The problem is that these materials, as they decompose under the influence of solar radiation, emit traces of methane and ethylene, which are components of greenhouse gases. This property is especially inherent in polycarbonate, acryloplast, polypropylene, as well as high and low-density polyethylene. Polyethylene, used for the production of bags, is considered the most active source of methane and ethylene emissions. As it has been established, methane is 30 times more powerful component for greenhouse gas formation than carbon dioxide.

The second group includes physical fields, which, depending on their nature, can manifest as:

- acoustic field resulting from the impact of various sources of sound waves;

- vibration field, as a result of the impact of elastic mechanical vibrations;
- thermal field, often resulting from an increase in ambient temperature;
- electromagnetic field caused by the action of various sources of electromagnetic waves;
- the radiation field formed as a result of ionizing radiation.

The 3rd group includes biological pollution, various forms of exposure to viruses and pathogenic forms of microorganisms of different taxonomic forms (bacteria, actinomycetes, mycelial fungi) that worsen ecosystem ecology and are sources of: biological decay (often uncharacteristic oxidative processes) of natural compounds, infectious diseases, negatively affecting the physiology and metabolic processes of humans, animals and plants. The listed factors not only negatively affect the human body, but also generally worsen the environmental situation at the wide regional level, contributing to the manifestation of various infectious diseases in people; causing particularly serious damage to big cities (places of their most likely spread), urban agglomerations and megalopolises.

Pollutants: natural and anthropogenic. Any natural or synthesized compound found in the environment in quantities exceeding the maximum permissible concentration (MPC) characteristic of the region can be considered as a pollutant. Any contaminant is a chemical compound with appropriate structures, physical, chemical, biological and environmental characteristics. Pollutants are classified according to various characteristics. The first and main feature of an aggregate substance is its physical state: gaseous, liquid and solid. Another important classification feature is its belonging to natural or anthropogenic factors. This factor largely determines the biodegradability, and compatibility of a substance in natural conditions.

For the environment, natural pollutants are quite different structure chemicals of toxic nature, volcanic eruptions, large-scale forest fires, sandstorms, waste metabolites of some organisms (microorganisms, plants) and other natural phenomena, including external space influences, which result in an imbalance of material substances and physical factors in the environment. A more serious environmental danger is posed by manmade permanently increasing wide spectrum of anthropogenic pollutants that exist in large quantities and are widely distributed. Such pollutants pose a more serious permanent and universal environmental danger for all ecological niches. The most often they are characterized by high stability, uneven distribution in the lithosphere and low/very low biodegradability. Briefly, up to one thousand tons of chemicals are produced annually in the world. In different ways a large amount of hazardous chemicals or products of their partial transformation are accumulated in different niches of environment affecting the regional ecological balance. In spite of their not natural origin, some organisms (definite species of microorganisms and plants) can assimilate the majority of those contaminants and remove them from the environment.

In modern conditions, the main environmental pollutants include methane, as a product of constant generation by various types of microorganisms. Toxic gases and solid particles released during volcanic eruptions; emissions of carbon mono- and dioxides, forest fires, sandstorms, oil extraction and transportation, seeping into soils, rivers, seas; heavy metals during the washing of ores, floods and landslides, formed products during natural and technical processes.

Anthropogenic factors negatively affecting the environment pose the greatest environmental danger due to their greater number and global distribution, equally polluting all ecological niches. Being the main form of environmental pollution, they fundamentally affect and change the micro-, and in some cases, the macro-environment of their location. Stable in biotic and abiotic conditions, they have a negative impact on all types of organisms either by themselves or in composite supramolecular complexes with other environmental components. Undoubtedly, the great majority chemically synthesized compounds such as plant protection and pest control agents, surfactants, aerosols, explosives, and many others, due to their high stability in biotic conditions, are characterized by much higher toxicity than natural compounds. Toxins produced by wide spectrum of microorganisms of all taxonomic groups are specific poisons. Most often, those toxins are compounds containing polypeptide chains consisting of hundreds of amino acids. These compounds in spite of their very high toxicity are distributed in nature in a small concentration that they should not be classified as contaminants. They have special application in different branch of medicine.

The basis of the existing ecological imbalance of the planet is the constant desire of the community to improve diverse living conditions, to earn as much profit as possible, especially widely known multinational companies. However, the unpredictably rising world population, over the past century, has increased the anthropogenic load on ecosystems to such extent, that it has already exceeded the biologically regenerative potential of the planet in a number of large regions. It has become necessary to solve the problems associated with the constantly progressive, intensive pollution of all components of nature: air, soil and water. The etymology of the concepts "demography" and "pandemic" expresses them as words having the same root "demos" – "people". In the second case, the "pandemic", "all the people" is the highest level of coverage of the population, which is the most dangerous. It is obvious that the demographic "footprint" of the pandemic, as a special form of environmental and economic crisis, is primarily manifested at the level of increasing mortality rates.

1.3 Atmospheric air

Undoubtedly, one of the most important components of the biosphere is atmospheric air. In the entire history of humanity, despite the chaotic geological, climatic, and evolutionary processes often taking place on Earth, there has not been a critical quantitative change in the main components of air – nitrogen, oxygen, carbon dioxide and argon. This is undoubtedly the result of the phenomenal ability of self-renewal and self-regulation of the ecological balance of nature. It can be assumed with high probability that even minor changes in the composition of the air can become the basis of uncharacteristic physiological and biochemical changes that can cause serious changes in the spectrum of many terrestrial organisms adapted to existing conditions, including humans.

Undoubtedly, the question is important: what phenomena affect the atmospheric air? The chemical composition of the atmosphere is influenced by any non-natural gaseous formation, which, in addition to mechanical mixing, reacts chemically with the components of the air, forming complex, quite often stable compounds. The gases existing in the air are characterized by the ability to disperse the radiation of waves of different lengths, which reduces their overall effect on all forms of living organisms.

More than 3,000 substances that are not part of the atmosphere, but fall into it, are also substances that pollute the atmospheric air. These compounds, firstly, pollute the air themselves, and secondly, reacting with air components, reduce their concentration, forming new, uncharacteristic components for air. In addition to the above, pollutants are also substances that are usually present in other layers of the atmosphere, for example, ozone in the stratosphere after it enters the troposphere. The main sources of the appearance of natural and non-specific anthropogenic gases are quite numerous. Gases arising in all industrial processes; contained in the exhausts of gasoline and diesel-powered vehicles; released by pathogenic microorganisms; having volcanic origin; penetrating from space – unusual for the Earth's atmosphere; gases formed in nature as a result of biological processes: putrefaction – biological oxidation of organic compounds and other microbiological processes carried out by pathogenic forms of microorganisms.

The development of industry at unprecedented pace and scale has caused a large variety (more than 3 thousand) of new techno-genic compounds, uncharacteristic for the environment. Good example is chlorine, to enter the atmosphere, such as pure chlorine, which is intensively used in chemical industry. Despite its small concentrations in the air and soil, this halogen is a great danger in natural conditions, forming organochlorine compounds that, when entering the food chain, and have an extremely negative effect on human and animal health.

Especially of long-term toxicity are characterized by a group of techno-genic, highly stable in natural conditions compounds - dioxins. This is a special group of organochlorine compounds, which is characterized by unusual stability in natural conditions and the constant preservation of the characteristic toxic structure for decades. Against the background of the negative impact on the atmospheric air of a huge number of natural and anthropogenic factors, their direct effects on living organisms and changes in the chemical composition in the lithosphere of the planet – water, air and soil, provoked by these same factors, are especially important. One of these is the so-called greenhouse effect caused by an increased amount of man-made gases, which is the "response" of the lithosphere to the background increase of gases in nature. This effect, formed in the XX-XXI centuries, is characteristic of the vast majority of big cities.

The most common anthropogenic compounds for different layers of atmospheric air are [6]:

- in the atmosphere – gaseous substances (sulfur dioxide, carbon and nitrogen oxides), solid particles (dust, soot, heavy metal compounds), organic compounds, including those forming photochemical smog and destroying the ozone layer of the atmosphere vapors of petroleum products;
- in the hydrosphere – soluble and insoluble gaseous substances (chlorine compounds, hydrogen sulfide, ozone, hydrogen), suspended solids and soluble salts of heavy metals, liquid pollutants (petroleum products, fats and oils, acids, alkalis, surfactants);
- in the lithosphere (especially in its upper fertile layer – soil) – gaseous substances (compounds of ammonia, chlorine, nitrogen), a wide variety of toxic compounds,

suspended solids and soluble salts of heavy metals, liquid pollutants (petroleum products, oils, acids, alkalis, pesticides).

It is anthropogenic pollution of the environment and, first of all, air and soil with gaseous, liquid and solid substances (fine dust), which damages the health of the population, remains the most acute environmental problem of priority social and economic importance. Almost all the gases in the air are hazardous eco-contaminants when present above their natural concentrations and can cause serious pollution of the environment. Oxides of carbon, nitrogen, sulphur, methane, chlorofluorocarbons, volatile organic compounds etc. belong to the class of potentially hazardous compounds.

The most common pollutants in the gaseous state should be mentioned the following:

Among the gases playing a special role in the contamination of the air, carbon monoxide formed by the incomplete burning of carbon-containing substrates should be considered as one of the most poisonous. The annual global emissions of carbon monoxide into the atmosphere have been estimated to be as high as 2600 million tons, of which about 60% are from human activities and about 40% from natural processes.

Carbon monoxide (CO) is a colorless, odorless gas. The molecular weight is 28.01. The density of CO at a temperature of 0 °C and a pressure of 760 mmHg is 1.25 kg/m^3, the heat capacity is 29.14 J/(mol·K), the melting point is -205.02°C, the boiling point is -191.50°C, the critical temperature is 140.2°C, the critical pressure is 3.48 MPa. Carbon monoxide is extremely toxic. Being a product of incomplete combustion of petroleum hydrocarbons, when exposed to the human body, it replaces oxygen molecules in the blood, which leads to vascular spasm, headache, decreased immunological activity, loss of consciousness, and in some cases even death. In the air of the working area of industrial premises, MPC of carbon monoxide is 20 mg/m^3, in the atmospheric air of the city, the maximum single MPC – 5 mg/m^3, and the average daily MPC is 3 mg/m^3.

Carbon dioxide (CO_2) is the final product of the complete oxidation of carbon-containing compounds (energy, fuel). Atmospheric CO_2 is in permanent exchange with soil, water and most kinds of living organisms. Plants permanently carrying out CO_2 fixation via photosynthesis are distinguished by their high CO_2 exchange potential. The natural sources of CO_2 formation are volcanic eruptions, exposure of carbon containing rocks, rotting of organic compounds (microbiological decomposition), respiratory processes and forest fires. Undoubtedly, even only the amount of CO_2 released from all these sources would be enough to exterminate all kinds of living organisms if not the processes of CO_2 fixation existing in nature. Photosynthesis and dissolution of CO_2 in seawater decreases the amount of carbon dioxide in the air to a level that does not inhibit preventing the vital processes.

Carbon dioxide (CO_2) is a colorless, non-flammable gas with a weak sour smell and taste. The molecular weight is 44,010. The density of CO_2 at a temperature of 0 °C and a pressure of 760 mmHg is 1.97 kg/m^3, the heat capacity is 819 J/(mol·K), the melting point is -56.6 °C, the boiling point is -78.47°C, the critical temperature is 31.05°C, the critical pressure is 7.38 MPa. The toxicity of carbon dioxide CO_2 is determined by its concentration. The source of CO_2 is the combustion processes of organic substances. At sufficiently high concentrations, carbon dioxide is able to displace oxygen from the air. A high concentration of carbon dioxide in the air causes suffocation. Carbon dioxide easily transmits sunlight in the ultraviolet and visible parts of the spectrum, but absorbs infrared rays emitted by the earth's surface. Carbon dioxide is classified as greenhouse gas [8].

The natural sources of SO_2 are volcanoes, forest fires, sea foam and the microbiological transformations of sulphur-containing compounds. Once in the atmosphere, sulphur dioxide can bind with lime thereby maintaining its stable concentration in the air. Anthropogenic sulphur dioxide is formed during the burning of coal and oil, during metallurgical processes, and the processing of sulphur-containing ore. Most of the anthropogenic sources of SO_2 (about 87%) are connected with power engineering and industry. Total anthropogenic SO_2 comprises more than 90% of sulphur dioxide existing in nature. SO_2 resides in the atmosphere exist approximately for two weeks. This interval is too small for its global dispersion. Therefore, in neighboring geographic regions, differences in the SO_2 content of the atmosphere are observed. The problem of SO_2 pollution is more or less typical for highly developed industrial countries and their neighbors.

Sulfur dioxide (sulphurous anhydride) SO_2 is a colorless gas with a pungent odor. The molecular weight is 64.066. The density of pure sulfur dioxide at a temperature of 0°C and a pressure of 760 mmHg is 2.9267 kg / m^3, the heat capacity is 39.8 J/(mol·K), the melting point is -75.46°C, the boiling point is -10.06°C, the critical temperature is 157.5°C, the critical pressure is 7.88 MPa. Pure sulfur dioxide condenses into a liquid at a temperature of 10.8°C and at a vapor pressure of SO_2 above the liquid phase of 760 mmHg. At a temperature of + 50.0 °C and a pressure of 0.84 MPa, SO_2 turns into a liquid state. The average specific heat capacity of liquid SO_2 in the temperature range from -20.6 °C to +9.8°C is 20.8 J/(mol ·K). At a temperature of - 72.5°C, SO_2 turns into a solid state.

After entering the air, sulfur dioxide remains in it for a relatively short time: from several hours (in moist air with foreign impurities, for example, ammonia) to three weeks (in dry and clean air). When SO_2 is mixed in the air with moisture droplets, chemical, photochemical, physical and other reactions occur, resulting in the formation of a secondary pollutant – sulfuric acid (H_2SO_4), which significantly increases the environmental hazard of sulfur dioxide. In addition, sulfur dioxide, interacting with suspended particles, forms sulfuric acid salts, which can settle in human lungs and cause serious diseases, up to the destruction of tissues. When inhaling relatively small concentrations of sulfur dioxide in humans, the upper respiratory tract becomes inflamed. In this case, lung damage occurs 1-2 days after SO_2 enters the respiratory tract [7, 21]. In the air of the working area of industrial premises, the maximum permissible concentration (MPC) of sulfur dioxide is 10 mg/m^3; in the atmospheric air of the city, the maximum single MPC is 0.5 mg/m^3, and the average daily MPC is 0.05 mg/m^3.

Nitrogen monoxide (NO) is a colorless gas formed as a result of direct contact of nitrogen compounds with oxygen. The molecular weight is equal to 30.008. The density of NO at a temperature of 0°C and a pressure of 760 mmHg is 1.3402 kg/m^3, the heat capacity is 29.86 J/(mol·K), the melting point is -163.7°C, the boiling point is 151.6°C, the critical temperature is 93°C, the critical pressure is 6.48 MPa. Being a component of air, NO is a highly toxic substance, and its action is directed at the central nervous system; has a destructive effect on the lungs, and in severe cases causes pulmonary edema and lowers blood pressure. In the air of the working area of industrial premises, the maximum permissible concentration of nitrogen monoxide is 5 mg/m^3, in the atmospheric air of the city the maximum single MPC is 0.4 mg/m^3, and the average daily MPC is 0.06 mg/m^3.

Nitrogen dioxide (NO_2) is a reddish-brown gas with a characteristic pungent smell. The molecular weight is 46,008. The density of NO_2 at a temperature of 0°C and a pressure of 760 mmHg is 1490 kg/m^3, the heat capacity is 36.7 J/(mol·K), the melting point is 11.2°C, the boiling point is 21°C, the critical temperature is 158°C, the critical pressure is 10.1 MPa.

Short-term exposure of nitrogen dioxide to the human body causes an imbalance of the lungs, acting on the mucous membranes of the eyes and nasopharynx, damages lung tissue and reduces the body's resistance to infectious diseases. In the air of the working area of industrial premises, the maximum permissible concentration of nitrogen dioxide is 2 mg/m^3, in the atmospheric air of cities, the maximum single MPC is 0.085 mg/m^3, and the average daily MPC is 0.04 mg/m^3.

The most common type of polluting components in the solid state is **fine dust**, which is divided into organic and inorganic (mineral):

– organic dust includes plant dust (for example, wood dust), as well as dust of some synthetic substances – dust of various plastics, rubber products, finishing fabrics, cotton wool, polyester resins;

– Inorganic dust includes metallic and mineral dust – for example, iron dust, lead dust and other heavy metals, iron oxide, sand dust, crushed stone, gypsum, cement, ceramic dust.

The properties of dust vary in wide ranges; depend on the conditions for the formation of dust particles and some other parameters. The main characteristics of dust are: dispersion – the size and shape of dust particles, structure, specific surface area, adsorption capacity, chemical composition, and density – true, apparent and bulk, electrical resistivity, adhesion, abrasiveness, wettability, equilibrium humidity and other properties that determine the nature of the impact.

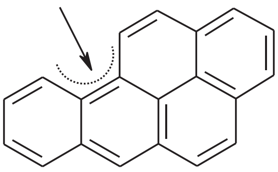
Dust particles of PM2.5 and PM10 are the most dangerous for people. The negative impact of dust on the human body is manifested in the case of penetration through the respiratory organs into the gastrointestinal tract, skin and mucous membranes. According to the nature of the impact on the human body, dust is divided into irritating and toxic. Depending on the chemical composition of the dust, the values of its MPC in the air of the working area range from 1 to 10 mg/m^3, while the maximum single MPC and average daily MPC of dust on average are 0.5 mg/m^3 and 0.15 mg/m^3, respectively.

An important role in air pollution is determined by **petroleum products,** complex mixtures of different hydrocarbons, in a small amount containing organic compounds of other classes. The main elements in the composition of oil are carbon – 83-87% and hydrogen – 12-14%. Of the other elements, sulfur, nitrogen and oxygen are included in the composition of petroleum products in certain quantities. The composition of oil also includes alkanes – paraffin's, cycloalkanes – naphthenes, aromatic hydrocarbons, asphaltenes, resins and olefins. In addition, oil, as a rule, contains insignificant amounts of trace elements. More than 1000 individual compounds have been identified in the composition of oil. Petroleum products include various hydrocarbon fractions obtained from oil. In a broader sense, the term “petroleum products” is used to denote commodity raw materials from oil that have undergone primary processing. Refined petroleum products are used in various types of economic activity: gasoline fuels – aviation and automotive, kerosene fuels – jet, tractor, lighting, diesel and boiler fuels, fuel oil, solvents, lubricating oils; tar; bitumen, paraffin, petroleum coke, petroleum acids, etc.

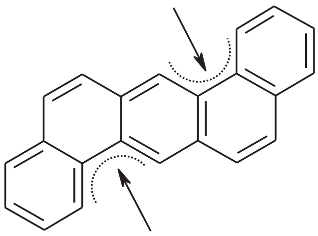
Oil is characterized by the content of light fractions of paraffin and sulfur. Light fractions have increased toxicity to living organisms; their low-temperature evaporation contributes to rapid self-purification. For example, paraffin vapors in the air do not have a strong toxic effect on living organisms, but due to the high solidification temperature, paraffin significantly affects the physical properties of the soil. Sulfur increases the risk of hydrogen sulfide contamination of soils.

It is advisable to allocate hydrocarbons, which are gases without color and with a characteristic smell, to a special group. Their molecular weight varies from 16.04 to 44.09. The density of hydrocarbons at a temperature of 0°C and a pressure of 760 mmHg ranges from 0.7168 to 2.019 kg/m^3, boiling point from -162°C to -42°C, critical temperature from -82°C to +96.8°C, critical pressure from 4.12 up to 4.49 MPa.

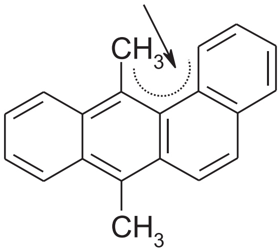
Polycyclic aromatic hydrocarbons (PAHs), belong to the group of aromatic hydrocarbons contain condensed rings. These compounds are almost insoluble in water, have high boiling points and are difficult to be decomposed in biotic conditions.



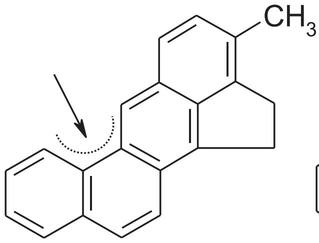
3,4-Benzopyrene



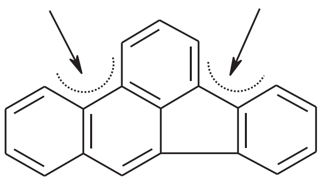
1,2-5,6-Dibenzanthracene



7,12-Dimethyl-
benzanthracene



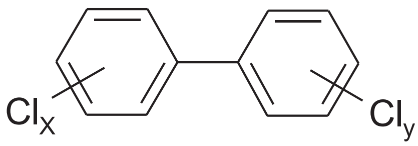
3-Methylcholanthrene



3,4-Benzofluorantrene

All these compounds have at least one reentrant cavity (marked by arrows) in their molecular structure. This feature is a characteristic for many carcinogenic compounds. No reliable information on PAHs release on the industrial scale is available. Compounds of this class are formed during combustion, and, many natural products contain them. PAHs can be found in pitches, bitumen, soot, and humus components of soil. They are components of the exhaust gases of engines, combustion products of cooking stoves or space heating furnaces, smoked foods, tobacco and a number of other natural and anthropogenic products. PAHs are widely distributed and very stable under practically any conditions, creating a real danger of their accumulation in living organisms in higher concentrations. Carcinogenicity of PAHs has been reported. After penetration of PAHs into the organism enzymes form epoxy compounds. These compounds react with guanine and block DNA synthesis, inducing disablement of transcription processes, or leading to mutations, which often promote cancer. There is substantial data in the literature indicating the potential of microorganisms and plants to degrade PAHs to regular cell metabolites.

Among the hydrocarbons, the most dangerous are **polycyclic aromatic hydrocarbons (PAH).** A family of over two hundred compounds are known for their extremely carcinogenic, mutagenic and teratogenic properties – benz[a]anthracene and crisene, benzo[b] fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi] pirylene, *coronene* dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene and ovalene.

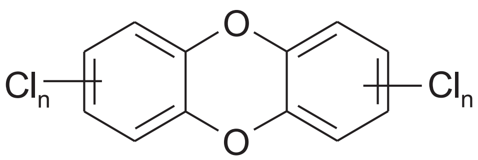


For example. PCBs. Aroclor–1254 has x+y=5

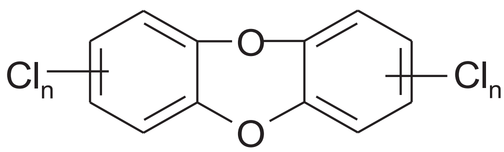
When exposed to hydrocarbons, lesions of the central nervous system, endocrine system, cardiovascular system, a decrease in the blood content of hemoglobin and erythrocytes are observed on the human body. In the air of the working area of industrial premises, MPC of hydrocarbons is 300 mg/m^3, in the atmospheric air of the city the maximum single MPC is 900 mg/m^3, and the average daily MPC is 300 mg/m^3.

Though PCBs are slightly soluble in water and have a high boiling point, they are widely distributed in air, water and soil. The present general environmental contamination with PCBs is connected with their wide application. Despite strict restriction of the application of PCBs in industry, they are found in large amounts in soils and sediments, and via this pathway in water and air. Due to their high chemical stability and lipophilicity, PCBs tend to be stable under natural conditions and remain unchanged for a long time. If PCB molecule contains 30% or less chlorine of total mass, it can be removed from organisms more easily, than PCBs with a high halogen content (60% or more). PCBs accumulate in plants and animal tissue, are inserted into the food chain, and therefore are ultimately dangerous for human health. PCBs toxicity increases proportionally to the increase of chlorine content. Poisoning by PCBs causes chloracne, changes blood composition and affects the liver and the nervous system. There is considerable evidence for the carcinogenic nature of these compounds. PCB residues are hard to annihilate. The best method is burning at a temperature above 1200°C. They belong to that category of substrates whose application must undoubtedly be restricted. Only a few bacterial strains are able to carry out the full mineralization of PCBs because of aerobic and anaerobic conversions. This process is slow, compared with the rate of microbial or enzymatic degradation of many natural and even synthetic compounds. Initially dehalogenation of PCBs molecule takes place and the aromatic biphenyl rings become accessible for the oxidizing enzymes that degrade toxic compounds up to cell regular metabolites. Polished data on plants' ability to degrade PCBs are very exiguous.

Dioxins. The group of polychlorinated dibenzodioxins and dibenzofurans called dioxins are distinguished by especially high toxicity.



Polychlorinated dibenzo-*p*-dioxin



Polychlorinated dibenzo-*p*-furan

These compounds are always found as a complex mixture, where *n* is the number of chlorine atoms and varies from 4 to 8 for the entire molecule. The basic sources of dioxins are chemical factories producing chlororganic pesticides, polychlorinated chlorobenzenes, solvents for a number of chlorine-substituted alkanes (mainly dichloroethane, trichloroethane, ethylene chlorohydrin), and chlorine substituted polymers (above all polyvinyl chloride). Dioxins are also found in the gas used in the chlorination of water supplies. Polychlorinated contaminants are formed as admixtures during the interaction of chlorine with carbon (e.g. of electrodes and aerial oxygen). It should be stressed that dioxins constitute a serious hazard to environment and human health.

According to the rate of environmental contamination by dioxins, the pulp and paper industry is the second worst after the chemical industry.

Dioxins are also formed at high-temperature chemical processes (including garbage incineration) in which organic and inorganic compounds with one or more atoms of chlorine (including molecular chlorine) participate. Motorcar transport is another source of dioxins: they are exhausted along with the combustion gases from the engines of cars working on fuel containing tetraethyl lead (antiknock agent) and 1,2-dichloroethane (added to reduce lead accumulation inside the engine). Their penetration often leads to the development of chloracne, a severe skin disease followed by long-lasting open sores and damage of the endocrine system adversely affecting proper sexual development and usually fatally affecting embryos. Dioxins cause immunodeficiency, increasing sensitivity to infectious diseases, and are of carcinogenic nature. Comparison of the minimal lethal doses with the semi-lethal doses of dioxins shows their high toxicity. The toxicity of TCDD is 3.1×10^{-9} mol/kg; while for the toxin curare, it is $7.2x10^{-7}$, for strychnine $1.5x10^{-6}$, for sodium cyanide $3.1x10^{-7}$, for diisopropyl fluorophosphate (a chemical warfare agent) $1.6x10^{-5}$ mol/kg. Only lethal doses of the toxins formed by the pathogenic botulism bacteria ($3.3x10^{-17}$) and diphtheria ($4.2x10^{-12}$) exceed the toxicity of dioxins. In spite of their high resistance, dioxins do appear to undergo very slow biodegradation. Although there are no data in the literature reporting the ability of plants to transform dioxins, some microorganisms are able to mineralize these harmful toxic compounds. The deep degradation of dioxin molecules is conducted by the joint action of aerobic and anaerobic microorganisms. Anaerobes, in particular *Dehalococcoides* sp. strain CBDB1, carry out reductive dehalogenation of dioxins leading to the formation of p-dioxins, which by aerobes *Sphingomonas* sp. RWI undergo enzymatic transformation with participation of dioxygenases and hydrolases, as a result of which the splitting of the aromatic ring is observed. Some microorganisms, for example soil microscopic fungi and actinomycetes, are sensitive to the effect of dioxins, and the absence of these taxonomic groups of microorganisms in soil can serve as a bioindicator of the level of contamination by dioxins (Fig. 2).

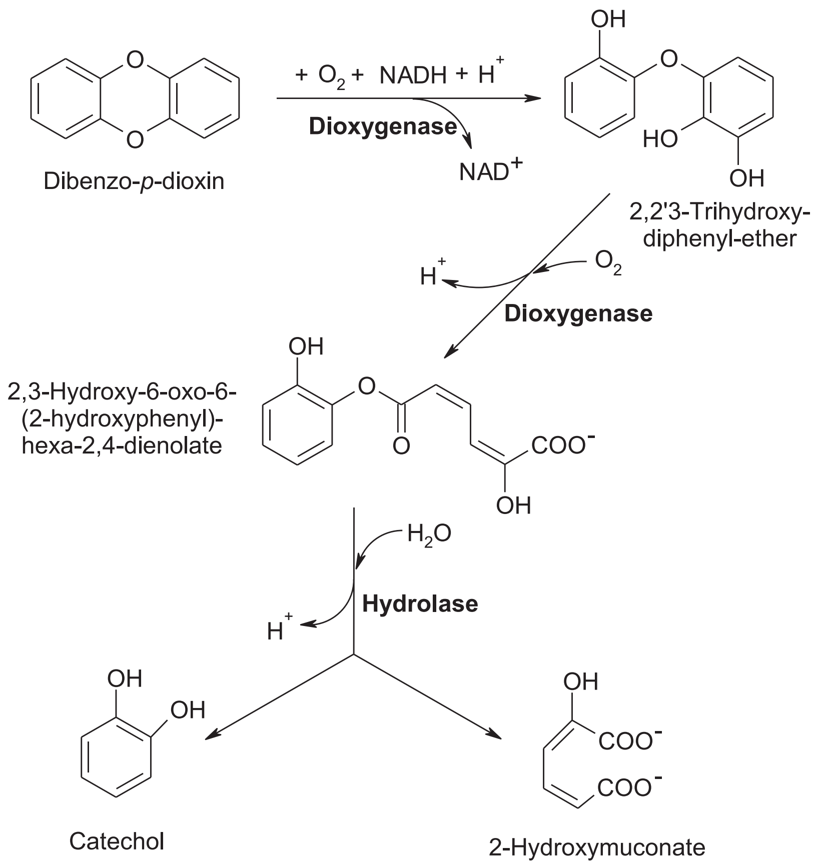
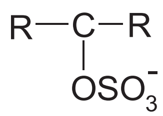


Fig. 2. Microbial degradation of dibenzo-p-dioxin [22]

Surfactants or detergents (tensides) create huge problems of water pollution. They are used as washing enhancers, reducing water surface tension. Their use is often followed by foaming. Surfactants are organic compounds with both hydrophilic and hydrophobic moieties, and they fall into several distinct classes. The most widely environmentally distributed surfactants are the alkylsulphonic acids, the sulphuric acid residue of which forms the hydrophilic moiety.



In the case of the polyoxyethylenes, compounds of nonionic character, alcohol groups form the hydrophilic part of the molecule. Polyoxyethylene can form an ester with the residue of a fatty acid, or ether with the residue of a high molecular mass alcohol:

$$RCOO\text{–}(CH_2 - CH_2O)_nH \qquad RCH_2O\text{–}(CH_2 - CH_2O)_nH$$

Ester Ether

Alkyl ammonium compounds contain positively charged quaternary ammonium as the polar (i.e. hydrophilic) component. Therefore, they are called inversion soaps. Their bactericidal action is noteworthy.

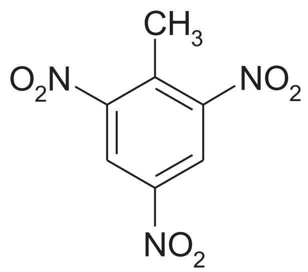
$$R_1 - N^{+}(CH_3)_2 - R_2$$

Increasing industrial demands for surfactants and their intensive application in everyday life has led to widespread accumulation of foam in rivers and reservoirs. Foam hampers navigation, and the toxicity of surfactants causes mass extermination of fish. Negative experience in surfactant exploitation in the 1950-s forced the search for biodegradable surfactants. Those having an unbranched chain, as for example nonionic detergents with alkyl benzene sulphonates have this property:

$$[CH_3(CH_2)_n{-}C_6H_4{-}SO_3^{-}]R^{+}$$

These compounds are furthermore characterized by low toxicity for humans and fish. Biotic disintegration of chains in their molecules is accomplished by β-oxidation, i.e. by splitting acetic acid residues. Even very low concentrations (0.05-0.1 mg/l) of surfactants in rivers are enough to activate toxic substances.

2,4,6-Trinitrotoluene (TNT) is a very toxic compound, used as an explosive.



2,4,6-Trinitrotoulene

The production and use of TNT for military purposes has led to its wide distribution. TNT is one of the most toxic explosives in the military arsenal, and has contaminated thousands hectares of ground. TNT mobility in soil is limited due to its strong absorption onto soil particles. TNT, assimilated via the digestive tract, skin and lungs, is accumulated mainly in the liver, kidneys, lungs and adipose tissue, stimulating chronic diseases. According to EPA data, TNT is classified as a carcinogenic substance of group C. In animal organisms, TNT is slowly metabolized via the reduction of nitro groups leading to the formation of nitroso derivatives, hydroxylaminodinitrotoluenes, aminodinitrotoluenes (ADNTs) and diaminonitrotoluenes. Besides, oxidation of the methyl group and formation of nitro- and amino-derivatives of benzyl alcohol and benzoic acid may take place. Some of these metabolites (mainly amino-derivatives) are conjugated with glucuronic acid. Formation of nitroso and hydroxylamino groups is the factor predetermining the toxic effect of TNT on an organism. These groups bind with cell biopolymers, including nucleic acids and finally lead to chemical mutagenesis.

Microbial transformation of TNT usually begins with reduction of one of the nitro groups. The enzymes that catalyze these reductions are non-specific NAD(P)H-dependent nitroreductase. Complete reduction of nitro groups significantly reduces the mutagenic potential and toxicity of TNT.

Microorganisms degrade TNT in the following ways:

– through elimination of nitrogen in the form of nitrite and further reduction of nitrite to ammonium under aerobic conditions.
– through reduction of nitro groups by nitroreductase under anaerobic conditions and further aerobic metabolism of amino derivatives.

There are data indicating that TNT can serve as a terminal electron acceptor in the respiratory cATP synthesis. Some strains of *Pseudomonas* and representatives of mycelial fungi are able to utilize TNT as a source of nitrogen and carbon, and incorporate atoms of these elements in the skeleton of regular cell metabolism compounds. This is a good example of how parts of toxic compounds can participate in the vital processes of organisms. *Phanerochaete chrysosporium* and some other strains of basidial fungi completely mineralize TNT. The enzymes of basidial fungi easily degrade reduced metabolites of TNT. Due to the high intra- and extracellular activities of woody biopolymers (polysaccharides) degrading enzymes (cellulases, hemicellulases), and such oxidases as lignin peroxidase, Mn-peroxidase, and laccase the strains of *Phanerochaete chrysosporium* and some others are characterized by a high degradation potential.

The ability to absorb and assimilate TNT is also characteristic for some plants. The aquatic plant parrot feather (*Myriophyllum aquaticum*), and the alga stonewort (*Nitella* sp.) are used for the remediation of TNT-contaminated soil and water. Enzyme nitroreductase, which reduces TNT nitro groups, is active in other algae too, in ferns, in monocot and dicot plants, as well as in poplar (*Populus* sp.) trees. Transgenic tobacco (*Nicotiana tabacum*) with expressed gene of bacterial nitroreductase acquires the ability to eliminate TNT by absorbing and degrading TNT from the soil of military proving grounds.

The next classification feature of pollutants is the level of their negative impact on the environment, which is reflected in the toxicity classification, which provides for 4 classes. This classification primarily takes into account the chemical properties of pollutants and is based on taking into account the values of the average lethal dose of a substance when it enters the human body through the respiratory tract (inhalation), skin (percutaneous) or gastrointestinal tract (oral) [9]. When assigning a pollutant to a particular class of toxicity, the path of penetration into the body in which the contaminant turns out to be the most toxic is taken into account. According to the degree of toxicity, substances polluting atmospheric air with pronounced chemical properties (toxicants) are divided into [10]:

– extremely toxic (class I);
– highly toxic (class II);
– moderately toxic (class III);
– low-toxic (class IV).

The degree of toxicity of a substance that has entered the body from the air depends on the amount (dose) of the substance settled in the body. The ways of its intake, distribution and excretion from the body, physical properties and duration of receipt of the substance, interaction with cellular structures, a person's gender and age, individual sensitivity to the toxicant. To eliminate the pathological effect of large doses of toxic compounds on terrestrial organisms, nature itself has a set of natural technologies, which include the detoxification potential of microorganisms and plants, climatic and temperature factors affecting the structure of toxicants (precipitation, temperature changes, seasons), leading to stoichiometric changes in toxic structures, oxidative processes under the influence of air oxygen. The process of photosynthesis, which utilizes a colossal amount of carbon dioxide, can also be assigned to the specific ecological processes. Photosynthesis: plant + solar energy → organic compound + oxygen is one of the most important natural processes that determine the existence of life on our planet, which has no analogue. Photosynthesis is a process used by plants and some other chlorophyll-containing organisms to convert light energy into chemical one. Through photosynthesis, green plants, algae, diatoms and certain forms of bacteria synthesize carbohydrates from carbon dioxide and water in the presence of chlorophyll, using the energy captured by chlorophyll from sunlight and releasing excess oxygen as a byproduct (Figure 3).

Due to the quantum energy of light incident on chlorophyll, adenosine triphosphate (ATP) is generated – the form of energy used by the cell, and the photo degradation of water occurs – the light phase. The resulting hydrogen is used to reduce NADP-H (nicotinamide-β-adenine dinucleotide phosphate), with the participation of which carbon dioxide is reduced to glucose in the dark phase. The energy source in these synthesis reactions is ATP (adenosine triphosphate). Oxygen formed during the photo degradation of water is released into the atmosphere.

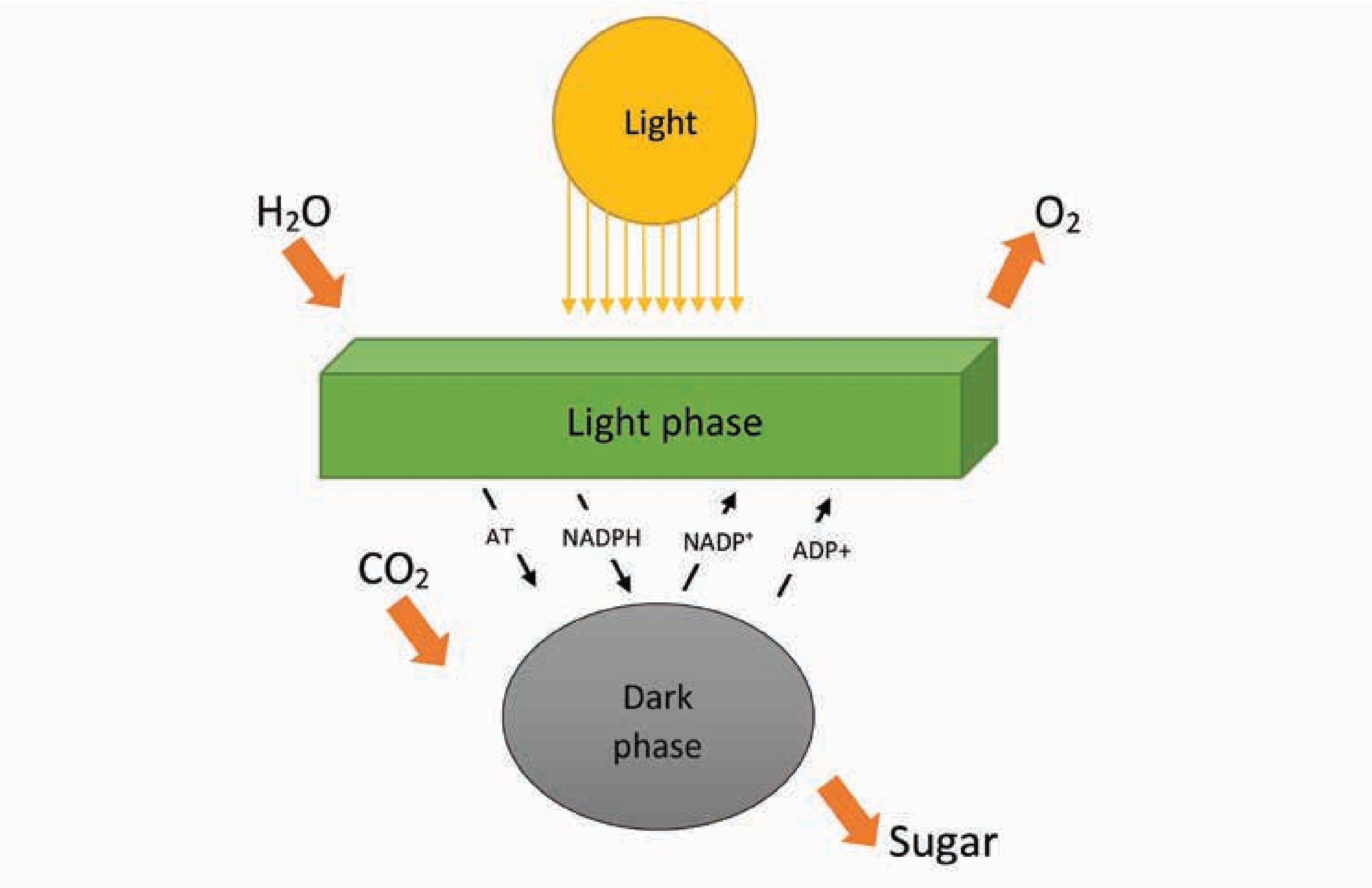


Fig. 3. Photosynthesis process – Daniel Mayer – original image. Vector version by Yerpo

Plants, assimilating carbon dioxide and converting it into organic compounds, largely determine the ecological balance of the planet and, accordingly, create the elementary necessary conditions for the existence of living organisms. The main substrate of photosynthesis, carbon dioxide (CO_2), in comparison with carbon monoxide (CO), is formed in much larger quantities and, as an inorganic pollutant, poses much less danger to the environment. According to available data, because of intensive industrialization, the amount of carbon dioxide in the environment is constantly increasing and, against the background of a constant decrease in the vegetation cover of the planet, has reached such a scale that problems arise related to the potential of its photosynthetic transformation.

In Figure 4, the green color indicates the regions of the planet that are actively engaged in photosynthesis. From the data of the same figure, it is clearly determined that not all of its potential has been used to possibly enhance the photosynthesis process on a global scale. Moreover, these non-photosynthetic regions are mainly located in tropical and subtropical zones, making up at least 15% of the entire land.

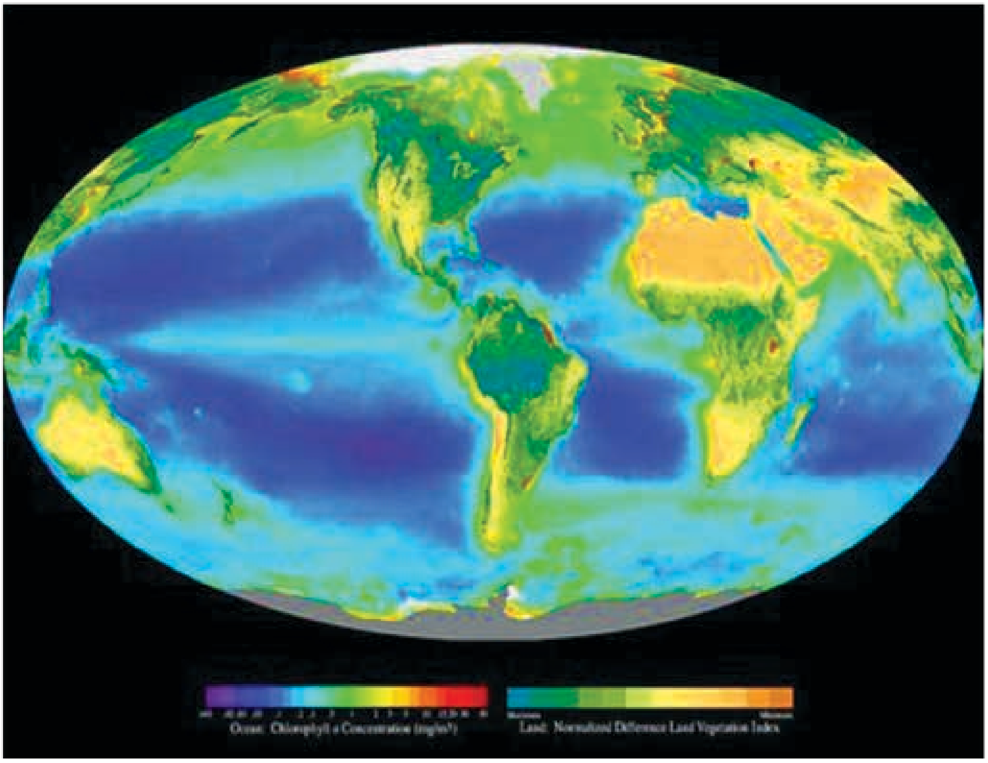
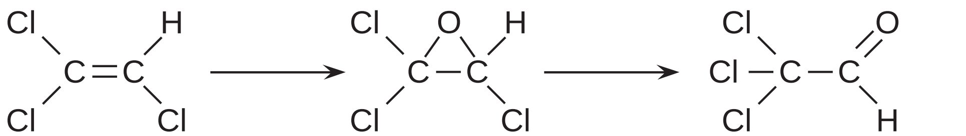


Fig. 4. Map of the global distribution of photosynthesis, including oceanic phytoplankton and terrestrial vegetation [11]

Of the numerous other toxic environmental pollutants, the following can be noted as the most dangerous. Among the chlorinated hydrocarbons widely spread in the atmospheric air, actively acting on the liver is trichloroethane. This solvent is used mainly for degreasing metal surfaces, as a solvent for a number of substances, including those of natural origin. In small quantities, trichloroethane finds use in organic synthesis. It is estimated that about 90% of all produced trichloroethane is in the air, and the rest is in solid waste and wastewater. Trichloroethane is extremely stable in aerobic conditions. In seawater, its half-life is about 90 weeks, and in fresh water – from 2.5 to 6 years. Under the action of anaerobic bacteria, the half-life of trichloroethane is reduced to 40 days, while part of trichloroethane undergoes decomposition to CO_2.

The toxic effect of trichloroethane on animal organisms is due to its metabolic transformations, usually catalyzed by monooxygenases. First, trichloroethane is converted into an epoxy compound, which is further converted into trichloroacetaldehyde (Figure 5).



Trichloroethylene Trichloroethylene epoxy Trichloro-acetaldehyde

Fig. 5. Enzymatic transformations of trichloroethylene in animal organisms

In addition to aldehyde, trichloroacetic acid, trichloroethanol and chloral hydrate can be formed in the body. Trichloraldehyde is a mutagenic substance: actively reacting with DNA, causes its structural changes.

Of course, the above presented list of pollutants of atmospheric air is not exhaustive, but it should be emphasized that pollutants common in different regions of the planet are quite diverse in their structure, function and degree of toxicity. Undoubtedly, atmospheric air is a rather sensitive component of the ecosystem that requires constant, special attention. In order to purify the air, both atmospheric and inside premises, a number of innovative technologies are being developed. For example, the company “Airocide” has developed a technology for cleaning indoor air that is not related to chemistry and, in particular, ozone. It explores the possibility of regulating the content of ethylene in the air, formed because of growing and storing a large number of cereals indoors. According to the company “Potok”, the technology they developed inactivates all taxonomic forms of air microorganisms – bacteria and fungi, viruses – more than 99%, in less than one second. The innovative technology can also be successfully used in technologies related to food production.

The special attention for the last three decades has been paid to plants. Until recently, plants, which still occupy above 40% of the world’s land area, were considered as organism’s just absorbing and accumulating contaminants of different structure, but having no potential to transform them into harmful compounds. According to the previously existing information, plants could only slightly transform toxic compounds, presumably oxidize, than conjugate and deposit in vacuoles. Analysis of experimental data has revealed the visible ecological potential of plants. It has been determined that plants can carry out the deep degradation of xenobiotics of toxic nature quite often leading to mineralization or deep degradation of contaminants [22]. As a result, enzymes carrying out partial/deep oxidation, conjugation and compartmentation processes have been revealed and characterized; the formation of anthropogenic contaminants conjugates with endogenous compounds has been shown. Although, there are still some unlearned biochemical steps in detoxification process carried out in plants closely related to the contaminants multistage degradation process, the authors are attempting for the evaluation of different aspects of plants great ecological potential from the modern understanding, revealing the deviations under the action of contaminants in ultra-structural architectonics of plant cells. Finally, it assumed that plants are one of the best supporters to the environment, to keep the ecological balance in global scale.

1.4 Soil

The soil is an invaluable natural wealth of humanity, or rather, the foundation of its existence and material security. The soil is the only and favorable environment of the *Worldbiome* for the habitat and reproduction of soil organisms: microorganisms, animals and plants, etc. The organisms inhabiting the soil, because of the metabolic processes carried out by them and the metabolites formed, create its fertility. For example, bacteria, fungi, actinobacteria decompose organic substances to low molecular weight, easily metabolizable inorganic components that dissolve in water and are absorbed by plant roots in the form of a soil solution, creating a mutually beneficial collaboration of soil microorganisms and plants. Plants, in turn, secrete so-called exudates that promote the vital activity and increase action of microorganisms.

The soil and plants are in constant mutual metabolism. The soil is the most important living environment, the support of the life of plants, other soil organisms and humans. Living organisms get water from the soil, and simultaneously with water – nitrogen compounds and all-important microelements necessary for the vital activity of living systems. The role of soil in the life of plants is extraordinarily great; undoubtedly, it is dominant. Plant takes oxygen, carbon dioxide, a small amount of water from the air, while mineral substances, all organic matter, and the main part of the plant's water are obtained through the soil. Without this necessary complex of nutrients, the plant cannot develop and function.

Special attention should be paid to the biological relationship between soil and plants, which is extremely fruitful, consisting in enriching the soil with exudates extracted from plants. These compounds significantly contribute to the activation of soil microflora processes. Soil, in turn, prepares organic and inorganic forms of nutrients enriched with oxygen, transforming them into water-soluble compounds for full assimilation by plants. Plants are able to use inorganic nitrogen-containing soil compounds to synthesize a wide variety of compounds, including carbon-bound nitrogen, which is extremely important for plant growth and soil fertility. An example of the diverse activity of plant cells can be the synthesis characteristic of plants in a great number of low molecular weight compounds. Some of those are referred to as so-called secondary metabolites (phenolic compounds, essential oils, carbohydrates, etc.). Secondary metabolites, also called special metabolites, toxins, other intermediate products of metabolism, are organic compounds produced by bacteria, fungi or plants that are not directly involved in the normal growth, development or reproduction of the body. Plants, as compared with other organisms, form a variety of secondary metabolites for their own physiological needs. It is interesting to note that in the vast majority of plant secondary metabolites are characterized with different physiological activity. Over the past couple of decades, new ones have been added to these well-known important characteristics of plants, consisting of the assessment of plants and soil rhizosphere microorganisms as environmental agents capable of removing toxic compounds from the soil due to high intracellular activity of redox, hydrolytic and other enzymatic reactions. This path of degradation and, accordingly, removal of a large variety of toxic structures from the soil based on their metabolic transformations is the most promising, since being completely natural, it does not need the use of special critical conditions or environmentally harmful chemical compounds [12].

The most important ability of some plants, in particular legumes, is their symbiosis with soil bacteria of the genus *Rhizobium*, which are able to assimilate molecular nitrogen of the air. Although the Earth's atmosphere consists of 78.03% nitrogen, this inert gas - N_2, can only be captured in the atmosphere and assimilated by nitrogen-fixing, free-living and symbiotic bacteria. Usually, bacteria in symbiosis with legumes assimilate 100-300 kg of molecular nitrogen per hectare of sown area, while free-living nitrogen fixing bacteria, on the same area and under the same conditions, assimilate only 1-3 kg of nitrogen of the same form.

An unusually wide world of plants – Plantae, living in the soil, belongs to the eukaryote domain. Among prokaryotes, there are a number of autotrophic organisms capable of using solar energy. These are purple *Rhodospirillum* and blue-green algae, also called cyanobacteria. In them, the process of photosynthesis proceeds, as in plants, with the release of oxygen, while in purple bacteria, oxygen is not released during photosynthesis.

It is indisputable that the soil and its fertility, after man began to cultivate the land, even in the most primitive way, is an invaluable natural wealth of *Homo sapiens*. The world of plants, microorganisms, and other soil organisms inhabiting the soil and carrying out its transformations are the foundation of the life of all organisms living on the planet. It has been proved that the biochemical processes occurring in the soil are most closely related to the ecology of the entire soil contamination. Local contamination of soil is more diverse and prolonged than that of water or air. The main factor controlling this phenomenon is the high adsorption capacity of soil, as well as the physical-chemical characteristics of the contaminants and particularly their solubility and resistance in a natural environment. The binding of toxicants is accomplished by the inorganic part and organic matter of soils. Among the minerals, strong adsorbents are clays for which toxicant adsorption ability generally decreases. Besides adsorption to humus, binding of toxicants by hydrogen and covalent bonds often takes place; therefore, toxic compounds in soil are retained longer by organic matter. For instance, it has been shown that 30% of the pesticide amiben (3-amino-2,5-dichlorobenzoic acid) introduced into soil is bound to humus, and 10% is adsorbed by clay.

Binding with humus proceeds via the polar functional groups of toxicants (hydroxyl: amine, carbonyl, carboxyl, etc.). These groups enhance the polarity of the toxicant molecules and enable the formation of hydrogen bonds between the toxicants and soil organic matter. Another reason of prolonged soil contamination is the stability of toxicants as determined by their chemical structure. The stability of aliphatic hydrocarbons is enhanced by saturation and branching of the chain. Aromatic hydrocarbons are more stable with respect to soil transformations, and the presence of substituted groups around the aromatic ring increases stability. Halogen-substituted aromatic hydrocarbons (especially when the substituents are chlorine and fluorine atoms) are the most stable. The total removal of toxic compounds from the environment proceeds only by their full mineralization, i.e. when the organic substrates are decomposed to CO_2, H_2O, HCl, NH_3 and some other inorganic substances. Such degradation of toxicants in soil can be accomplished via both abiotic and biotic pathways. Abiotic transformations include photochemical and chemical oxidative-reductive processes, as well as hydrolytic splitting. Soil organic matter, metal oxides and minerals participate in these processes. In the soil the following processes proceed in abiotic way: reducing dehydrochlorination of the insecticides lindane and DDT, reduction of nitro groups to amides in parathion and pentachloronitrobenzene, and saponification of organophosphorus insecticides. The main pathway of full destruction of toxic organic compounds is their biological mineralization, i.e. degradation by microorganisms capable of using these substances as nutritional sole carbon source. The velocity of microbiological toxicant decomposition depends on exogenous factors such as oxygen concentration in the soil, temperature, soil pH, the presence of inorganic and organic nutrients, etc. Among these factors the content of oxygen in soil, which limits the intensity of aerobic microorganism growth, is the most significant.

Stability, i.e. persistence of toxic compounds, is estimated by the time needed for transformation of 95% of the toxicant. Persistent organic contaminants (POPs) are: dioxins, PCBs, most organochlorine pesticides (aldrin, dieldrin, endrin, chlordane, lindane, heptachlor, hexachlorobenzene, mirex, toxaphene, DDT, etc.), PAHs etc. For dioxins, the period of 95% destruction is 14-15 years, for PCBs it is 10-12 years, for DDT – 4 years, for heptachlor – 3.5 years, for lindane – 3 years, etc. Widely distributed sym-triazine pesticides (simazine, atrazine, prometryn) are retained in soil for about 2 years, carbamates from some months to a year, and organophosphorus insecticides (chlorophos, metaphos etc.) and derivatives of phenoxyacetic acids (2,4-D, 2,4,5-T, etc.) are destroyed within several months. In most cases, the process of mineralization of POPs requires the joint action of anaerobic and aerobic microorganisms in a definite sequence. As a rule, it is first necessary to remove chlorine atoms or substitute them by hydroxyl radicals. Anaerobic microorganisms in oxygen- poor soil generally accomplish such transformations. As a result of such action the aromatic ring remains from the initial toxicant structure. It is accessible only for the oxidases of aerobic microorganisms (Mn-peroxidases, phenoloxidases, laccases, etc.). As established, plants and microorganisms symbiotically much more effectively decontaminate harmful compounds, including toxic ones [13].

The useful thickness of soil for agricultural, decorative, sports and other purposes in different regions of the planet ranges from 20-25 to 150 cm. Existing within these limits, the soil layer surrounding most of the Earth, together with solar energy, and the necessary amount of precipitation is the main foundation for the existence of life. The importance of the ecological state of soil is evidenced by the fact that the existence of a healthy generation of people is possible only in conditions of healthy soil. Soil, under conditions of constant metabolism carried out by soil organisms, is a complex natural system. Its minimal components are mineral and organic compounds, water, and air; microorganisms and other organisms inhabiting the soil are responsible for the multifunctional activity of soil. As a result of biological, chemical, photochemical transformations and stoichiometric processes constantly occurring in the soil, soil self-renewal, degradation up to regular cell structure or mineralization of foreign inorganic and organic compounds and synthesis of new ones characteristic of existing soil and climatic conditions are carried out. Thus, the soil retains its usual fertility. For the self-formation of a full-fledged soil, it takes a long time, presumably in a good condition at least ten years. Under conditions of active natural processes characteristic of the soil, being dominant and functionally active, the beneficial microflora of the soil relatively rarely contains pathogenic soil organisms (bacteria, viruses, fungi). One of the remarkable properties of the soil is its ability to self-clean, thanks to which it evolves, adapting to environmental conditions. The following types of soils are distinguished: sandy, loamy, limestone, peat, podzol, sod-podzol, permafrost-taiga, gray forest, chernozyoms, and chestnut, brown soils, tundra soils, etc. There are at least 28 of them.

It is extremely important that a healthy soil, as one of the main components of the environment and an important biological system, also affect the microclimate of the region. This ability is due to a number of factors: the presence of plants, soil microflora, rhizosphere microorganisms, other soil organisms, which ensures high stability of the “immune” system of the soil, preventing the spread of pathogenic microflora, erosion, waterlogging and other undesirable factors. It is fair to note that a healthy and normally functioning soil is an important component of the “immune” system of the whole nature and at the same time plays a colossal ecological role. **According to the Food and Agriculture Organization of the United Nations, (data of 2019), annual production of soil, covering the request of *Worldbiome* is, more than 760 million tons of wheat, 510 million tons of rice, 1100 million tons of corn, 350 million tons of potatoes, 175 million tons of sugar, 335 million tons of meat, 852 million tons of milk and a large amount of other agricultural products**.

It is recognized that the ecological state of the soil has intensively deteriorated over the past 100 years. These data are expressed in figures as follows: so far, about a little, more than 40% of the planet’s land is covered with vegetation; in fact, almost 2 billion hectares are subject to erosion, and 4.5 billion hectares are subject to desertification; 24 billion tons of fertile soils are lost annually due to erosion (https://www.fao.org/in-action). The area occupied by forests is being reduced by an average of 10 million hectares a year. In modern conditions, there is a little more than 0.4 hectares of soil per capita on the planet, and this indicator tends to decrease constantly. Currently, the vast majority of land is actively exploited, and there are almost no new, ready-to-use, fertile soil suitable for agriculture on the planet.

According to forecasts, in 3 decades the availability of land for agricultural purposes – cultivation of cereals, fruit plantations, etc. – per capita will decrease to 0.1 hectares, which will be a critical level and the beginning of an ecological and food catastrophe.

The soil is actually an extremely complex, changeable and living system environment. It contains 25% of the world's biodiversity, twice as much carbon as in the atmosphere; about 95% of food products are directly or indirectly related to the soil. The reason for the deterioration of the soil as the most important ecological niche is the influence of a number of external factors, which include the presence in the soil of constantly increasing techno-genic toxic compounds of various stability and structure. The fact that industry and the environmental situation are immanently mutually exclusive factors is beyond doubt.

Therefore, special attention should be paid to the creation of new nature-friendly green technologies. In order to maintain an acceptable regional ecological balance, a number of developed countries are transferring the environmentally harmful industries to developing countries (Figure 6).

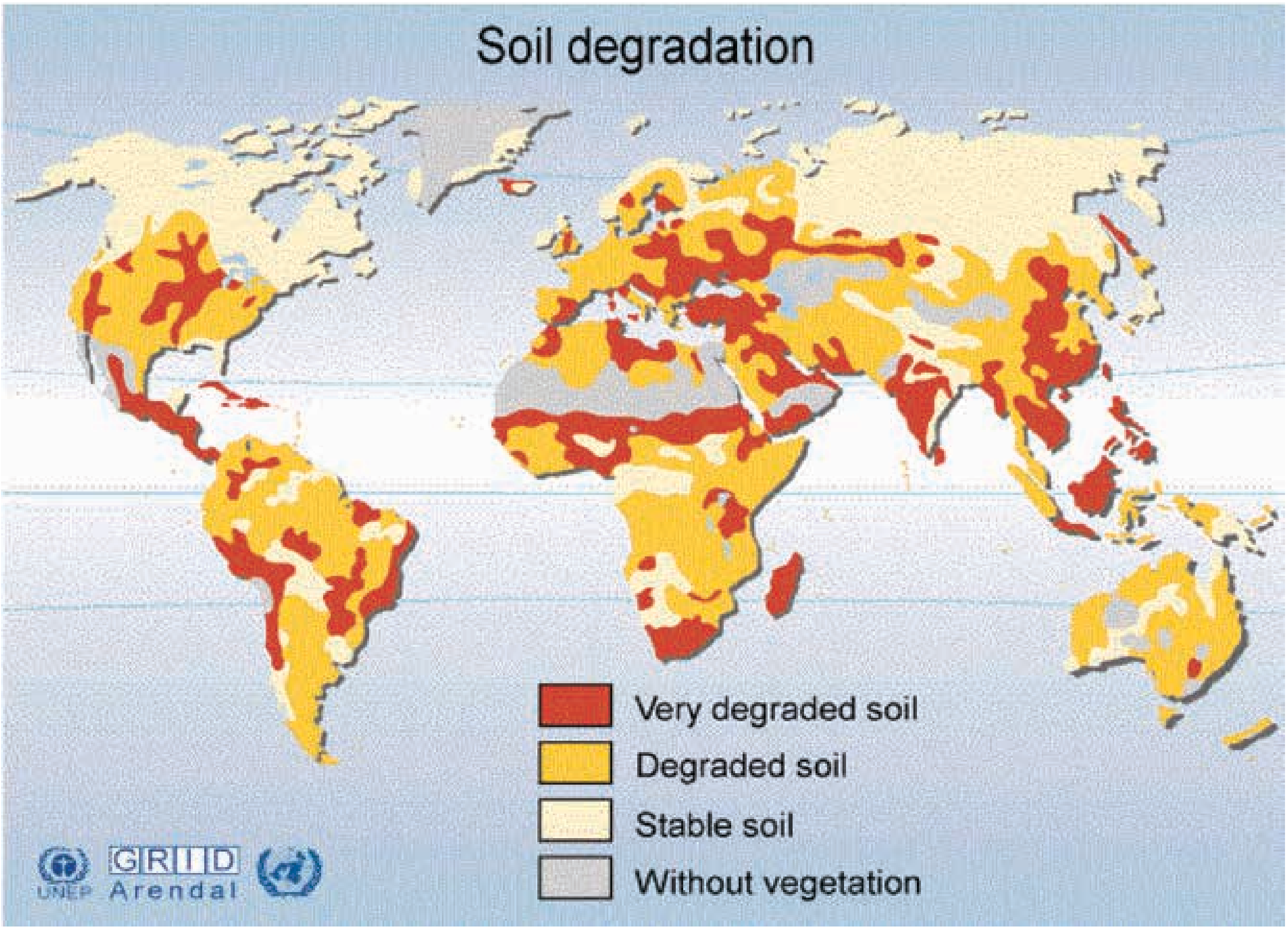


Fig. 6. The ecological condition of the soils of the entire planet
(The map was developed by the United Nations Environment Program,
GRID Arendal https://www.grida.no/resources/5507)

Migration of contaminants into different ecological systems. The circulation of toxicants in the ecosphere can be presented by the following scheme (Figure 7).

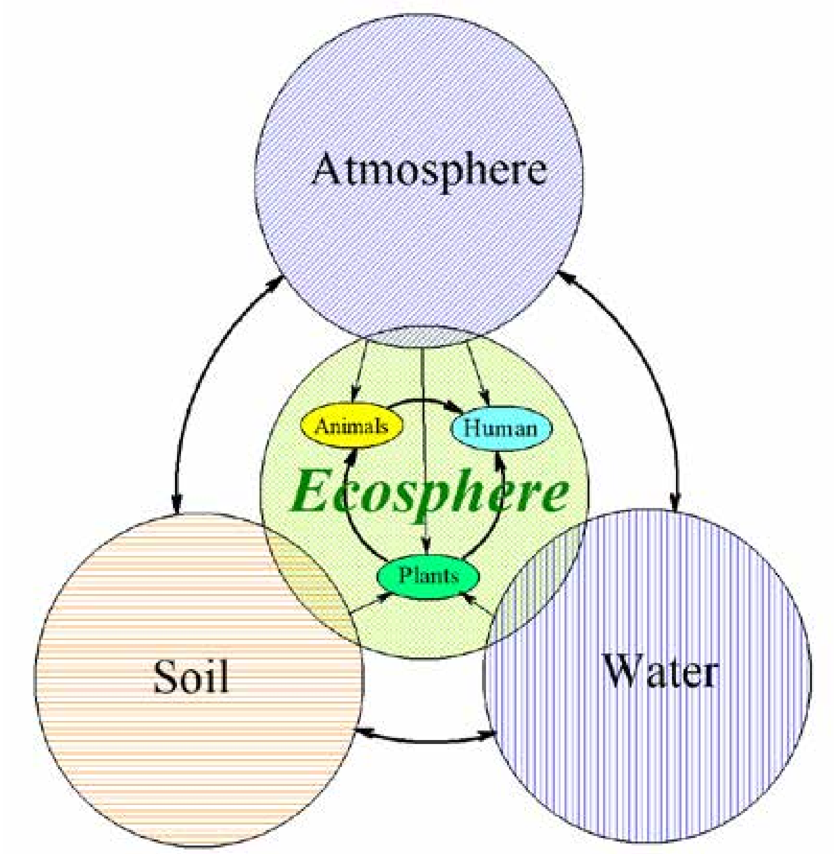


Fig. 7. The circulation of contaminants in the ecosphere [52]

The circulation of contaminants in the ecosphere is first the tendency of compounds of different structures and molecular masses to be dispersed in the environment. It is a very complicated multistage process controlled by many physical, chemical and biological mechanisms and factors, in particular: – basic physical-chemical characteristics of substances such as molecular mass, water solubility, "hydrophobicity" (calculated as the coefficient of substrate partitioning between nonpolar and polar solvents – typically octanol and water – designated as K_{ow}). Contaminants in the environment undergo to the number of physical processes of mass transfer, such as adsorption, desorption, diffusion, impedance, convection, dispersion, molecular mass dependence, dry and wet precipitation, etc.

- chemical processes such as oxidation, hydrolysis, photolysis, conjugation of toxic compounds or their derivatives with natural raw materials, etc.
- geographical processes of substance circulation such as wind, precipitation, and ocean flow, river transportation, etc.
- biological activities of organisms participating in the global processes of substance circulation in nature: bioconcentration, biomultiplication, bioaccumulation, biotransformation, biodegradation, biotic transportation of substances, etc.

The initial stage of toxic compound dispersion is escape from the zone of their initial occurrence. The rate of this process depends on the technology associated with the handling of the chemicals. Much depends on the closeness of the application system to the desired recipient, the presence of geographic factors, etc. One of the key features of toxic compounds determining their distribution is fugacity, i.e. the tendency of substances strive to come out of the phase in which they exist. The initial stage of substance dissemination in the zone of their initial application is followed by their nonhomogeneous distribution in the nearest ecosystem. Biotic and abiotic transfer of substances in the natural environment – soil, water and air – is an important part of this stage of environmental contaminants movement and distribution.

Migration of contaminants between soil and water often are dispersed in the soil via rainwater or artificial irrigation. On the other hand, water flowing on the surface of soil (the so-called run off water), or penetrating into the depths of the soil, could lead to significant contamination of ground water by soil pollutants. Therefore, it is obvious that the basic processes leading to chemical contamination of soil and ground water by toxic compounds takes place on the soil-water phase boundaries. The processes of adsorption are of utmost importance in the chemical contamination of soil and the dissemination of contaminants. Due to the different adsorption abilities of soil components, an uneven distribution of contaminants takes place in the soil. Contaminants are adsorbed on lipophilic soil organic matter, mineral (clay) particles, and are covalently bound. The adsorption process is typically not completely reversible, since an opposing process– desorption – proceeds in salty aqueous solutions, which is however incapable of releasing the contaminant molecules bound chemically or electrochemically to humus macromolecules and clay minerals from the soil. Adsorption significantly limits mass transfer and hence distribution in the soil. The process of mass transfer is the basic power of contaminant migration in soil and is accomplished via diffusion, convection and dispersion of substances. Diffusive mass transfer, i.e. the spontaneous movement of structural particles of a substance (molecules, atoms or ions) along a concentration gradient is accomplished as the result of Brownian (thermal) movement. The intensity of this process does not depend on the velocity of water flow and is determined by the following parameters:

– soil porosity (soil pore sizes and quantities).
– molecular characteristics of diffusing substances (molecular mass, volume, water solubility, etc.).

– the difference in the concentrations of the particular compound in soil and water (magnitude of the concentration gradient vector).

Hence, high soil porosity, large molecules (contaminants), and a small concentration gradient, etc. are factors reducing diffusion. Besides diffusion, contaminant migration is forced by the entrained flow of dissolved substances by flow of their solvent (water), i.e. convective mass transfer. Its velocity depends on the volumetric water flow and the concentrations of the dissolved substances. Heterogeneity of soil pores promotes dissimilar movement of flowing compounds in soil pores, causing dispersive mass transfer. Dispersion plays an important role in the total mass transfer of chemical substances in ground water. More complicated is processes of mass transfer, which include the rise of water from the depths of the soil caused by evaporation of water from soil surface; the existence of a triple phase balance between the contaminant, its water solution and the same substance adsorbed; the flow of water from macro pores of soil (fissures, paths of earthworms, etc.), etc. When discussing the process of toxic compound migration from soil to water, it is very important to keep in mind that contaminants in most cases are accompanied by the products of their partial transformation mainly caused by the action of the enzymes of soil microorganisms and of plants exudates. Intermediates could also form due to abiotic reactions proceeding under the action of solar rays, aerial oxygen and water. Soil mineral substances (iron, aluminum, etc. oxides) often serve as catalysts for such transformations.

Taking into account the high degree of emission of toxic compounds into the environment and their high stability to abiotic conditions, as well as the likelihood of their long-term presence in the soil, degradation of the upper layer and associated processes of soil erosion is inevitable: salinization, desertification, waterlogging. The causes of these processes are toxic emissions, waste from energy complexes, and chemical, metallurgical, oil refining enterprises, toxic exhaust from automobile and other types of transport, as well as intensively developing agriculture. Based on the scale of industrial development, especially in developing countries, a large number of new industrial enterprises and implemented technologies, factor of anthropogenic pollution, both local and global, is significantly increasing and has already acquired a threatening character.

Regions on Earth, where the level of soil contamination with some toxic compounds significantly exceeds the maximum permissible concentration (MPC) have long been identified. Accra (Ghana), Ranipet and Sukinda (India), Kabwe (Zambia), Dhaka (Bangladesh), Karabach and Dzerzhinsk (Russia) and other cities are among them.

According to the international classification, countries in a difficult environmental situation include Saudi Arabia, Kuwait, Bahrain, Qatar, the Arab Emirates, Oman, and Libya. All these countries are oil producing, and most of them produce natural gas.

Significant damage to the environment and especially the soil on a territorial scale is caused by wars that are constantly going on in different countries of the world. The huge environmental damage caused to the environment only by the wars of the XX-XXI centuries remains uncounted. In addition to the visible casualties and destruction characteristic of wars, in the conditions of military operations, all components of the environment, including soil, as well as other ecosystems, are polluted with explosive substances of a carcinogenic nature, aggressive solutions and other compounds uncharacteristic of soil, including components of chemical and biological weapons. A classical representative of toxic explosives of a carcinogenic nature is trinitrotoluene (TNT) – also known as trotyl – one of the components of armament of military units of all countries in the world. This compound, prepared by chemical synthesis, contains three nitro groups and exhibits high stability to biotic and abiotic conditions. After getting into the soil, it retains its extremely high toxic, unnatural structure for years, causing great damage to the soil. The usual microflora of the soil, annual and perennial plants root system, cannot rapidly neutralize action of TNT. At the initial stage of degradation of this explosive, the restoration of nitro groups is required. It should also be taken into account that intermediate products of partial conversion of TNT also have high toxicity. In this context, it is impossible not to mention chemical weapons obtained by chemical synthesis and consisting of active chemicals, poisons and other biologically aggressive components, which significantly complicates their biological neutralization by enzyme systems of microorganisms and plants in natural conditions.

All components of the environment and ecosystems of a belligerent or post-war country, including soil and water resources – lakes, ponds, groundwater's, due to the presence of a large number of toxic compounds, mainly in the form of explosives, as well as toxic products of their partial biotransformation, require serious environmental control, and the implementation of special remediation technologies.

In this regard, a good example is the technology of remediation of soils containing TNT. The technology of soil decontamination was developed with the authors of this book and consists in a combined approach using phytoremediation technologies for soils contaminated with TNT. The essence of this innovative biotechnology is a three-stage process of biological tillage and remediation in the following sequence (Figure 8):

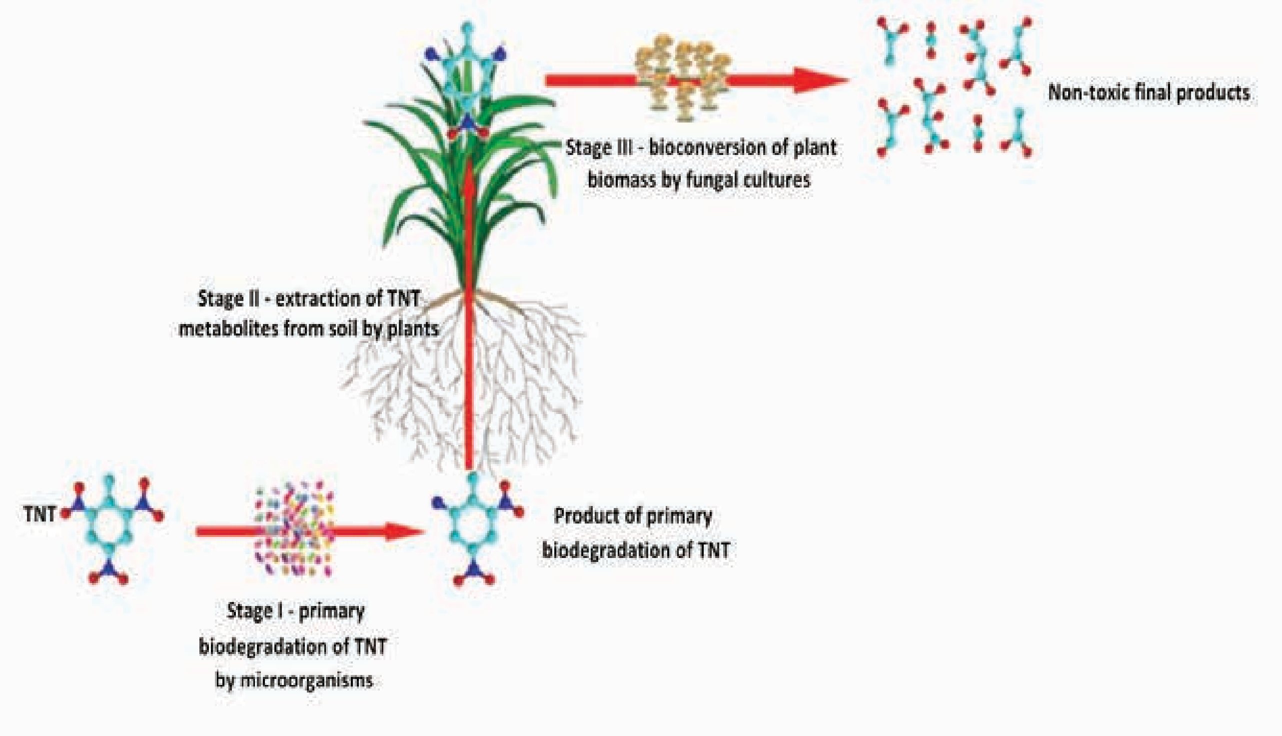


Fig. 8. Scheme of three-stage biotechnology for remediation of soils contaminated with TNT

– at the first stage, specially selected rhizosphere microorganisms are introduced for these purposes, which in the near-root system (rhizosphere forms) carry out the initial transformation of explosives, turning them into relatively less toxic, more hydrophilic compounds that are more easily absorbed and metabolized by plants;

– at the second stage – "extraction" – plants specially selected for this purpose, having a high phytoremediation potential, continue degradation process of explosives, effectively remove the products of partial transformation of explosives from the soil and, ultimately, transform them mainly in the aboveground parts of plants;

– at the third stage – "bioconversion" – plant residues used in phytoremediation are processed by strains of basidial fungi, which completely destroy the carbon carcass of toxic explosive residues, thereby achieving the maximum degree of neutralization of TNT and its partial degradation products by their transformation into non-toxic metabolites.

Highly toxic, soil polluting substances are divided into the following groups according to their intended purpose: pesticides – in agriculture, petroleum products – in chemical and petrochemical industry, construction and machine-building industry, polymer materials – in solvents and dyes, detergents – in car service systems and consumer services, explosives – in military-industrial complex, mining industry, pyrotechnics.

Pesticides are a common name for plant protection chemical products used to control weeds, harmful insects, phytopathogenic fungi and various plant diseases. Most of them have structures responsible for the toxic nature of these compounds. Pesticides include more than 1000 representatives of various classes of chemical compounds. Globally, the production and use of pesticides is measured in hundreds of millions of tons per year, reaching a billion. According to the type of action, pesticides are usually divided into the following groups [14]:

- algicides – used in the fight against algae;
- acaricides – means against ticks;
- atractants – means for luring parasites, insects and rodents;
- bactericides, biocides, disinfectants and sanitizers – are used to destroy microorganisms and, in particular, to protect against bacterial diseases;
- herbicides – for the destruction of weeds and poisonous vegetation;
- desiccants – chemicals that contribute to the drying of the roots of unwanted plants;
- defoliants – to accelerate leaf fall, usually used to facilitate harvesting;
- insecticides – insect repellents;
- molluscicides – to protect underwater surfaces from snails;
- nematocides – used to protect against harmful nematodes, roundworms;
- ovicides – used to destroy insect eggs and worms;
- repellents – repellents that repel pests, including insects (such as mosquitoes) and birds;
- rodenticides – means to control rodents;
- plant growth regulators – changing the rate of growth, flowering and reproduction of plants;
- pheromones – anti-insect breeding agents;
- fumigants – preparations for the destruction of pests in buildings and/or soil;
- fungicides – means to protect against fungal diseases and mold.

Pesticides are classified as inorganic and organic compounds. The vast majority of them are compounds of toxic nature. In order to avoid undesirable long-term effect on the soil, their use should have a limited period, after which they should be biodegraded into composites environmentally harmless components. Because they are structures obtained by chemical synthesis, their biodegradation by hydrolytic and oxidative enzymes of soil microorganisms and the root system of plants is not always feasible. Recently, increased attention has been paid to bio pesticides obtained by microbiological synthesis, biodegradable compounds decomposed much faster by soil microflora.

Among inorganic pesticides, the most common are copper compounds – copper sulfate and basic copper sulfates used in Bordeaux liquid; fluorine – sodium fluoride, sodium, potassium, ammonium, zinc, magnesium silicofluorides; arsenic – arsenate's and arsenates of sodium and calcium, acetate-arsenate of copper (II) – the so-called "Paris greens" (Figure 9), lead hydro arsenate, etc., barium and mercury – in the form of chlorides, etc. In addition, one of the important inorganic pesticides is sulphur and its various compounds. For example, elemental sulphur in finely ground form – the so-called colloidal sulphur is effectively used against herbivorous mites and powdery fungi.

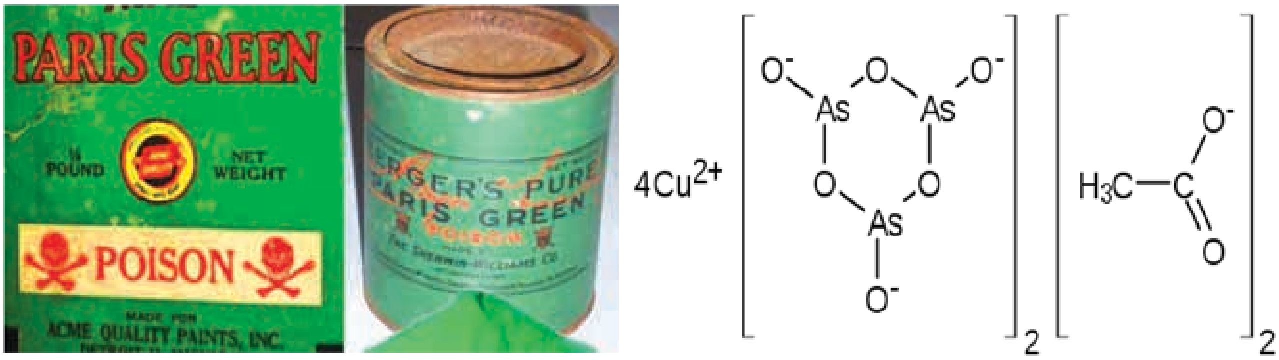


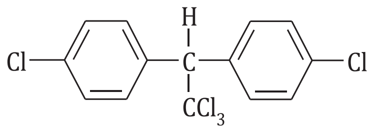
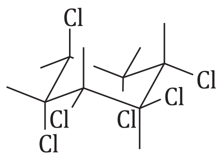
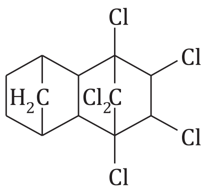
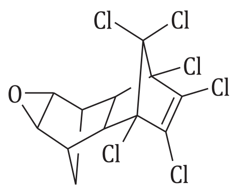
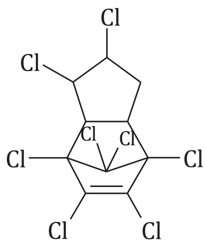
Fig. 9. "Paris green" – acetate-arsenate of copper (II)

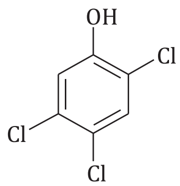
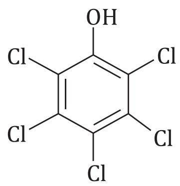
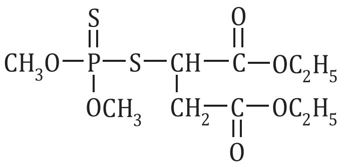
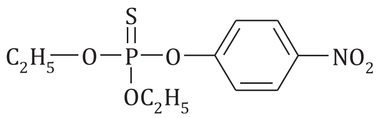
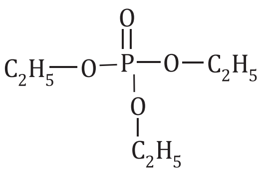
By the nature of the action, pesticides can be contact and systemic ones. Contact pesticides include those that cover the surface of plants and thus protect plants from the action of pests. In most cases, contact pesticides are not able to penetrate the intracellular part of plants. In contrast, systemic pesticides intensively penetrate the intracellular part and are distributed along the entire length of plants, causing lethal action against phytopathogenic insects and microorganisms.

Organic pesticides obtained by chemical synthesis are mainly organochlorine, organophosphorus, organometallic. In some cases, they are classified according to the compound of which they are derivatives: urea, phenoxyacids, bipyridiles, alkaloids – permethrin derivatives – etc. The table below shows the data of the most widely used pesticides (Table 1).

Names, structural formulae and assignment of some of the most common pesticides

Table 1

Name	Assignment	Structural formula and chemical name
1	2	3
Organochlorine compounds		
DDT	Insecticide against mosquitoes, lice, bedbugs and other various harmful insects	 1,1,1-tricolor-2,2-bis (p-chlorophenyl)-ethane
Lindane	Insecticide against pests of cotton, rice, as well as wood-destroying insects	 1,2,3,4,5,6 hexachlorocyclohexane (γ-izomer)
Aldrin	Insecticide against ants, beetles and worms	 1,2,3,4,10,10-hexachloro-1,4,4α,5,8,8α-hexahydro-1,4:5,8-dimethanonaphthalene
Dieldrin	Insecticide of broad spectrum applications	 (1aR,2R,2aS,3S,6R,6aR,7S,7aS)-3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-2,7:3,6-dimethanonaphtho[2,3-b]oxirene
Chlordane (Chlordanes)	Insecticide of broad spectrum applications	 Octachloro-4,7-methanohydroindane

Name	Assignment	Structural formula and chemical name
1	2	3
2,4,5-Tri-chlorophen-oxyacetic acid	Defoliant	 2,4,5-trichlorophenol
PCP **Pentachloro-phenol**	Insecticide of broad spectrum applications	 2,3,4,5,6-pentachlorophenol
Organophosphorus compounds		
Carbophos (Malathion)	Insecticide for destruction of pests of fruit trees, vegetables, ornamental plants and mosquitoes	 O,O-dimethyl-S-(1,2-dicarbethoxyethyl) dithiophosphate
Thiophos (Parathion)	Insecticide of broad spectrum applications	 O,O-Diethyl O-(p-nitro phenyl) nitro phenyl thiophosphate
Triethyl phosphate	Insecticide of broad spectrum applications	 Triethyl phosphate

Anthropogenic pollution of the environment by uncharacteristic gaseous, liquid and solid substances remains an acute environmental problem having priority social and economic importance.

Petroleum products are complex mixtures of gaseous, liquid and solid hydrocarbons and organic compounds of other classes. The main elements determining the chemical composition of oil are carbon – 83-87% and hydrogen – 12-14%. Of the other elements, sulphur, nitrogen and oxygen are included in the composition of oil in certain quantities. Petroleum products, being one of the main pollutants of soil, are very widely used in industry and are represented by various hydrocarbon fractions contained in crude oil. Oil refining products used in various types of economic activity have a wide range.

A number of soil microorganisms – bacteria and mycelial fungi in aqueous solutions decompose oil components into simple hydrocarbons. Heavy oil fractions have increased resistance to the effects of soil microflora, therefore they settle almost unchanged. The predominance of the processes of transformation, migration and accumulation of petroleum products is largely determined by the natural and climatic conditions and the physical-chemical characteristics of the soil itself. When oil enters the soil, deep changes in the chemical, morphological, physical, and microbiological properties of the soil occur, which leads to a significant decrease in fertility, and sometimes to the complete rejection of contaminated areas from agricultural use.

Plants are not always able to carry out the complete oxidative degradation of hydrocarbons during the process of crop formation, what is extremely undesirable, these hydrocarbons or also toxic products of their partial transformation may end up in food products. When hydrocarbons enter the human body, there are lesions of the central nervous system, endocrine system, and cardiovascular system, as well as a decrease in the content of hemoglobin and red blood cells in the blood.

Large-scale use of pesticides causes pollution of soils, groundwater, rivers, lakes, reservoirs, etc. Pesticides and intermediate products of their transformation can get into food products, causing various diseases and pathologies in living organisms.

By the nature of the action, both within structural analogues and interclass representatives, pesticides differ significantly. These differences are manifested at the level of various properties: stability, solubility in water, the possibility of transition to a gaseous state and in the mechanisms of their biological and chemical effects. Usually, pesticides are sprayed on plantations, or agro technically introduced into the soil. In the soil, pesticides are mainly subjected to anaerobic transformations, as a result of these transformations, chlorine atoms are replaced by hydroxyl groups, although this leads to a significant decrease in their biological and toxicological activity.

Especially strong toxicants are organochlorine pesticides, such as DDT, lindane, chlordane, dieldrin, etc. They are able to easily enter the human body, penetrating through the skin or digestive tract, as a result of which they damage the nervous system. DDT is one of the extremely active drugs with insecticidal action. This compound was synthesized in 1874, and since 1930 dye to insecticidal properties were established, its intensive use against the causative agent of malaria, the anopheles mosquito, has been beginning.

2,3,4,5,6-pentachlorophenol is characterized by strong fungicidal, bactericidal and insecticidal properties, which is widely used for indoor treatment. Carbamates are derivatives of carbamic acid have a common formula and belong to pesticides, among which some act as insecticides, fungicides and molluscicides.

Organophosphate pesticides, such as phosphoric and thiophosphoric acid esters, for example, insecticides – alkyl phosphates, parathion, etc., as well as carbamates – herbicides – barban, betanal; fungicide – maneb and others, act on the nervous system by blocking enzymes that regulate the activity of the neurotransmitter – acetylcholine. They are strong inhibitors of acetylcholinesterase. This affects the transmission of a signal to the nerve endings with the acetylcholine receptor. Decrease in the activity of the enzyme leads to the accumulation of acetylcholine, which in turn, depending on the dose of this metabolite, causes signs of diseases such as salivation, pulmonary edema, colic, diarrhea, nausea, visual impairment, increased blood pressure, muscle spasms and convulsions, speech disorders, respiratory paralysis.

Dipyridiles, for example, the herbicide paraquat, already in external contact with the skin causes the formation of blisters and ulcers. When ingested, dipyridyl damages the kidneys and liver, and then causes fibrotic changes in the lungs, leading to death. Due to the high toxicity of dipyridiles, they require extremely careful handling. Pyrethroid pesticides, which are synthetic analogues of the widespread insecticide pyrethrin, a compound isolated from chrysanthemum, also have toxic properties.

Crude oil permanently hundreds of different chemical components, more than 75% of which are hydrocarbons, the rest are various derivatives of hydrocarbons containing sulfur, nitrogen and oxygen. Petroleum hydrocarbons contain paraffin's – 10-30%, cycloparaffins or naphthenes – 30-60%, aromatic and naphthenic-aromatic hydrocarbons – up to 5%.

Hydrocarbons constantly undergo mainly oxidative decomposition as a result of the action of soil microorganisms, as well as due to photo- and chemical oxidation. However, it should be noted that such a taxonomic type of microorganisms has not yet been found, an individual representative of which would have the ability to assimilate all the components of oil. Microorganisms assimilate alkanes easier and faster, and cycloparaffins and aromatic hydrocarbons are much slower to succumb to microbial assimilation.

Complete degradation of oil components is possible only with the participation of individual active representatives of microorganisms of various taxonomic groups – bacteria, fungi, actinobacteria, which is practically impossible regarding a large scale of soils in natural conditions. The microbiological transformation of petroleum hydrocarbons leads to the formation of intermediate compounds, most often having polar functional groups – alcohols, aldehydes and others. Such products of transformation of hydrocarbons in seawater dissolve more easily than the hydrocarbons of oil themselves, and therefore pose a danger to the life of marine organisms that assimilate these compounds. Important factors affecting the processes of microbiological decomposition of oil are temperature and partial pressure of oxygen in water.

Assessing, the state of the soil on a global scale, it should be noted that approximately 40-45% of the world's population lives and works on heavily degraded agricultural land. Restoring soil functionality by increasing organic carbon, removing toxic contaminants, and balancing nutrients will significantly facilitate food security, climate regulation, improve quality and increase the amount of low-salt water, and ensure the biological diversity of the soil cover [15-17].

A number of factors determines the process of remediation of air, water and soil by plants: intensity of light, temperature, composition of soil microorganisms degrading toxic compounds, absorbing heavy metals and participating in the photosynthesis process. The combined action of microorganisms and plants can be represented as a double-barreled ecological weapon that carries out all necessary function of soil and detoxification of nature's ecological niches by various mechanisms. A direct indicator of the ecological state of any large region is the diversity of all forms of microorganisms and all other characteristic for the soil-climatic zone living organisms.

1.5 Water

The technical and technological progress of the past century has created a number of environmental problems, primarily with regard to drinking water, infecting it with uncharacteristic and harmful components. Almost any substance dissolved in water, if it is not a drug or a mixture for technical or agricultural use, is a pollutant. Water is a unique substance with incomparable physicochemical and biological properties. The peculiarity of drinking water is that before it is used, it passes through a number of natural processes, undergoing not only purification, but also enrichment with organic matter and metal ions. Multi-stage natural water treatment is the basis of its usefulness and differences in the chemical composition of drinking water in different geographical and soil-climatic conditions. Water is a mobile and easily infested system with a pronounced set of abnormal properties, depending on the kind of actions of the environment on it. There is no chemically pure water in nature; chemically pure water is obtained by special treatment for the needs of medicine, technical reasons, and scientific research. The term "exclusively" can be applied to water infinitely. It is an exceptional solvent, dissolving the vast majority of substances in any aggregation state: liquid, solid and gaseous. As for harmful and radioactive substances, there are more and more of them all over the planet, which, unfortunately, negatively affects the quality of water.

Living organisms cannot exist without water. Water is a structural component of all cells and tissues. In humans, the water content is about 60% of the total body weight. Water is part of the cytoplasm of cells and tissue fluid. Tissue fluid serves as an intermediary between the cellular elements of the body and blood: cells receive all nutrients from it and transfer metabolic products to it.

Water is an essential component of many metabolic reactions: hydrolysis, oxidation, synthesis, chemical rearrangements, hydration and others. It participates in the implementation of anabolic and catabolic processes, particularly in the cleavage of macromolecules and some other food components, as well as the synthesis of high-molecular and secondary metabolites characteristic of the body using inorganic components. Water is directly involved in many chemical reactions and transformations associated with the functional activity of all components of the cell. Water solubility determines the normal course of cellular metabolism, which is so important for all physiological processes. Together with water, metabolic products formed in cells are transported and excreted from the body. Water is directly involved in the regulation of the body's heat balance – the preservation, distribution and release of heat. Water is an absolutely necessary and irreplaceable component of technological processes in almost all branches of modern industry.

In the XXI century, one of the most important tasks of humanity is the replenishment of drinking water and its rational use. Despite this, more than one third of the world's population is already experiencing a shortage or acute shortage of water. There are reasons for this: water scarcity is primarily caused by unpredictable population growth and, accordingly, a systematic increase in water consumption. Over the past 100 years, the number of countries experiencing water scarcity has exceeded 80 L per day; analysis of data on the daily use of the existing volume of potable water confirms this trend. Already, in some regions of the world, the use of water is on the verge of disaster. A huge number of reservoirs, large and small rivers of all continents contain water that does not correspond to purity, sometimes simply unsuitable for drinking.

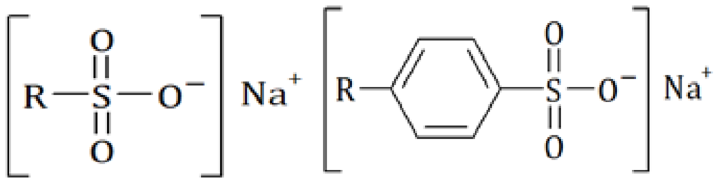
There is still a large water reserve on Earth, exceeding 1400 million km^3. Despite this, the specific volume of fresh water is approximately 35 million km^3, that is, 2.5% of the total supply. In the current situation, desalination of seawater is of particular importance on a global scale. Based on the growth of the world's population, about 100 million people a year, by 2035 the world's population will be about 9 billion people, which obviously is also not the limit. If today the annual water consumption per capita in the whole world is 490 m^3, then due to the expected population growth, a significant replenishment of the fresh water supply will become necessary.

Currently, about 70% of non-infectious diseases are caused by water that does not meet the required standards of cleanliness. Because of long-term observations, it has been established that the main cause of almost 80% of diseases is the use of poor-quality water. Data on the spread of water-borne diseases are as follows: malaria – 800 million patients, trachoma – 500 million, schistosomiasis – 200 million, gastroenteritis – 400 million. Gastroenteritis kills 4 million children and 18 million adults annually. In general, diseases kill 2 billion people, i.e., more than 25% of the world's population, and this is caused by poor-quality water.

Determining the quality of potable water, it should be noted the required presence of a certain part of organic and inorganic chemical elements in the water, which is not always the case. Particular importance is attached to the content of calcium and magnesium salts in drinking water, which determine its hardness, although their maximum permissible doses are standardized by legislation. As for the physiological usefulness of water, the content of calcium in it should be 25-130 mg/l, and magnesium – 5-65 mg/l. With prolonged consumption of highly mineralized waters, urolithiasis, pathologies caused by an imbalance of various types of salts, cardiovascular diseases, hypertension, premature birth, frequent abortions, etc. develop. When consuming water with low mineralization, diseases caused by potassium and magnesium deficiency are noted, which, first, negatively affects the cardiovascular system. In addition, water quality in any part of the world must meet specific characteristics that positively affect human health, and meet organoleptic, chemical and microbiological requirements. The chemical composition of water is very diverse. A small concentration of iron, iodine, zinc, etc., can be detected in water. In addition, there are such undesirable compounds in the water that are in the most of anthropogenic origin.

Water for technical use in industry must also meet specific requirements with respect to possible impurities. The causes of anthropogenic pollution of water bodies and groundwater are wastewater from domestic and industrial sewers containing detergents and disinfectants, and other uncharacteristic components. Water used for agricultural purposes often contains traces of pesticides, fertilizers, insecticides. Detergents include a large group of organic compounds with high surface-active properties, which are substances that pollute water bodies. Surfactants are substances of different chemical classes, which are characterized by the presence of hydrophilic and hydrophobic sites in the structure.

Detergents are divided into three groups – anionic, cationic and neutral surfactants. For example, alkyl sulfonic and aryl sulfonic acids with a hydrophilic group in the form of a sulfuric acid residue belong to anionic surfactants (Figure 10)



Alkyl sulfonic acid Alkyl benzene sulfonic acid

Fig. 10. Alkyl sulfonic acids

Cationic surfactants include alkyl ammonium compounds having a quaternary ammonium group as a hydrophilic site (Figure 11).

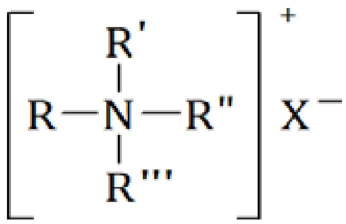


Fig. 11. Alkyl ammonium surfactants. R, R' и R'' – alkyl radicals, R''' – phenyl group, X – anion of halogen or acid residue.

The increased demand for surfactants in industry, as well as their intensive use in everyday life, primarily in the washing process, led to foam accumulations in groundwater, riverbeds and reservoirs. Foam hinders navigation, and the high toxicity of surfactants leads to mass death of fish. The negative experience of the use of surfactants obtained by chemical synthesis forced to resort to the use of such biodegradable surfactants, which are degraded under the influence of biological factors. Relatively easily degradable surfactants include tensides with an unbranched chain, such as detergents of a nonionic nature and alkyl benzenesulfonates, which, in addition, have low toxicity to humans and fish. Biotic decomposition of chains in molecules is carried out by β-oxidation, i.e. cleavage of acetic acid residues.

Insignificant concentration of surfactants in river water – 0.05-0.1 mg/l – is sufficient to activate toxic substances adsorbed on bottom sediments. Water leaked into the soil and accumulations of wastewater containing detergents also leads to the activation of toxic components.

According to the European Union, due to the existing ecological situation, more than 100 thousand species of inhabitants of the seas are on the verge of extinction. All industries – energy, manufacturing, medicine, pharmacology, agriculture, food industry and others – consume a large amount of water. The quality and purity of water in agriculture is also of great importance. A universal requirement for irrigation of plant plantations – fruits, vegetables, cereals – is the use of fresh water, if possible having natural characteristics. At the same time, out of 510 million km^2 of the planet's area, about 360 million km^2 are covered with water. Despite the fact that the land area is almost two and a half times smaller than the water surface, about 11% of the planet is made up of deserts and eroded lands formed due to lack of water resources.

Dozens of technologies have been developed to obtain clean fresh water, among which only a few that find practical application, and on a small scale, can be distinguished. Thus, membrane technologies for the production of clean water are of interest, the large-scale application of which, unfortunately, has not yet been implemented due to the technical difficulties of the production process. In addition, mechanical and biological filters have been created to purify water for various needs. On a non-industrial scale, purification technologies based on electrolysis and other processes are used, the efficiency of which is quite high, but does not fully provide desalination of seawater.

In some Arabic countries, the people over 80% of drinkable water use desalinated seawater being treated in special membranes and after added some regular salts, characteristic for drinkable water. Despite many attempts, it has not yet been possible to develop a cost-effective large-scale technology for desalination of salt water, which would solve the problems of desertification of a large part of the planet, agriculture, healthcare, food supply to the population and, at the same time, the ecological situation overall planet would significantly improve. The fact of dehydration and disturbance of the ecological balance is the drying up of the Aral Sea, whose area 30 years ago was 58 thousand km^2. Today, the total area of all the individual residual lakes of this sea taken together is approximately 7 thousand km^2 – 8% of the total area of the Aral Sea. The bottom of the dried sea is a mixture of dry salts, pesticides and other chemicals. In conditions of high temperatures up to 45 and reaching 50 °C, the mixture is transported by existing dry hurricanes in the region over long distances – 400-500 km, which poses a serious environmental threat to the countries of Central Asia. The Aral Sea is not the only example of complete desertification and the transformation of large natural resources into a useless territory due to lack of water.

Based on the acute shortage of water, it should be emphasized that the lack of cheap large–scale industrial technology for desalination of seawater is one of the most important problems of the world level. In order to obtain fresh water, several technologies have already been developed and applied – distillation, electro dialysis, ion exchange, freezing and reverse osmosis. Summing up the above, it can confidently conclude that the shortage of fresh water is already a problem for all humanity, and in the near future, this problem will significantly worsen.

There are new views on water purification that have not yet been widely recognized, among which the so-called electro plasma technologies should be noted, which have a significant advantage over many existing traditional methods. These are physical methods that use electric and magnetic fields. As a result of the action of both individual factors and synergistic effects on water flows, disinfected fresh water is obtained at the output of the technological complex. The main advantages of the electro plasma method over others: versatility, high degree of purification from microflora and organic pollutants in comparison with other methods, high degree of desalination of the water flow.

It should be noted that all existing water desalination technologies have a specific scope of application. However, these technologies do not solve the main problem of obtaining clean, potable water in the quantity required for humanity. Given the increasing need for potable water in the conditions of today's unpredictable population, it is obvious that the potential of existing water purification technologies is still clearly insufficient.

Many indicators control potable water. However, the spectrum of possible impurities, even after water purification, in some cases remains quite diverse. The history of drinking water use is replete with cases of mass outbreak of infectious diseases of people with fatal outcomes. Therefore, in the water treatment system, technologies are very important, the purpose of which is to remove chemical and biological factors infecting water: disinfection of water by chemical technologies and removal of pathogenic bacteria, mycelial fungal spores and viruses from the water, etc. For these purposes, chlorine and ozone are most often used, which, in addition to their main purpose – disinfection of water, enter into physical-chemical interaction with the residues of humic acids, petroleum products, detergents, pesticides and some other chemicals dissolved in water, forming uncharacteristic substances such as chlorine-phosphorus-nitrogen organics and even a number of dioxin-like compounds. These substances contained in drinking water in homeopathic concentrations are mutagenic and carcinogenic. There are more than 2000 such compounds. Reliable, relatively cheap methods of removing all chemical and biological factors polluting water from potable water do not yet exist. The WHO has begun to pay increased attention to the problem of mutagenicity and carcinogenicity of potable water due to the growth of oncological and hereditary diseases. Recent studies have proved that even a minor manifestation of mutagenicity of potable water, is the main cause, firstly, of such severe and fatal diseases as cancer, atherosclerosis, cerebral vascular sclerosis and others, as well as irreversible damage to the gene pool. There is an assumption that it is not enough to purify water from foreign compounds, because water has a homeopathic memory effect, i.e., the ability to preserve a trace of effects on its molecular structure. The probability of the importance of such an assumption further complicates the problems associated with obtaining adequate potable water.

Many existing companies, scientific groups, individuals, involved in water science are now concentrated in the problem of developing an industrial, economically acceptable technology for seawater purification in order to turn it into drinking water, as close as possible to the characteristics of pure natural water. This required an in-depth study of numerous scientific sources, analysis of modern concepts of physics, chemistry and biology of water; it was necessary to revise the modern theory of drinking water, analyze numerous designs and experimental industrial developments. Unfortunately, despite certain successes, it has to be stated that the problems with the creation of technologies for large-scale production of potable water in an amount that provides the satisfaction of the growing population of the planet have not yet been solved.

Summing up this chapter, we can emphasize the following. Pollution of certain regions of the planet with heavy metals and organic toxicants occurs unevenly. There are environmentally safe countries in the world, for example, Canada, Sweden, Finland, Switzerland, Scotland, Norway, Iceland and some others. The ecology of the other countries can be assessed as small, medium and heavily polluted areas. Even in the Arctic conditions – in the soil, fish, birds, seals and other animals – the presence of toxic compounds of an anthropogenic nature has been established, which once again indicates the universal spread of toxicity on a global scale.

It should be taken into account that the ecological condition of the Earth is already in a difficult situation, burdened by unnatural negative factors, as indicated by at least the process of global warming which has already caused an increase in ocean levels, a number of infectious diseases, etc. The complication of the ecological situation is indicated by frequent mudflows, abnormally high temperatures in different regions and droughts. The current situation requires special attention at all stages of human activity and this, in turn, requires the search for new approaches to solving vital problems. In the current situation, it is undoubtedly, vitally important to develop qualitatively new large-scale technologies related to the desalination of seawater.

1.6 Resource capacity of the planet

Ecology, nature usage, renewable and non-renewable resources of the planet, their long-term existence in the conditions of modern, permanently increasing scale of their usage – this is a list of the most vitally important problems of today. The geological potential of the planet's minerals, the foundations of our existence in the XX-XXI centuries, has been studied in such detail that it allows us to accurately assess their longevity, which determines the prosperous existence of *Homo sapiens*. As the analysis of the available capacity of natural resources shows (Tables 2, 2.1), it is already quite limited, especially according to the stereotype of life to which the world community is exposed today. Surprisingly, despite the exceptional importance of the problem, the global world community does not assess the severity of the planet's depleted resources and judges them exclusively in a consumer way.

Having neither political, nor confessional, nor any other criterion, the problems of maintaining homeostatic balance in nature, associated with the inevitable exhaustion of its resources and the increase in toxicism (content of toxic compounds) of all ecological niches, are very far from being resolved today. It is particularly surprising that so far they have not become the subject of international discussion. Certainly, it is very difficult to comprehend all the attractors of a complex system, which is wildlife in all its diversity. However, truly amazing is the carelessness with which a person consumeristic ally looks at the degradation and destruction of the biological foundations of life – the mother's womb of his being! In order not to turn into humanoid carriers of artificial intelligence, the primary task is not only scientific monitoring of the ecological balance of the planet and maintaining an acceptable level of its self-reproduction, but also painstaking educational work with the mass awareness aimed at loosening the consumer temptations of post-industrial society. The need for a thrifty attitude to the environment, conscious consumer self-restraint, put under the control of reason and conscience, has become an urgent task of our time. This part of the monograph is devoted to the discussion of this range of issues, with an appeal to everyone who cares about it.

The materials presented in the monograph encourage reflection on the existential choice of mankind: overconsumption or conservation of the natural foundations of their being?! With the current level of consumption, characteristic of the countries of the "golden billion", drinkable water or a breath of fresh air will become a colossal problem for our grandchildren . . . If we don't learn to curb our consumer appetites, such a "war against all" (T. Hobbs) awaits us in several decades. Today, it is necessary to study the planet's resource potential in detail, and to make a choice: what should the citizen of the Earth strive for?

The fate of the planet and humanity still can be changed to a better way of being. There is an urgent need to start a scientific search and creation of environmentally friendly technologies and extremely lean and rational use of the planet's resources.

The colossal consumption of electricity and water, increase in the volume of garbage, household waste, the growth of unsanitary conditions, the shortage of food, the growing conflict of interests among all social strata of the population, the degradation of personality, the lack of equal conditions for nutrition, education, treatment, along with the colossal wealth of a small part of society... However, this is precisely the picture that has emerged on our planet now. Humanity must seek for new answers to everyday problems. Obviously, it is critical that every interested inhabitant of the planet has an objective concept of how long it is feasible to live in the manner of

Homo consúmens, the direct inheritor of *Homo sapiens*. At the same time, it should be mentioned that overconsumption of everything has led to the depletion of the planet's natural resources, as indicated by the data in Tables 2 and 3 below.

Resource availability of the planet with minerals

Table 2

Resource	Global reserves		Current consumption (2021)	Resource availability, period, years	
	Unit of measurement	Quantity		Considering current consumption level	Considering projected consumption level (Table 2.1)
1	2	3	4	5	6
Oil	bln tons	225	4,80	47	**30 - 33**
Coal	bln tons	1030	7,43	138	**48 - 50**
Natural gas	trln m^3	188,1	4,20	45	**33 - 36**
Iron	bln tons	84	2,10	40	**21 - 23**
Manganese	mln ton	1300	19,4	67	**33 - 35**
Gold	T ton	53	3,20	17	**12 - 14**
Silver	T ton	530	26,02	20	**12 - 14**
Copper	mln ton	2100	24,99	84	**45 - 47**
Nickel	mln ton	94	2,57	36,5	**18 - 20**
Lead	mln ton	95	4,70	20	**15 - 17**
Zinc	mln ton	250	12,8	19,5	**15 - 17**
Wood	bln m^3	365	5,60	65	**36 - 38**
Wolfram	mln ton	3,4	0,0915	37	**21 - 23**
Molybdenum	mln ton	18	0,3	60	**36 - 38**
Antimony	mln ton	1,5	0,153	10	**6 - 8**
Bismuth	T ton	680	19	36	**21 - 23**
Tin	mln ton	15,4	0,31	50	**33 - 35**
Cobalt	mln ton	7	0,140	50	**18 - 20**
Uranium	T ton	8 070,4	74,019	109	**48 - 50**

[1] - Data on minerals and their consumption according to the US Geological Survey https://pubs.usgs.gov/periodicals/mcs2021/mcs2021.pdf

Undoubtedly, all these data relate to the lithosphere – the upper part of the planet. There are undoubtedly mineral resources in the bowels of the earth that, due to the lack of appropriate technologies for their extraction, are not available for use in industrial processes.

Prognosis of mineral consumption considering population growth

Table 3

Name of the resource	Indicators	Period					
		2022-2024	2025-2027	2028-2030	2031-2033	2034-2036	2037-2039
Oil	**Consumption volume, bln tons**	14,99	15,91	16,89	17,92	19,02	20,18
	Growth* %		6.14%	6.16%	6.10%	6.12%	6.10%
	Remaining reserves, bln tons	210,01	194,1	177,21	159,29	140,27	120,09
Coal	**Consumption volume, bln tons**	22,75	23,98	25,81	27,07	28,87	30,16
	Growth%		5.41%	7.63%	4.88%	6.65%	4.47%
	Remaining reserves, bln tons	1007,25	983,27	957,46	930,39	901,52	871,36
Natural gas	**Consumption volume, trln m^3**	12,93	13,54	14,14	14,76	15,41	16,08
	Growth%		4.72%	4.43%	4.38%	4.40%	4.35%
	Remaining reserves, trln m^3	175,17	161,63	147,49	132,73	117,32	101,24
Iron	**Consumption volume, bln tons**	6,96	8,1	9,93	11,61	13,47	15,64
	Growth%		16.38%	22.59%	16.91%	16.02%	16.11%
	Remaining reserves, bln tons	77,04	68,94	59,01	47,40	33,93	18,29
Manganese	**Consumption volume, mln tons**	62,50	69,49	77,26	85,91	95,52	106,21
	Growth%		11.18%	11.18%	11.19%	11.18%	11.19%
	Remaining reserves, mln tons	1237,5	1168,01	1090,75	1004,84	909,32	803,11
Gold	**Consumption volume, T tons**	10,20	11,10	12,20	13,30	6,20	
	Growth%		8.8%	9.9%	9%		
	Consumption volume, T tons	42,8	31,7	19,5	6,2	0	
Silver	**Consumption volume, T tons**	87,6	104,14	123,68	146,89	67,69	
	Growth%		18.88%	18.76%	18.77%		
	Remaining reserves, T tons	442,4	338,26	214,58	67,69	0	
Copper	**Consumption volume, mln tons**	78,78	84,91	91,31	98,04	105,58	113,70
	Growth%		7.78%	7.54%	7.37%	7.69%	7.69%
	Remaining reserves, T tons	2021,22	1936,31	1845	1746,96	1641,38	1527,68
Nickel	**Consumption volume, mln tons**	9,34	11,25	12,97	14,38	15,80	17,36
	Growth%		20.45%	15.28%	10.87%	9.87%	9.87
	Remaining reserves, mln tons	84,66	73,41	60,44	46,06	30,26	12,9

Lead	**Consumption volume, mln tons**	14,82	15,99	17,22	18,54	19,96	8,47
	Growth%		7.89%	7.69%	7.66%	7.65%	
	Remaining reserves, mln tons	80,18	64,19	46,97	28,43	8,47	0
Zinc	**Consumption volume, mln tons**	39,96	42,50	44,99	47,76	50,68	24,11
	Growth%		6.35%	5.85%	6.15%	6.11%	
	Remaining reserves, mln tons	210,04	167,54	122,55	74,79	24,11	0
Wood	**Consumption volume, bln m^3**	18,01	19,31	20,70	22,19	23,79	25,51
	Growth%		7.21%	7.19%	7.19%	7.21%	7.22%
	Remaining reserves, bln m^3	346,99	327,68	306,98	284,79	261	235,49
Wol-fram	**Consumption volume, mln tons**	0,30	0,35	0,40	0,46	0,53	0,61
	Growth%		16.67%	14.29%	15.00%	15.22%	15.09%
	Remaining reserves, mln tons	3,10	2,75	2,35	1,89	1,36	0,75
Molyb-denum	**Consumption volume, mln tons**	0,94	1,00	1,07	1,14	1,22	1,30
	Growth%		6.38%	7.00%	6.54%	7.02%	6.56%
	Remaining reserves, mln tons	17,06	16,06	14,99	13,85	12,63	11,33
Anti-mony	**Consumption volume, mln tons**	0,49	0,51	0,49			
	Growth%		4.08%				
	Remaining reserves, mln tons	1,01	0,493	0			
Bismuth	**Consumption volume, T tons**	61,20	68,05	75,67	84,14	93,56	104,03
	Growth%		11.19%	11.20%	11.19%	11.20%	11.19%
	Remaining reserves, T tons	618,8	550,75	475,08	390,94	297,38	193,35
Tin	**Consumption volume, mln tons**	0,97	1,03	1,09	1,16	1,23	1,30
	Growth%		6.19%	5.83%	6.42%	6.03%	5.69%
	Remaining reserves, mln tons	14,43	13,40	12,31	11,15	9,92	8,62
Cobalt	**Consumption volume, mln tons**	0,49	0,61	0,76	0,94	1,17	1,46
	Growth%		24,49%	24,59%	23,68%	24,47%	24,79%
	Remaining reserves, mln tons	6,51	5,9	5,14	4,2	3,03	1,57
Ura-nium	**Consumption volume, T tons**	234,22	253,64	274,66	297,42	322,07	348,77
	Growth%		8.29%	8.29%	8,29%	8,29%	8,29%
	Remaining reserves, mln tons	7836,18	7582,54	7307,88	7010,46	6688,39	6339,62

* GROWTH PERCENTAGE IS CALCULATED IN RELATION TO THE PREVIOUS PERIOD

Name of the resource	Indicators	Period					
		2040-2042	2043-2045	2046-2048	2049-2051	2052-2054	2055-2057
Oil	**Consumption volume, bln tons**	21,42	22,73	24,12	25,60	26,22	
	Growth%	6.14%	6.12%	6.11%	6.15%		
	Remaining reserves, bln tons	98,67	75,94	51,82	26,22	0	
Coal	**Consumption volume, bln tons тонн**	31,93	33,26	34,99	36,35	38,05	80,63
	Growth%	5.87%	4.17%	5.20%	3.89%	4.68%	111.91%
	Remaining reserves, bln tons	839,43	806,17	771,18	734,83	696,78	616,12
Natural gas	**Consumption volume, trln m^3**	16,80	17,53	18,31	19,11	19,96	9,53
	Growth%	4.48%	4.35%	4.45%	4.37%	4.45%	
	Remaining reserves, trln m^3	84,44	66,91	48,6	29,49	9,53	0
Iron	**Consumption volume, bln tons**	18,16	0,13				
	Growth%	16.11%					
	Remaining reserves, bln tons	0,13	0				
Manganese	**Consumption volume, bln tons**	118,09	131,31	145,99	162,34	180,51	64,87
	Growth%	11.18%	11.19%	11.17%	11.19%	11.19%	
	Remaining reserves, mln tons	685,02	553,71	407,72	245,38	64,87	0
Gold	**Consumption volume, T tons**						
	Growth%						
	Remaining reserves, T tons						
Silver	**Consumption volume, T tons**						
	Growth%						
	Remaining reserves, T tons						
Copper	**Consumption volume, mln tons**	122,44	131,86	141,99	152,91	164,67	177,32
	Growth%	7.68%	7.69%	7.68%	7.69%	7.69%	7.68%
	Remaining reserves, mln tons	1405,24	1273,38	1131,39	978,48	813,81	636,49
Nickel	**Consumption volume, mln tons**	12,9					
	Growth%						
	Remaining reserves, mln tons	0					

Lead	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Zinc	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Wood	**Consumption volume, bln m³**	27,35	29,32	31,43	33,64	36,03	38,62
	Growth%	7.21%	7.20%	7.19%	7.03%	7.10%	7.18%
	Remaining reserves, bln m³	208,14	178,82	147,39	113,75	77,72	39,10
Wol-fram	**Consumption volume, mln tons**	0,70	0,05				
	Growth%	14.75%					
	Remaining reserves, mln tons	0,05	0				
Molyb-denum	**Consumption volume, mln tons**	1,39	1,48	1,59	1,69	1,81	1,93
	Growth%	6.92%	6.47%	7.43%	6.29%	7.10%	6.63%
	Remaining reserves, mln tons	9,94	8,46	6,87	5,18	3,37	1,44
Anti-mony	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Bis-muth	**Consumption volume, T tons**	115,67	77,67				
	Growth%	11.19%					
	Remaining reserves, T tons	77,68	0				
Tin	**Consumption volume, mln tons**	1,38	1,47	1,56	1,65	1,75	0,81
	Growth%	6.15%	6.52%	6.12%	5.77%	6.06%	
	Remaining reserves, mln tons	7,24	5,77	4,21	2,56	0,81	0
Cobalt	**Consumption volume, mln tons**	1,57					
	Growth%						
	Remaining reserves, mln tons	0					
Ura-nium	**Consumption volume, T tons**	377,68	408,99	442,89	479,60	519,35	562,40
	Growth%	8,29%	8.29%	8.29%	8,29%	8,29%	8,29%
	Remaining reserves, mln tons	5961,94	5552,95	5110,06	4630,46	4111,11	3548,71

Oil	**Consumption volume, bln tons**						
	Growth%						
	Remaining reserves, bln tons						
Coal	**Consumption volume, bln tons**	113,78	119,14	124,95	130,79	127,46	
	Growth%	41.11%	4.71%	4.87%	4.67%		
	Remaining reserves, bln tons	502,34	382,20	258,25	127,46	0	
Natu-ral gas	**Consumption volume, bln tons**						
	Growth%						
	Remaining reserves, bln tons						
Fer-rum	**Consumption volume, bln tons**						
	Growth%						
	Remaining reserves, bln tons						
Man-ganese	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Gold	**Consumption volume, T tons**						
	Growth%						
	Remaining reserves, T tons						
Silver	**Consumption volume, T ton**						
	Growth%						
	Remaining reserves, T tons						
Cop-per	**Consumption volume, mln tons**	190,95	205,63	221,44	18,47		
	Growth%	7.68%	7.68%	7.68%			
	Remaining reserves, mln tons	445,54	239,91	18,47	0		
Nickel	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Lead	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						

Zinc	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Wood	**Consumption volume, bln m³**	39,10					
	Growth%						
	Remaining reserves, bln m³	0					
Wol-fram	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Mo-lybde-num	**Consumption volume, mln tons**	1,44					
	Growth%						
	Remaining reserves, mln tons	0					
Anti-mony	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Bis-muth	**Consumption volume, T tons**						
	Growth%						
	Remaining reserves, T tons						
Tin	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Cobalt	**Consumption volume, mln tons**						
	Growth%						
	Remaining reserves, mln tons						
Ura-nium	**Consumption volume, T tons**	609,02	659,50	714,16	773,35	792,68	
	Growth%	8,29%	8.29%	8.29%	8,29%		
	Remaining reserves, mln tons	2939,69	2280,19	1566,03	792,68	0	

Initial data for the projected growth in percentage (%):

- Organization of the Petroleum Exporting Countries (OPEC) (https://www.opec.org/opec_web/en/998.htm#:~:text=By%202025%2C%20the%20share%20of,at%20about%2028%20per%20cent).
- International Energy Agency (https://www.iea.org/data-and-statistics/charts/changes-in-global-coal-consumption-by-region-2018-2025)
- Analytical and consulting organizations: Coherent Market Insights (https://www.coherentmarketinsights.com /), Market Insight Reports (https://www.marketinsightsreports.com /)

The above data in Tables 2 and 2.1, **indicating the forecast of mineral consumption taking into account the growth of the world's population**, are the result of long-term observations and analysis. The work uses numerous literature data, reports of international organizations, consultations with experts in this field. Relying on the reliability, they can be used as a basis for further discussions about the possible prospects that await *Homo sapiens* both in the near and somewhat distant future.

According to the current situation in the world, over the past 150 years, oil hydrocarbons have been the most important source of energy. The share of hydrocarbons in the structure of global energy demand remains predominant today (at least 80%). Hydrocarbons are still one of the main sources of fuel and electricity. The operation of most industrial enterprises is based on the use of hydrocarbons, including the extraction of raw materials for industry (ferrous and non-ferrous metal ores, rare earth metals, inert materials, etc.). At the same time, it should be noted that the hydrocarbons themselves and other products created on their basis are characterized by high toxicity and carcinogenicity. Along with the non-renewable nature of petroleum hydrocarbons, this very serious reason and the main basis for intensive search for new alternative energy sources.

Hydrocarbons:

The Oil

Currently, oil provides about 33% of the world's energy needs. Crude oil refining products, such as gasoline, diesel fuel, kerosene, are used in almost all types of transport. According to existing data, in the event of depletion of oil reserves and the absence of an alternative source, humanity will face serious problems, which may lead to the restructuring of international logistics.

Coal

Currently, coal provides 30% of the world's energy needs. Accordingly, without coal, a 30% shortage of electricity in the world is not avoidable, which so far there is nothing to replace. Especially considering that, gas and oil reserves will run out before coal reserves. Significant depletion of coal reserves is expected in about 50 years.

Natural gas

Currently, natural gas provides more than 20% of the world's energy needs. It is used as fuel for vehicles (so far on a small scale) and in the chemical industry in the production of plastics and other organic compounds. The resource availability of natural gas is less than 40 years.

Iron (iron ore)

The percentage of use of scrap iron in the world as a source of raw materials reaches 40%. The reason is the depletion of iron ore deposits. The resource availability of iron ore is just over 20 years.

Manganese

Almost 90% of all metal is used in ferrous metallurgy, in the manufacture of alloy of manganese, copper and nickel. The resource of manganese will end in less than 40 years.

Gold

The depletion of gold will actually lead to a complete loss of the jewelry market. It will also affect the chemical industry, electronics and the production of measuring instruments, aviation and the space industry.

The gold resource of the planet due existence of additional, numerous poor deposits is difficult to calculate, although, according to some calculations, it is determined for a period of 15-20 years.

Silver

In addition to its use of silver in the jewelry industry, it is used in food, chemical, electrical engineering, medicine, the production of batteries and solar panels. The silver resource of the planet is presumably designed for a period of up to 50 years.

Copper

The main use of copper is the production of wires, cables, network conductors, power transmission lines. The high electrical conductivity of copper is the main property determining its preferential use. The lack of copper casts doubts overall world green economy. Copper is also needed in the production of alternatives to internal combustion engines – electric vehicles. The resource availability of copper is up to 50 years.

Nickel

The main field of application of nickel is metallurgy. The lack of nickel will lead to problems in the metallurgical industry. The depletion period is not more than 20 years.

Lead

Up to 45% of lead goes to the manufacture of lead-acid battery plates, which are used in all road transport.

A shortage of lead will lead to an avoidable crisis in the motor-car industry.

Resource availability is no more than 20 years.

Zinc

The main field of application of zinc is metallurgy. As in the case of manganese and nickel, the absence of this metal will lead to difficulties in the metallurgical industry. The medical industry uses 10% of total zinc. The resource availability is up to 20 years.

Wood

The depletion of the lignocellulose substrates (biomass) will lead to serious environmental problems: soil erosion, decrease in the water content of rivers, and, undoubtedly, to a shortage of clean potable water. The annual fixation of molecular carbon dioxide, on a global scale, is at least 160 billion tons of renewable biomass. The reduction of woody, as well as shrubby and annual plants will certainly enhance the formation of the greenhouse effect and, in general, will have a negative effect on the immune system of the whole nature. According to the latest estimates, there are now 3.04 trillion trees on the planet. So far there are 380 trees per person in the world. Taking into account the projected consumption, the wood stock is calculated up to 40 years.

Wolfram

Wolfram is mainly used in metallurgy and mechanical engineering. Based on the special hardness of this metal, medical instruments and special instruments requiring high strength (drills) are made from tungsten alloys. Resource availability – up to 25 years.

Molybdenum

Mainly is used in metallurgy, aerospace industry, production of nuclear engineering structures. For the manufacturing of the coating and frame elements of supersonic aircraft and rockets, heat exchangers, shells of rockets and capsules returning to earth, heat shields. Resource availability – up to 40 years.

Antimony

Is a composing part of almost 200 different types of alloys? The bulk of the antimony produced goes to the production of solid lead for the production of plates and batteries. Resource availability – up to 10 years.

Bismuth

The main user of bismuth is metallurgy. Bismuth is in high demand in the production of aluminum, mainly for the aviation industry. Resource availability – up to 25 years.

Tin

Most of the smelted tin is used in metallurgy. The alloys are used for the production of packaging foil, and white food tin – the main source of food storage containers (canned food). Resource availability – up to 35 years.

Cobalt

Cobalt mainly is used in metallurgy. In agriculture, veterinary medicine and pharmaceuticals, it is an important component of fertilizers, feed additives for livestock, animals, bees, and number of medicines. Resource availability – up to 20 years.

Uranium

Metallic uranium or its compounds are mainly used as nuclear fuel in nuclear reactors. The resource availability of uranium is up to 50 years.

These characteristics more or less correspond of the world stock of mineral resources of the planet available to humanity. The amount of some, undoubtedly contained in the bowels of the earth, has not yet been estimated due to the lack of appropriate technologies; although there is no doubt that, there are substantial amounts of mineral resources in the deep layers of the planet. Of course, there are inexhaustible sources of energy, such as solar, wind energy, river energy, etc. There are alternative energy sources: wind farms, solar panels, hydroelectric power plants, the role of which is constantly increasing. The only way that could make up for the necessary shortage of hydrocarbons and uranium is thermonuclear fusion. The main fuel for this process – hydrogen is quite dangerous – an inexhaustible resource of our planet. According to British Petroleum (Statistical Review of World Energy 2022), by the end of 2021, the world's electricity production is 28466.3 terawatts (TW) – an average of 3.6 megawatts (MW) per person, 9.9 kilowatts (kW) per day.

Of particular concern is the ever-increasing shortage of potable water. In recent decades, the shortage of fresh water has arisen in regions where it was previously nonexistent and is permanently enhancing everywhere, for example, in China, Egypt, etc [30]. https://www.bloomberg.com/opinion/articles/2021-12-29/china-s-water-shortage-is-scary-for-india-thailand-vietnam, https://ecfr.eu/article/commentary_the_end_is_nile_international_cooperation_on_egypts_water_crisis/.

The obvious reason is increase in water consumption by an unpredictably growing population and economy. However, an alarming fact is that fresh water of the appropriate drinking quality is becoming less not only in relative, but also in absolute quantity. This extremely serious circumstance, for unknown reasons, remains without appropriate attention There are many reasons for water shortage: for example, according to some reports, in Europe, water scarcity occurs due to climate change. https://www.ft.com/content/887170b2-99ed-4c78-96a0-f40273cadc10).

Climate change as a result of anthropogenic human activity, increased toxicity in all ecological niches, the growth of the world's population, uncontrolled urbanization and irrational land use have a catastrophic impact on the reduction of the world's reserves of clean fresh water, and in fact – lead to the destruction of freshwater ecosystems. (UN Water Resources Database AQUESTA, http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en).

Below are presented the data of the world's potable water reserves compiled by the authors over many years (Table 4, 5).

Period of depletion of the available world reserves of clean potable water

Table 4

Continent	Rate of freshwater pollution, billion m^3/year	Total available fresh water reserves, billion m^3/year	Period of depletion of clean drinking water reserves, years
North America	93,7	7117,8	76
Latin America	130,3	17974,7	137,9
Europe	92	7851,1	72,5
Caribbean basin	16,4	98,4	6
Sub-Saharan Africa	74,1	5477,2	73,9
Asia	1453,6	14120,1	9,7
Oceania	5,7	1648,6	290
Middle East and North Africa	190,7	411,1	2,2

Period of depletion of the available world reserves of clean potable water of individual countries

Table 5

Assessment of the depletion period of available fresh water reserves by country							
Name of the country	Total available water resources, billion m^3	Fresh water consumption, billion m^3/year			Volume of purification of consumed fresh water, %	Volume of polluted fresh water, billion m^3/year	Period of depletion of clean fresh water reserves (gr.2/gr.7), years
		Water treatment	Direct source	Total			
1	2	3	4	5	6	7	8
Kuwait	0	0,8	0	0,8	84,7	0,12	0
Libya	0,7	0,15	5,5	5,7	16,6	4,75	0,1
Saudi Arabia	2,4	12,7	8,5	21,2	80	4,24	0,6
Barbados	0,08	0,03	0,07	0,1	2,8	0,097	0,8

Yemen	2,1	0,1	3,5	3,6	34,4	2,36	0,9
Turkmenistan	24,8	1,6	26,3	27,9	14,8	23,77	1,0
Uzbekistan	48,9	4,5	54,4	58,9	32,3	39,88	1,2
Pakistan	246,8	12	188	200	1	198,00	1,2
UAE	0,15	0,5	2,1	2,6	95,9	0,11	1,4
Sudan	37,8	1,1	25,8	26,9	3,4	25,99	1,5
Egypt	58	13,4	50,8	64,2	45,5	34,99	1,7
Iran	137	9,3	83,7	93	22,1	72,45	1,9
Palestine	0,812	0,19	0,21	0,4	6,33	0,37	2,2
Syria	16,8	2,2	11,8	14	45,2	7,67	2,2
Tunisia	4,6	1,1	3,7	4,8	59,7	1,93	2,4
Tadjikistan	21,9	0,9	9,5	10,4	13,3	9,02	2,4
Saint Kitts and Nevis	0,024	0,001	0,009	0,01	25,9	0,007	3,2
Dominican Republic	23,5	1,5	7,6	9,1	20,4	7,24	3,2
Afghanistan	65,3	0,4	19,9	20,3	5,7	19,14	3,4
Iraq	89,9	2,7	35,8	38,5	37,1	24,22	3,7
Kyrgyzstan	23,6	0,6	7,1	7,7	18,9	6,24	3,8
India	1911	62,2	585,3	647,5	26,6	475,27	4,0
Sri Lanka	52,8	1,6	11,3	12,9	1,3	12,73	4,1
Morocco	29	1,4	9,2	10,6	36,1	6,77	4,3
Armenia	7,8	0,8	2,1	2,9	40,1	1,74	4,5
Lebanon	4,5	1,1	0,7	1,8	45,7	0,98	4,6
Somalia	14,7	0,1	3,2	3,3	10,5	2,95	5,0
Eswatini	4,5	0,1	1	1,1	17,9	0,90	5,0
Algeria	11,7	3,6	6,2	9,8	76,2	2,33	5,0
Maldives	0,03	0,009	0,001	0,01	41,7	0,006	5,1
Jordan	0,9	0,5	0,4	0,9	82	0,16	5,6
Azerbaijan	34,7	3,5	9,3	12,8	57,4	5,45	6,4
Cuba	38,12	2,5	4,5	7	18,9	5,68	6,7
South AFRICA	51,4	8	11,4	19,4	61,3	7,51	6,8
Northern Macedonia	6,4	0,6	0,4	1	9,1	0,91	7,0
Kazakhstan	108,4	8,6	13,9	22,5	35,7	14,47	7,5
Mauritius	2,8	0,3	0,3	0,6	38	0,37	7,5
East Timor	8,215	0,1	1,1	1,2	12,7	1,05	7,8
Zimbabwe	20	0,6	2,7	3,3	23	2,54	7,9
Kenya	30,7	0,8	3,2	4	9,4	3,62	8,5
Jamaica	10,82	1,3	0,1	1,4	13,7	1,21	9,0
Philippines	479	25	67,8	92,8	42,9	52,99	9,0
North KOREA	77,2	2,1	6,6	8,7	7,2	8,07	9,6
Turkey	211,6	9,1	50,9	60	63,3	22,02	9,6
Saint Lucia	0,3	0,01	0,03	0,04	24,1	0,03	9,9

Mauritania	11,4	0,1	1,2	1,3	12,3	1,14	10,0
Thailand	438,6	5,7	51,6	57,3	24,4	43,32	10,1
Haiti	14	0,2	1,3	1,5	10,7	1,34	10,5
Bahrain	0,1	0,17	0,03	0,2	95,6	0,009	11,4
Puerto Rico	7,1	0,87	0,03	0,9	32,5	0,61	11,7
Indonesia	2019	32,9	189,7	222,6	24,6	167,84	12,0
Cyprus	0,79	0,1	0,1	0,2	67,2	0,07	12,0
Dominika	0,2	0,019	0,001	0,02	18,2	0,016	12,2
Saint Vincent and the Grenadines	0,1	0,009	0,001	0,01	21,5	0,008	12,7
El Salvador	26,3	0,7	1,4	2,1	2	2,06	12,8
Ethiopia	122	0,9	9,6	10,5	10	9,45	12,9
Eritrea	7,3	0,1	0,5	0,6	6,3	0,56	13,0
Mexico	461,9	21,1	66,7	87,8	59,6	35,47	13,0
Malawi	17,3	0,2	1,2	1,4	6,5	1,31	13,2
Vietnam	884,1	4,3	77,6	81,9	18,5	66,75	13,2
China	2840	210,7	381,1	591,8	64,8	208,31	13,6
Cape Verde	0,3	0,002	0,028	0,03	31	0,02	14,5
Djibouti	0,3	0,017	0,003	0,02	10,9	0,018	16,8
Burkina Faso	13,5	0,4	0,4	0,8	2,3	0,78	17,3
Bulgaria	21,3	4,9	0,8	5,7	79,2	1,19	18,0
Tanzania	96,3	0,6	4,6	5,2	5,3	4,92	19,6
Senegal	39	0,2	2	2,2	14,2	1,89	20,7
Niger	34,1	0,2	1,5	1,7	4	1,63	20,9
Trinidad and Tobago	3,84	0,299	0,001	0,3	38,8	0,18	20,9
Израиль	1,8	0,5	0,7	1,2	93,1	0,08	21,7
Mali	120	0,1	5,1	5,2	3,4	5,02	23,9
Belgium	18,3	3,995	0,005	4	81,3	0,75	24,5
Grenada	0,2	0,009	0,001	0,01	19,7	0,008	24,9
Moldova	12,3	0,76	0,04	0,8	38,5	0,49	25,0
Spain	111,5	10,9	20,3	31,2	86	4,37	25,5
Madagascar	337	0,6	13	13,6	9,3	12,34	27,3
Albania	30,2	0,4	0,8	1,2	13,4	1,04	29,1
Ukraine	175,3	5,6	3	8,6	34,3	5,65	31,0
Portugal	77,4	2	7,1	9,1	73,6	2,40	32,2
Antigua and Barbuda	0,1	0,003	0,001	0,004	24,3	0,003	33,0
Poland	60,5	9,1	1	10,1	81,9	1,83	33,1
Nepal	210,2	0,2	9,3	9,5	37,2	5,97	35,2
Argentina	876,2	9,8	27,9	37,7	36,5	23,94	36,6
Qatar	0,056	0,2	0,1	0,3	99,5	0,0015	37,3
Myanmar	1168	3,8	29,4	33,2	10	29,88	39,1
Bangladesh	1227	4,4	31,5	35,9	16	30,16	40,7

Serbia	162,2	4,7	0,7	5,4	27,1	3,94	41,2
Burundi	12,5	0,1	0,2	0,3	4	0,29	43,4
Nigeria	286,2	7	5,5	12,5	48,3	6,46	44,3
Ghana	56,2	0,4	1	1,4	12,1	1,23	45,7
Costa Rica	113	0,9	2,3	3,2	23,3	2,45	46,0
Laos	333,5	0,3	7	7,3	10,1	6,56	50,8
Chad	45,7	0,2	0,7	0,9	2,3	0,88	52,0
Guatemala	127,9	1,4	1,9	3,3	27,2	2,40	53,2
Venezuela	1325	5,9	16,7	22,6	13,90%	22,57	58,7
Romania	212	5,3	1,5	6,8	48,3	3,52	60,3
Botswana	12,2	0,13	0,07	0,2	2,3	0,20	62,4
Ecuador	442,4	1,9	8	9,9	31,1	6,82	64,9
Georgia	63,3	0,8	1	1,8	46	0,97	65,1
Грузия	13,3	0,1	0,1	0,2	2,6	0,19	68,3
South Sudan	49,5	0,45	0,25	0,7	2,5	0,68	72,5
Sao Tome and Principe	2,18	0,02	0,02	0,04	25	0,03	72,7
Zambia	104,8	0,4	1,2	1,6	14,2	1,37	76,3
Lesotho	3	0,037	0,003	0,04	2,3	0,04	76,8
Uruguay	172,2	0,5	3,2	3,7	39,4	2,24	76,8
USA	3069	268,2	176,2	444,4	91,1	39,55	77,6
Mongolia	34,8	0,23	0,27	0,5	10,4	0,45	77,7
Estonia	12,71	1,79	0,01	1,8	91,1	0,16	79,3
Russian Federation	4525	45,8	18,6	64,4	12,9	56,09	80,7
Ivory Coast	84,1	0,6	0,6	1,2	14,2	1,03	81,7
Czech Republic	13,15	1,5	0,1	1,6	90	0,16	82,2
Honduras	92,2	0,4	1,2	1,6	30,2	1,12	82,6
Greece	68,4	2,2	9	11,2	92,7	0,82	83,7
Togo	14,7	0,13	0,07	0,2	15	0,17	86,5
Gambia	8	0,06	0,04	0,1	11,1	0,09	90,0
Belarus	57,9	1	0,4	1,4	56,5	0,61	95,1
Uganda	60,1	0,35	0,25	0,6	2,4	0,59	102,6
Italy	191,3	17,1	16,9	34	94,7	1,80	106,2
France	211	23,3	3,1	26,4	92,5	1,98	106,6
Brunei	8,5	0,094	0,006	0,1	21,2	0,08	107,9
Slovenia	31,9	0,896	0,004	0,9	67,2	0,30	108,1
Comoros	1,2	0,005	0,005	0,01	5,6	0,01	127,1
Australia	492	5,8	10,1	15,9	76,2	3,78	130,0
Panama	139,3	0,8	0,4	1,2	21,5	0,94	147,9
Mozambique	217,1	0,4	1,1	1,5	6,7	1,40	155,1
Nicaragua	164,5	0,3	1,2	1,5	31,8	1,02	160,8
Peru	1880	3	13,1	16,1	28,3	11,54	162,9

Bosnia and Herzegovina	37,5	0,2	0,2	0,4	46,8	0,21	176,2
Namibia	39,9	0,09	0,21	0,3	26,3	0,22	180,5
Paraguay	387,8	0,5	1,9	2,4	16	2,02	192,4
Brazil	8664	26,3	39,4	65,7	33	44,02	196,8
Guinea-Bissau	31,4	0,05	0,15	0,2	21,4	0,16	199,7
Denmark	6	0,4	0,3	0,7	95,9	0,03	209,1
Finland	110	6,4	0,2	6,6	92,3	0,51	216,5
Suriname	99	0,18	0,42	0,6	23,8	0,46	216,5
Colombia	2360	7,2	6,4	13,6	21,3	10,70	220,5
New Zealand	327	3,8	6,1	9,9	85,1	1,48	221,7
Hungary	104	4	0,5	4,5	89,6	0,47	222,2
Guyana	271	0,1	1,3	1,4	18,5	1,14	237,5
Japan	430	26,9	54,3	81,2	97,8	1,79	240,7
Belize	21,7	0,03	0,07	0,1	17,2	0,08	262,1
Chile	923,1	6	29,4	35,4	90,5	3,36	274,5
Benin	26,4	0,075	0,025	0,1	4,3	0,10	275,9
Cameroon	283,1	0,4	0,7	1,1	8,3	1,01	280,7
Angola	148,4	0,55	0,15	0,7	29,2	0,50	299,4
Cambodia	476,1	0,1	2,1	2,2	30,6	1,53	311,8
Canada	2902	33,1	2,6	35,7	75,9	8,60	337,3
Croatia	105,5	0,63	0,07	0,7	60,3	0,28	379,6
Bolivia	574	0,2	1,9	2,1	29,3	1,48	386,6
Ireland	52	0,63	0,17	0,8	83,4	0,13	391,6
Slovakia	50,1	0,57	0,03	0,6	79,8	0,12	413,4
Fiji	28,55	0,04	0,06	0,1	31	0,07	413,8
Oman	1,4	0,4	1,2	1,6	99,8	0,003	437,5
Bhutan	78	0,02	0,28	0,3	41	0,18	440,7
Южная Корея	69,7	12	17,2	29,2	99,5	0,15	477,4
Guinea	226	0,3	0,3	0,6	21,4	0,47	479,2
Norway	393	1,85	0,85	2,7	75,7	0,66	599,0
Malaysia	580	3,6	3,1	6,7	87,8	0,82	709,6
Sierra Leone	160	0,16	0,04	0,2	8,4	0,18	873,4
Germany	154	24,1	0,3	24,4	99,3	0,17	901,6
Lithuania	24,5	0,23	0,07	0,3	93,4	0,02	1237,4
Central African Republic	141	0,099	0,001	0,1	0,6	0,10	1418,5
Great Britain	147	7,2	1,2	8,4	98,8	0,10	1458,3
Sweden	174	2,33	0,07	2,4	95,2	0,12	1510,4
Austria	77,7	3,43	0,07	3,5	98,6	0,05	1585,7
Equatorial Guinea	26	0,019	0,001	0,02	22,3	0,02	1673,1
Luxembourg	3,5	0,04999	0,0001	0,05	96,3	0,002	1891,9
DR Congo	1283	0,63	0,07	0,7	12,3	0,61	2089,9

Iceland	170	0,2999	0,0001	0,3	73,5	0,08	2138,4
Gabon	166	0,07	0,03	0,1	22,5	0,08	2141,9
Papua New Guinea	801	0,399	0,001	0,4	10,8	0,36	2245,0
Latvia	34,9	0,13	0,07	0,2	93,1	0,01	2529,0
Liberia	232	0,092	0,008	0,1	14,3	0,09	2707,1
Switzerland	53,5	1,55	0,15	1,7	99,2	0,01	3933,8
Netherlands	91	7,97	0,03	8	99,8	0,02	5687,5
Singapore	0,6	0,48	0,02	0,5	99,99	0,0001	12000,0
Malta	0,051	0,022	0,018	0,04	99,99	0,000004	12750,0
Republic of Congo	832	0,05	0,002	0,05	7,2	0,05	17931,0
World	**54699**	**1127,16**	**2754,3**	**3881,5**	**47**	**2056,5**	**26,6**

With the current rate of freshwater pollution and the maintaining of water consumption per capita at the current level, the amount of clean water will decrease catastrophically by 2050 (see Table 4). This forecast is optimistic, since the indicator of freshwater consumption or total water-intake, according to official World Bank data, was taken into account at the level up to 2017. https://data.worldbank.org/indicator/ER.H2O.FWTL.K3

As of 2022, according to statistics, growth of total freshwater consumption, taking into account population growth, makes up from five to 10% annually.

Homo sapiens faces a rather acute need for the same indicators of potable water quality, indicating both geographical and time indicators that allow taking into account the variability of water pollution in time and space. The values requiring measurement are: the total level of contamination of a water body; the duration and volume of clean and polluted runoff; the permissible load of a water body with a contaminant; the size of emerging pollution zones in rivers, lakes, reservoirs, the accumulation of harmful substances in reservoirs; require an integrated approach and uniform standards for their accounting.

Considering the current level of water pollution, 55% to 80% of untreated wastewater is discharged into the environment, which significantly exceeds the permissible levels of natural processes of self-cleaning of water reservoirs (https://sdg6data.org/indicator/6.3.1).

Wastewater cannot be treated by 100%, or even by 70-80%, and this water is unsuitable for human consumption and can only be used in some industries, and, partially, in agriculture. According to the WHO (World Health Organization), up to 2 million people die every year in the world due to diseases caused by the consumption of bad-quality potable water.

According to reliable data, it turns out that a colossal amount of surface water – from 2 to 3.1 thousand cubic km – is polluted in the world annually (https://sdg6data.org/indicator/6.3.1). The pollution of water bodies that currently serves as one of the main causes of water shortage, and instability of water use.

Countries experiencing an acute shortage of fresh water, for which water consumption is higher than the natural replenishment of water resources, use desalinated water. Extraction of water in large amounts from wells is not considered as a perspective technology of water supply, since due to intensive pumping of groundwater, gradual salinization of aquifers occurs.

There are 16,000 desalination plants operating in 177 countries (https://idadesal.org/wp-content/uploads/2019/04/The-state-of-desalination-019.pdf) with the capacity of fresh water production – 95 million m^3 per day, and, as a by – product, salt brine – 142.5 million m^3. To produce 1 liter of desalinated water, a minimum of 2.5 liters of seawater is required. The average salinity of the World Ocean water is 35 g/l. Thus, the salinity of the brine from the desalinated water is about 87.5 g/l. As a result, 12.5 million tons of spent and contaminated salt are dumped into the ocean, or every day deposited on land. It amounts to 4.6 billion tons of salt a year. This has a catastrophic effect on the ecology of the region and the ecosystem of the World Ocean. At shallow depths and the absence of fresh water runoff in the places of brine discharge, the salinity of the water triples, which leads to an increase in the cost of the further desalination process.

The main problem of desalinated water is the lack of international standards for desalinated potable water containing deuterium and oxygen [18]. The International Atomic Energy Agency (IAEA) notes that seawater contains isotopes of heavy metals, which are undoubtedly harmful to human health, and are not completely removed from the water as a result of desalination. Heavy isotopes of ordinary tap fresh water have a negligible effect on health of young organisms under the age of 20. However, as a result of aging, stress and a number of external influences, the body's protection forces weaken, and DNA molecules are saturated with deuterium, water exchange worsens, and immunity decreases [19].

Desalinated seawater also lacks four essential minerals vital to human health – calcium, magnesium, fluorine and iodine. Minerals are removed in the desalination process along with salts. [https://www.sciencedirect.com/science/article/abs/pii/S001393511830358X].

Despite numerous attempts, it has not yet been possible to develop a cost-effective and large-scale technology for desalination of sea water, which would solve the problems of desertification of a large portion of the planet, agriculture, healthcare, food supply to the population, and significantly improve the ecological situation on the whole planet.

In March 2019, the UN Environment Assembly adopted a resolution on the protection of the marine environment from terrestrial human activities, such as the operation of desalination plants, because it is associated with serious environmental damage [20].

Assessing the overall environmental situation in the world, it should be noted that only in a few regions of the planet it is satisfactory; for the rest it is complex and very complex. Undoubtedly, it affects the life expectancy of people and the biodiversity of the region. Providing natural resources for the lifestyle that most *Homo consúmens* live today cannot be justified. Based on the data from the above tables, it is clear that the duration of such a carefree existence can be no more than 40-50 years.

Here, obviously, a question that should be answered, “What will happen when the mineral resources of the planet run out”?

II. TOXIC SUBSTANCES IN THE LIFE OF *HOMO SAPIENS*

2.1 The diversity of natural and anthropogenic chemical structures and their natural circulation

Nowadays, living standards of *Homo sapiens* include the production and usage of thousands of different structures of chemicals. Some of them are products of nature (fruits, vegetables, etc.), which, in great majority, undergo biodegradation; others are chemically synthesized products, mainly of toxic nature. These substances become regular components of the air, soil, and water reservoirs. According to their action, fate and impacts on ecosystems, they are the major source of pollution. Detail investigation of these components intends to evaluate the nature, possible transformation and distribution of different structures in environment, their function, exposure and lethality effects on organisms, that greatly depends on their distribution velocity. Currently, there are 70,000 chemicals mostly synthesized and utilized worldwide. The rate of introduction of new a substance is equal to up to 1000 new chemicals annually [126].

In the beginning of the 20th century pollution on a large scale began, and continues in most developed and developing countries. The technological race that started in the 20th century included chemicals as an essential part of modern development. For instance, communications and transport have benefited enormously from the use of a new metals and alloys to make transistors, batteries and other more durable metallic products. Synthetic organic compounds, mostly derived from petroleum, underwent a revolution: polychlorinated biphenyls (PCBs), used as insulating fluids in the electrical industry; chlorofluorocarbons (CFCs) used in refrigeration and air conditioning systems; plastics to serve a wide range of uses, from building materials to household items and toys. Pesticides to control insect and rodent pests, weeds and plant diseases, and the immense array of chemicals used to make paints, cleaning products, cosmetics and pharmaceuticals. Many of these new substances toxic in nature, have become environmental pollutants in air, water and soil, and created unforeseen problems related to their waste and disposal [127].

- The distribution and content of organic and inorganic contaminants in an environment is a complex process highly depending on soil-water-atmosphere-plant-rizospheric microorganism's interaction. Often, native and biologically partially transformed contaminants, still having high levels of toxicity, are the part in atmospheric, geographical and biological circulations, distributing toxicity all over the world. Natural ecological niches are characterized by the potential to accumulate various structures of chemical compounds; the dynamics of their accumulation clearly shows that their concentration in nature undergo to permanent increase. The circulation of the foreign, including carbon and nitrogen-containing compounds of toxic nature, are constantly entering in the environment, partially transforming into harmful forms acceptable to the *Worldbiome*. Because, of the number of natural processes, uncharacteristic compounds of a toxic nature are created. However, the formation of toxicants is largely the result of industrial processes: energy, transport, industry, agriculture and other forms of human activity. The technogenic, uncharacteristic for nature, toxicity formed in this way, having a tendency of constant growth, negatively effects on the normal life of all organisms, especially their biodiversity. Therefore, according to the existing chemical pollution of the environment, compounds of toxic nature could be divided into natural and anthropogenic.

The worsening of local ecology, sometimes a quite significant one, could be the result of natural processes: volcanic eruptions, often accompanied by the release of toxic gases and uncharacteristic stable chemical compounds formed in high-temperature in deep underground regimes. Biological oxidation of natural compounds accompanied by the release of toxic gases from confined air spaces and swamps, formed as a result of aerobic and anaerobic microorganisms consortiums actions, earthquakes, heavy gales, and other natural processes.

The damage caused to the environment by technogenic activity has surpassed the environment in many ways. Man, being the result of the multi-stage evolution of living matter, has gained and developed intelligence, due to which he managed to create large sources of energy and, on this basis, significantly influence the course of natural processes. Because of urbanization, the unpredictable growth of industry, oil production and refining, transportation, agriculture, incessant hostilities, etc., *Homo sapiens*, due to overproduction and consumption, has created a powerful weapon of toxic contaminants directed at himself. According to the existing ideology, the most important cause of the inevitable ecological catastrophe is an unprecedented increase in population, which the potential of the planet in existing conditions is barely able to satisfy. The changes that have occurred have clearly proved the inconsistency of the uncontrolled activity of the *Worldbiome*, it is vital that the vector of humankind activity should significantly be shifted towards the "greening" of the planet. Another important reason that has significantly been speeding up the ecological catastrophe over the past decades has become the dominant technological imperative in nature management, directly related to the wasteful consumption of a wide variety of goods and all kinds of services that determine the well-being of *Homo consúmens* (the person consuming).

Modern science, which over the past two centuries has been developing technologies with widely varied profiles based only on their effectiveness, has not yet fully resolved the application of new generation technologies through the lens of ecology. Much is missing, including acceptable worldwide, ecologically beneficial types of technologies, societal goodwill and agreement, and the necessary investment. Furthermore, the increasingly dominant culture of the new society of *Homo consúmens* (consumer) causes challenges in fully realizing the existing scientific potential through many temptations.

Nowadays, the environmental cleanup turnover annually has been estimated to be 80 billion USD, including traditionally used, becoming classical (physical, chemical and biological) and modern technologies, including those, based on biological nature of organisms. Widely spread contaminants that concern industry, agriculture, oil extraction, refining and use, municipal and radioactive wastes, etc., required special cleaning technologies for the existence of *Homo sapiens,* in the world scale, becoming more and more industrialized nations. Another important problem of the environment seems to be the diversity of spread-out contaminants, almost each of them requiring a special utility for remediation. That explains why the technologies used to manage and clean up and restore polluted sites are so broad.

2.1.1 **Toxic substances of biological origin**

Natural toxins belong to the toxic compounds that are produced by living organisms. These toxins exist in nature in concentrations that are not harmful to the organisms themselves but they may be toxic to others, including humans, when eaten or via skin contact. The multiple forms of these chemical compounds have completely diverse structures and differ in biological function and toxicity. Natural sources of toxins are mainly of plants and microbial origin. Toxins formed by algae in the ocean and fresh water are called algal toxins. Algal toxins can cause diarrhea, vomiting, tingling, paralysis and other effects in humans, other mammals or fish. The algal toxins can be retained in shellfish and fish or contaminate drinking water. They have no taste or smell, and are not eliminated by cooking or freezing. Another distributed natural poison belongs to the group of cyanogenic glycosides, which are phytotoxins (toxic chemicals produced by plants) is a potential at least of 2000 plant species. Cassava, sorghum, stone fruits, bamboo roots and almonds are especially important foods containing cyanogenic glycosides. In humans, the clinical signs of acute cyanide intoxication can include rapid respiration; drop in blood pressure, dizziness, headache, stomach pains, vomiting, diarrhea, mental confusion, cyanosis with twitching and convulsions followed by terminal coma. Furocoumarins having a specific structure are present in many plants such as parsnips, celery roots, citrus plants (lemon, lime, grapefruit, and bergamot) and some medicinal plants. Furocoumarins are stress toxins and are released in response to stress, such as physical damage to the plant. Some of these toxins can cause gastrointestinal problems in susceptible people. Many types of beans contain specific toxins called lectins, and kidney beans have the highest concentrations – especially red kidney beans. As few varieties of bean can cause severe stomachache, vomiting and diarrhea. Lectins are destroyed when the dried beans are soaked for at least 12 hours and then boiled vigorously for at least 10 minutes in water. Mycotoxins are poisons of microbial origin (molds) naturally occurring toxic compounds. Molds that can produce mycotoxins grow on numerous foodstuffs such as cereals, dried fruits, nuts and spices. Most mycotoxins are chemically stable and survive food processing. The effects of food-borne mycotoxins can be acute with symptoms of severe illness and even death appearing quickly after consumption of highly contaminated food products. Long-term effects on health of chronic mycotoxin exposure include the induction of cancers and immune deficiency. Allsolanacea plants: tomatoes, potatoes, and eggplants, contain natural toxins called solanines and chaconine (glycoalkaloids). High concentrations of these compounds are found in potato sprouts, bitter-tasting peel, and green parts, as well as in green tomatoes. To reduce the production of solanines and chaconine it is important to store potatoes in a dark, cool and dry place, and not to eat green or sprouting parts. Wild mushrooms often contain toxins, such as muscimol and muscarine, which can cause vomiting, diarrhea, confusion, visual disturbances, salivation, and hallucinations. Fatal poisoning is usually associated with delayed onset of symptoms, which are very severe, with toxic effect on the liver, kidney and nervous systems. Pyrrolizidine alkaloids (PAs) are toxins produced by an estimated 600 plant species. The main plant sources of (PAs) are the families *Boraginaceae*, *Asteraceae* and *Fabaceae*. Many of these are weeds that can grow in fields and contaminate food crops. PAs can cause a variety of adverse health effects; they can be acutely toxic and of main concern is the DNA-damaging potential of certain PAs, potentially leading to cancer. PAs are stable during processing, and have been detected in herbal teas, honey, herbs and spices and other food products, such as cereals and cereal products.

Toxic components created by nature, are not only components of atmospheric air, soil and water reservoirs, but also an integral part of the entire living world of plants, microorganisms, mammals and humans, being the cause of serious pathologies and unnatural processes. The organisms inhabiting the planet are forced to have some additional protective properties against the general aggressiveness of environmental organisms for their own protection.

For example, poisons of biological origin are found as high-molecular substances of the protein type, however, low-molecular toxins, such as tetrodotoxin, animal poisons and others, are also known [31]. Toxins produced by microorganisms, plants and animal organisms are characterized by universal geographical distribution. They depress physiology by inhibiting metabolically active enzymes and disrupting the course of metabolic processes in the human body. In most cases, the effects of poisons of biological origin are characterized by a fatal outcome. According to the action, toxins are divided into the following groups (Table 6).

Classification of toxins by their effect on the human body

Table 6

№ п/п #	Toxins	Nature of the action
1	2	3
1	Haemotoxins (Haemotoxins)	Acting on the blood
2	Neurotoxins (Neurotoxins)	Acting on the nervous system
3	Myotoxins(Myotoxins)	Acting on the muscles
4	Haemorrhaginstoxins (*Haemorrhaginstoxins*)	Affecting blood vessels
5	Haemolysinstoxins (Haemolysinstoxins)	Affecting red blood cells
7	Nephrotoxins (Nephrotoxins)	Disrupting the activity of the kidneys

8	Cardiotoxins (Cardiotoxins)	Disrupting cardiac activity
9	Necrotoxins (Necrotoxins)	Causing necrosis

The strongest natural poison is considered to be botulinum toxin type D (lethal dose is 0.32×10^{-6} mg/kg), which is millions of times more toxic than potassium cyanide. It is followed by botulinum toxin type A, dioxin, tetrodotoxin (puffer fish), sea snake venoms, cobra venom, hydrogen cyanide, potassium cyanide. Of the non-protein poisons, the strongest is batrachotoxin – isolated from the skin of a Colombian frog.

Natural poisons formed and used by various organisms for self-defense are neurotoxins. These are botulinum toxin, poneratoxin, tetrodotoxin, batrachotoxin, and poisons of bees, snakes and scorpions (Table 6).

Natural poisons formed and used by various organisms for self-defense are neurotoxins: botulinum toxin, poneratoxin, tetrodotoxin, batrachotoxin, and poisons of bees, snakes and scorpions (Table 7).

General characteristics of natural toxins

Table 7

Name	Source	Molecular mass, D	LD_{50}	
			mg/kg	mmol/kg
1	2	3	4	5
Botulinum toxin A	Rods of *Clostridium* botulinum	150000	$2,6 \cdot 11^{-8}$	$1,7 \cdot 10^{-13}$
Botulinum toxin B	Rods of *Clostridium* botulinum	167000	$1,0 \cdot 11^{-8}$	$0,6 \cdot 10^{-13}$
Tetanus toxin	Rods of *Clostridium tetani*	140000	$2,8 \cdot 11^{-8}$	$2,0 \cdot 10^{-13}$
Ricin	Castor seeds	65000	$2,8 \cdot 10^{-3}$	$4,3 \cdot 10^{-8}$
Typoxin	Venom of the Australian Taipan	42000	$2,0 \cdot 10^{-3}$	$4,8 \cdot 10^{-8}$
Beta-Bungarotoxin	Krait ‘s Venom	28500	$2,5 \cdot 10^{-2}$	$8,8 \cdot 10^{-7}$
Cobrotoxin	Cobra Venom	6782	$5,0 \cdot 10^{-2}$	$7,4 \cdot 10^{-6}$
Toxin II	Scorpion Venom	7249	$0,9 \cdot 10^{-2}$	$1,2 \cdot 10^{-6}$

According to the mechanism of action, toxins of biological origin are significantly differing. Neurotoxins, as exceptionally highly toxic compounds, serve to protect the host organisms synthesizing them (from microorganisms to vertebrates). Another type of such compounds – neurotoxins entering the body from the external environment are exotoxins, they include gases (CO), metals (mercury), liquids (ethanol), as well as a number of solids.

Hemotoxins formed by animal organisms, plants and microorganisms damage the membranes of red blood cells and destroy them, i.e. cause their hemolysis [33]. The existence of hemotoxins of various origins formed by conditionally pathogenic and pathogenic streptococci, staphylococci and other microorganisms; plants (ricin, saponins, etc.); animal organisms such as parasitic worms, spiders (arachnolysins), snakes (venoms) has been established. The result of the action of these and a number of other chemical compounds, including drugs, is nephrotoxicity, which affects the liver. More often, nephrotoxicity manifests itself before taking medications in people who have had signs of decreased liver function.

Well-known groups of natural toxins of plant origin are cyanogenic glycosides, pyrrolizidine alkaloids, furocoumarins, lectins, and glycoalkaloids. These plant-origin natural toxins can cause a variety of adverse health effects and pose a serious health threat to both humans and livestock. Some natural toxins could be found in food being defense mechanisms of growing plants, through their infestation with toxin-producing mold, or through ingestion by animals of toxin-producing microorganisms. Natural toxins can cause a variety of adverse health effects and pose a serious health threat to both humans and livestock. Some of these toxins are extremely potent.

The list of existing natural toxicants, their structures, functions and mechanisms of action on the population for *Homo sapiens* is not fully studied and generally are of great interest from the point of view of medicine and modern toxicology/environmental science.

2.1.2 **Toxic substances of non-natural structures**

There is a category of pollutants that are characterized by an unnatural structure, are not biodegradable or degrade very slowly over time, i.e., they have high stability in environmental conditions and almost all of them exhibit toxic properties. These are chemical compounds formed during incomplete combustion of organic substances, chemically synthesized pesticides, some types of fertilizers, varnishes and paints, organic solvents, emulsifiers, preservatives, petroleum products, household chemicals, chemicals used in the production of polymers (polymers, monomers, pigments, plasticizers, stabilizers and others), products of the pharmaceutical industry, surfactants; freons, explosives, packaging materials, etc.

A special group of pollutants includes radionuclides, which are a source of ionizing radiation and have an extremely negative effect on all organisms and life processes. Radionuclides are a special group of environmentally extremely dangerous pollutants for the environment, for the neutralization of which special remediation technologies are being developed, that should ensure their maximum reduction or complete removal from ecosystems [34].

Separate groups of toxic compounds are ubiquitous heavy metals, the result of various toxic, industrial emissions into the atmosphere and components of natural ecological niches.

Heavy metals are chemical elements with a certain density that is 5 times heavier than the density of water. In small quantities, these elements are necessary for living organisms, but an increased content any of them causes acute or chronic poisoning. The toxicity of heavy metals, in increased amount, are expressed by the suppression of the growth and development of microorganisms and plants, causing serious damage to human and animal health. Heavy metals cause dysfunction of the central nervous system, changes in blood composition, negatively affect the functions of the lungs, kidneys, liver and other organs, cause the formation of cancerous tumors, allergies, dystrophy, physical and neurological degenerative processes. Of the 35 metals, 23 have found wide application and are produced on an industrial scale. According to their toxicity, arsenic, lead, mercury and cadmium occupy the 1st, 2nd, 3rd and 7th places, respectively.

2.2 Heavy metals

Increased concentrations of non-essential heavy metals/metalloids in soils and water affects human health greatly. Healthy soil and a healthy nation are closely intertwined. A set of technologies has been developed to clean environment. Well-known microbial bioremediation of the soil includes the use of following taxonomic groups of microorganisms: bacteria, vesicular-arbuscular mycorisial fungi, a number of other mycelial fungi, and actinomycetes. This is a well-known strategy to reduce the concentration of a wide spectrum of organic contaminants, including heavy metals, in the soil due to the ability of microorganisms to sequester and transform heavy metals. Typical concentrations of microorganisms in non-vegetated soils are in the range of 10^5 to 19^8 cells per gram of dry soil. In comparison, rhizosphere soil contains population that is in 1-2 orders of magnitude higher than the amount of balk surface soil [128]. Cleaning potential of microorganisms depends on growth-promoting characteristics; metal resistance is related to natural molecular mechanisms. In-depth analysis of the most commonly evaluated genera, *Agrobacterium, Bacillus, Klebsiella, Enterobacter, Microbacterium, Pseudomonas, Rhodococcus,* and *Mesorhizobium* showed significantly different tolerance levels among them and highlighted the deployment of different biochemical and molecular mechanisms associated with plant growth promotion or with the presence of resistance genes located in the *cad* and *ars* operons [129].

In order to clean the soil, there is a set of "technological tools", such as chemical, physical (mechanical) and biological. In the great majority, these technologies require critical conditions: high temperature, organic solvents, alkali, acids, different rays etc., deeply negatively affecting on soil microflora, often annihilating them. To avoid this extremely negative effect of the various environmental concerns, the technologies based on phytoremediation have been developed. The concept of phytoremediation based on some plants potential that tolerate and accumulate heavy metals in sufficient amount is the only environmentally friendly, cost-effective technology to eliminate heavy metals from soil. Simultaneously, phytoremediation is one of the globally distributed form of natural technologies to degrade and utilize heavy metals by transporting them in above ground parts and cleaning the soil this way. Simultaneously, in this process, many other organic and inorganic contaminants of different structures and compositions undergo degradation. Because of overall significant toxicities, bioaccumulation, and persistence, heavy metals such as Cd, Cr, As, Hg, Pb, Cu, Zn, and Ni have been identified as priority control contamination. Soil is the most important and sensible element of the environment and foundation for human survival. Accumulation of heavy metals in soil may result in deteriorating soil quality, reduce soil fertility and crop production, and even threaten human and animal health [130, 131].

Multiple methods, such as geographic information system (GIS), principal component analysis (PCA), and positive matrix factorization (PMF) were used to find the distinct distributions and sources of heavy metals in soils. Moreover, multiple indicators such as geoaccumulation index (*Igeo*), potential ecological risk index, and human health risk (non-carcinogenic and carcinogenic risks) have been employed to comprehensively evaluate the heavy metal pollution in soils [132].

2.2.1 **Arsenic**

One of the most toxic elements actively used in various fields is the semimetal arsenic. All arsenic compounds are extremely toxic. Upon heating, they are decomposed, releasing poisonous arsenical vapors. Sources of environmental pollution with arsenic are emissions from the extraction and processing of arsenic ores; industrial production of arsenic and its compounds; melting of copper, lead and zinc; combustion of coal, etc. Arsenic compounds – oxides, arsenide's and arsenates are mainly used for wood processing; 88% of the total amount of arsenic has been registered for this purpose. Arsenic compounds are part of insecticides, herbicides and desiccants, are used in the manufacture of various types of glasses, anti-corrosion alloys, ammunition, and acid batteries. High purity arsenic found use in semiconductors, solar panels, lasers and integrated circuits.

Arsenic compounds entering the atmosphere with emissions settle on the surface of soil, reservoirs, and also are adsorbed and penetrate into plants, and then enter the food chain. Arsenic and its compounds are carcinogenic substances. They cause the formation of tumors of the skin, liver, intestines, bladder and lungs. Some tropical algae are resistant to arsenic. They are able to absorb arsenic in the form of arsenate, reduce it to arsenide and bind to phospholipids. The conjugates formed are stored in fat droplets or cell membranes. With a high content of phosphates in the water, the same algae lose their ability to neutralize the toxic effects of arsenate ions and perish. In this case, arsenic covalently binds to the sulfhydryl groups of enzymes, causing a significant inhibition of their activity. Some types of mycelial fungi and bacteria are also capable of assimilating and converting arsenic compounds. For example, methanogenic bacteria in aerobic conditions are able to convert inorganic arsenic into methylated compounds, which are reduced to volatile alkylarsins with the help of enzymes.

2.2.2 **Lead**

Lead is one of the heavy metals widely used in different branches of industry. Metallic lead and its compounds – oxides, halides, carbonates, chromates, sulfates, etc., are used in mechanical engineering. In the production of batteries, piezoelectric elements, rubber, glass, glazes, enamels, drying oils, putties; in printing; for the manufacture of paints, in particular lead pigments and whitewash; serve as an additive to varnishes and paints to increase the stability of coatings; used as anti-detonator additives to gasoline; to protect against gamma radiation, etc.

The volume of global lead production is several million tons annually. Among the most important technogenic sources of lead emissions are emissions and wastewater generated during high-temperature technological processes of metallurgical, metalworking, machine-building, chemical, chemical-pharmaceutical, petrochemical and other industries; exhaust gases of internal combustion engines; extraction, transportation and processing of metal; erasure of parts containing lead, etc. A high degree of lead contamination is also found in soils at the sites of military operations and polygons [36].

With exhaust gasses, lead compounds (oxides, chlorides, fluorides, nitrates, sulfates, etc.) are taken out in the form of solid particles, about 20% of which settle in the immediate vicinity of the road. Therefore, it is not recommended to build plantations of agricultural plants directly along highways, especially fast-growing vegetable crops that do not have time to decompose toxic compounds during the growth process.

Excessive lead content in the soil leads to a decrease in the number of the main representatives of the soil microbiocenosis. The degree of toxicity of lead to microflora depends on the type of soil: in chernozems, the neutralization of toxicity occurs faster than in other type of soils. The most resistant to lead compounds are some representatives of eukaryotes – microscopic fungi, and some prokaryotes. Actinomycetes and nitrogen-fixing bacteria react much more sensitively to the presence of lead. Obviously, the presence of these microorganisms also is the bioindicator to assess the degree of lead contamination. The level of lead in the soil, which reduces the yield or plant height by 5-10%, is considered toxic. When the lead content in the soil is above 50 mg/kg, its concentration in garden crops exceeds the permissible norm. It should be noted that lead enters the human body mainly through the food chain (about 90%) of which 60-70% are plant products [37].

Lead causes chronic poisoning called "saturnism" with various clinical manifestations: it affects the central and peripheral nervous systems, bone marrow, blood, vessels, suppresses protein synthesis, acts on the genome of the cell, has gonadotoxic and embryotoxic effects, and activates oncological processes [38].

The difference in the toxicity of all lead compounds is explained by the unequal solubility of these compounds in gastric juice, intestines, blood and cytoplasmic fluid of the body. Hardly soluble lead compounds also undergo transformations in the intestine, because of which their solubility and absorbability are significantly increased. Lead whitewash, sulfate and divalent lead oxide are more toxic than other compounds. Lead based chemicals containing a toxic anion, such as orthoarsenates, chromates and azide, are particularly toxic. Biocidal properties are distinguished by organic compounds of lead, in particular tetraethyl lead, which is used to increase the octane number of gasoline. Volatile tetraethyl lead spreads rapidly in the air and, as a result of the action of UV rays, splits into radicals (Figure 12). The triethyl lead radical reacts with various substances (A) having acceptor properties [35].

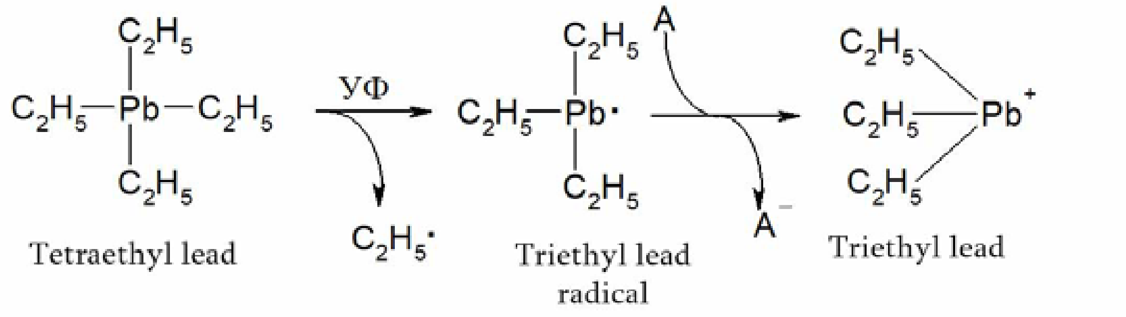


Fig. 12. Formation of a radical and triethyl lead ion from tetraethyl lead (A – Acceptor)

The formed triethyl lead ion $Pb(C_2H_5)_3^+$ exhibits hydrophilic properties due to the ion charge, and the presence of ethyl groups gives the ion a lipophilic character, allowing the triethyl lead ion easily penetrates cell membranes and binds to sulfur atoms, proteins and peptides, causing changes in their structure. It should be noted that due to the high toxicity, the use of leaded gasoline is prohibited or restricted in many countries.

2.2.3 **Mercury**

This heavy metal exists in the earth's crust in the form of cinnabar (HgS), as a relatively harmless substance. The consumer activity of *Homo Consúmens* has led to the accumulation in the oceans of more than 50 million tons of this heavy metal in the form of toxic compounds. Particularly important anthropogenic sources of mercury distribution include electrochemical production of chlorine, mercury-containing devices, paints for synthesis and others [39]. Natural sources are weathering of rocks, and volcanic activity.

Under natural conditions, mercury compounds are accumulated in river sediments. Mercury slowly releases from the sediments and dissolves in water, which leads to the formation of a chronic source of pollution. Initially, mercury enters the water in the form of the Hg^{2+} ion, then under the action of anaerobic microorganisms it quickly interacts with organic substances and forms extremely toxic compounds: dimethyl mercury (CH_3–Hg–CH_3) and methylmercury ion $(CH_3–Hg)^+$ [40]. Due to its high solubility, methylmercury quickly penetrates into algae, shellfish, fish, etc., and enters the blood, via food chain, into brain tissue, destroying the cerebellum and cerebral cortex. The clinical symptoms of such a lesion are numbness, loss of orientation, deterioration of vision. Poisoning with mercury compounds can be fatal.

Mercury compounds cause inactivation of some key enzymes of cellular metabolism, in particular, Cytochrome c participating in the respiration process. In addition, mercury combines with sulfhydryl groups inactivating enzymes, and damaging cell membranes.

2.2.4 **Cadmium**

Cadmium belongs to a group of heavy metals characterized by high toxicity. The distinguishing property of cadmium is high mobility and permeability. Metallic cadmium and its compounds are mainly used for the production of pigments as stabilizers of plastics (especially polyvinyl chloride), for the manufacture of batteries, rods of nuclear reactors, electrical cables, car radiators, solders, alloys, phosphorous fertilizers, etc.

Cadmium sulfide (CdS) and selenide (CdSe) are heat-resistant dyes of yellow and red colors, respectively, widely used in printing, in the production of lacquers, paints and rubber products, as well as in the coloring of leather. Cadmium oxide (CdO) and carbonate ($CdCO_3$) are used for painting glasses, preparing enamels, applying glaze to ceramics, etc. [41]. The most important anthropogenic sources of cadmium emissions into the atmosphere are the production of steel and other metals, the burning of fossil fuels and garbage, tobacco smoke, the use of fertilizers, leaching of cadmium from agricultural plantations, etc. [41].

Cadmium attaches mainly to dust particles that can enter the body when breathing. When cadmium is deposited from the atmosphere (dry and wet), plants actively are exposed to cadmium, and some of the cadmium can penetrate into the leaves through cuticles. In case of high cadmium concentration in plants, most often leads to a violation of normal growth. For example, the yield of legumes and carrots is reducing up to 50%. Unlike plants, many types of fungi accumulate cadmium in large quantities that creates interest as a technological step to gather the metal.

The main source of cadmium ingress into animal organisms is food. Cadmium reduces the activities of the digestive tract enzymes such as trypsin and pepsin. In addition, cadmium is a calcium antagonist – with a calcium deficiency in the body, cadmium accumulates in an increased amount. Since the need for calcium in young organisms is higher than in adults, therefore, they are more susceptible to the accumulation of cadmium. The increased accumulation of cadmium causes the "itai-itai" disease, which is exposed in a decrease in the calcium content in the bones, leading to their softening. In the kidneys, liver and gallbladder, cadmium binds to proteins and peptides that are involved in the exchange of cadmium between various tissues and organs. The most sensitive and cadmium-affected organ is the kidneys. Excess cadmium enters into competition with zinc, inhibits the action of zinc-containing enzymes, which disrupts the normal functioning of the kidneys [42]. As a result, proteinuria arises. In the liver, cadmium blocks enzyme systems containing sulfhydryl groups.

2.3 Aromatic hydrocarbons

2.3.1 Benzene

Over 90% of the benzene produced is connected with the petrochemical industry, the rest with the coal industry and natural gas. The UK, the major exporter of benzene, annually produces around one million ton of this substance.

The basis of the toxicity of many organic compounds is the aromatic ring of benzene. Benzene itself and its homologues are extremely toxic. Most benzene and its homologues in different admixtures (the so-called BTEX, – benzene-toluene-ethylbenzene-xylene) are used in many sorts of fuel to increase the octane rating, instead of a very toxic petrol additive tetraethyl lead. Besides, benzene is used as the raw material in the production of styrene, cyclohexane, ethylbenzene, cumin, nitrobenzene, aniline etc., and as a solvent or additive in the production of dyes, pesticides, inks, rubbers, glues, lubricants, spot removers, furniture waxes, detergents, medicines, pesticides. Benzene is also a component of cigarette smoke.

The main anthropogenic sources of spread of benzene and its homologues in the environment are:

- benzene emission during crude oil refining and processing;
- emissions from enterprises producing and processing pitches and coal;
- industrial emissions of technologies, where benzene is the final product in organic synthesis;
- emission from burning oil and fossil fuels;
- leakage from underground storage tanks for combustible products.

Benzene primarily enters the atmosphere during its production or use, from where it penetrates into other ecosystems. Benzene is found in various quantities in the waters of oceans, seas, lakes, reservoirs and rivers, in groundwater, even in potable water, soils, etc.

Benzene and its homologues are well-known carcinogenic substances, which cause leukemia. After getting into the liver or lungs, benzene as a nonpolar and relatively stable compound undergoes initial oxidation by cytochrome P450-containing monooxygenase, forming benzene oxypin and benzene oxide [43]. These compounds are characterized by increased solubility and reactivity compared to benzene.

Furthermore, the products of benzene primary oxidation are spared out via blood flow from the liver to other tissues, including the bone marrow. Benzene oxypin and benzene oxide undergo further enzymatic transformations in these tissues: firstly they are reduced to phenol, which is then oxidized to catechol or hydroquinone. These phenols are oxidized to benzoquinones. Enzymes of marrow cells catalyze transformation of diphenols preferentially. The benzoquinones formed are characterized by enhanced reactivity. Each of them can bind proteins or nucleic acids via oxo-groups, and this leads to the destruction of the normal biological functioning of the genome and change the regular sequence of metabolism [43].

2.3.2 **Polycyclic aromatic hydrocarbons (PAHs)**

Polycyclic aromatic hydrocarbons, highly toxic compounds, are almost insoluble in water, have a high boiling point, and hardly are subject to biological degradation [35]. These compounds have become quite widespread in the environment: 3,4-Benzopyrene; 1,2-5,6-Dibenzanthracene; 7,12-Dimethyl-benzanthracene; 3-Methylcholanthrene; 3,4-Benzofluoranthrene. On an industrial scale, PAHs are not produced; compounds of this class are formed during combustion, and many natural products contain them. PAHs are components of pitches, bitumen, soot, and humus components of soil, exhaust gases of internal combustion engines, smoked products, tobacco and many other products. PAHs are detecting in air, water and soil. These compounds are extremely stable in any environment, and according to their stability, creating a real danger of their accumulation in all organisms in higher concentrations.

In the vast majority of cases, PAHs are carcinogenic compounds. After penetration of PAHs into the organism, they undergo to the action of intracellular enzymes. These compounds react with guanine and block DNA synthesis, inducing disablement of transcription processes, or leading to mutations, which often promote cancer. Only a small number of microorganisms and plants can degrade PAHs to regular cell metabolites [44].

2.4 **Pesticides**

Chemicals that are widespread as modern plant protection products created by *Homo sapiens*, mainly by chemical synthesis, are united under the common name "pesticides". Taking into account the area of their distribution, they are currently the largest compounds that pollute the environment, primarily the soil. According to the latest data from the Environmental Protection Agency (EPA) and the World Health Organization (WHO), pesticides include more than 1,000 compounds representing various chemical classes. Among them are amides, dipyridiles, diphenyl ethers, thiocarbamates, carbamates, carbamides, coumarins, nitro phenols, pyrazoles, pyrethroids, triazines, phenoxyacetates, and urea derivatives. Organ element compounds containing chlorine, bromine, fluorine, phosphorus, arsenic, tin, mercury, copper and others also belong to this class of compounds. The production of pesticides is growing, which is around one billion tons annually. The increasing scale of their use in agriculture [45-47] causes this growth. Pesticides are divided according to their physical-chemical characteristics and structures of carbon carcasses.

Widely used organophosphate pesticides are esters of phosphoric and thiophosphoric acids e.g., insecticides – alkylphosphates, parathion), as well as carbamates e.g., herbicides – barban and betanal, fungicide – maneb and others), are chemical agents that act ruinously on the nervous system. They block the active center of acetylcholinesterase. This enzyme removes the neurotransmitter acetylcholine from the nerve synapse. Because of inhibition of acetylcholinesterase, excess acetylcholine accumulates at the synapse, which causes a violation of signal transmission by the acetylcholine receptor.

Organochlorine insecticides (chlordane, lindane, dieldrin, dichlorodiphenyltrichloroethane – DDT), used in the form of a solution, easily penetrate into the human body both through the digestive organs and the skin. Due to their high lipophilicity, they accumulate in adipose tissues and affect cell membranes. Organochlorine insecticides have a particularly harmful effect on the membranes of nerve cells and disrupt their normal cycle. Almost all organochlorine insecticides are characterized by vividly expressed carcinogenic properties. When ingested in a sufficiently large amount, phosphates and carbamates, alkyl phosphates (triethyl phosphates) and others, signs of diseases such as salivation, pulmonary edema, colic, diarrhea, nausea, visual impairment, increased blood pressure, muscle spasms and convulsions, speech disorders, paralysis of the respiratory tract, etc. appear. Organochlorine compounds change the excitability of nerve cells. At first, nerve pathways are damaged, and then, at higher concentrations, sensory neurons lose their function. Among other pathologies characteristic of these pesticides, chlordane and dieldrin are compounds with a pronounced carcinogenic nature of action.

Practically unlimited application of insecticide DDT led to its worldwide distribution. High solubility in fat favored its incorporation into food chains. As a result, in the terminal steps of food chains the concentration of DDT is increased almost for three orders, e.g. starting from rainwater and ending at human milk. DDT is well absorbed by clays, as well as is accumulated in humus rich in pine needles, where it is dissolved in the wax of the needles, which has an extremely negative effect both on the trees themselves and locally on the ecosystem, destroying many organisms similar of pine trees. DDT is a typical contact poison that quickly penetrates through the skin. It disrupts the normal cycle in the membranes of nerve cells, as it lowers the sensitivity of the Na^+ pump; therefore, after the excitation of nerve signals, there is no restoration of the normal resting potential. Ingestion of a large amount of DDT causes paralysis of the limbs. It is assumed that through the mother's milk, this insecticide can seriously harm the health of the child or, penetrating the gonads, disrupt the ability to procreate.

Under natural conditions, DDT decomposes slowly and only partially. Under aerobic conditions, decomposition products are derivatives of dichloroethylene, which are less toxic than DDT; under anaerobic conditions the dichloroethane derivatives are formed, which are easily transformed into derivatives of acetic acid [35].

The mechanisms of physiological action of herbicides on the human body and plants are significantly differing. Thus, 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) have herbicidal properties to a lesser extent than 2,3,7,8-tetrachlordioxydibenzodioxin (TCDD), which is associated as an admixture, characterized by extremely high toxicity. The toxicity of this substance is 500,000 times higher than the one of the herbicide itself. If the content of TCDD in the herbicide is even 0.005 mg/kg, this concentration cannot be considered environmentally harmless. TCDD in any natural environment is characterized by exceptional stability.

There is a current historical fact [48]: to avoid dust at horse races, 10 m^3 of technical oil was splashed onto the ground of a hippodrome, in the small Missouri town of Times Beach. Several days later the hippodrome was covered with dead birds, and a day after that three horses and a rider fell ill. 29 Horses, 11 cats and 4 dogs died within one month. After 3 months, several more adults and children fell ill, after which the authorities were forced to carry out a special investigation to establish the true cause of what was happening. The fault turned out to be dioxins and furans, the concentration of which in the ground of the racetrack reached 30-53 mg/kg. The technical oil was a waste from 2,4,5-trichlorophenol – an intermediate product in the production of 2,4,5-T. This substance, which is a defoliant, is known as the "Orange reagent", which was the cause of the disaster in Times Beach.

Dipyridyls, for example, the herbicide paraquat induce the formation of blisters and ulcers upon external contact with the skin. When ingested, it damages the kidneys and liver, and then causes fibrotic changes in the lungs, leading to death. Pyrethroid pesticides are synthetic analogues of the widespread insecticide pyrethrin, a compound isolated from chrysanthemum.

The most powerful decontamination potential of almost all contaminants structures are demonstrated by microorganisms of different taxonomic groups: bacteria, fungi, actinobacteria. By analogy with microorganisms, plants have the ability to assimilate toxic compounds of anthropogenic origin, and through hydrolytic and redox enzymatic reactions by degrade, i.e., neutralize them, bringing the carbon skeleton structure of toxic compounds to ordinary cellular metabolites or to water and carbon dioxide. Being completely natural, this way of detoxification of toxic organic structures, based on their metabolic transformations in plants and microorganisms, is the friendliest for the improving the multifactorial biological environment, that has been created by *Worldbiome*. The carbon atoms making up the backbone of the contaminants structure, products of intracellular degradation of toxic compounds (resulting in decarboxylation) making up the backbone of the contaminants compounds, are used by plant and microbial cells as material in the constructive synthesis of cellular compounds.

2.5 Organochlorine toxicants

Organochlorine toxicants, in addition to chlorine-containing pesticides, also include dioxins, polychlorinated biphenyls, chlorinated derivatives of methane, ethane, ethylene and others. Chlorine atoms, which are part of these, significantly enhance their resistance to the action of oxidases (cellular oxidative enzymes system) involved in the processes of both abiotic oxidation and detoxification of organochlorine toxicants. In addition, most compounds containing chlorine are characterized by high lipophilicity, due to which they easily reach the cell membrane barriers and accumulate almost unhindered in various organs, including the nucleus, causing irreversible changes [49-53].

2.6 Dioxins

This group of compounds unites polychlorinated dibenzodioxins and dibenzofurans. Dioxins are highly toxic substances with teratogenic, mutagenic and highly carcinogenic character of action [54-56]. In the environment, dioxins are always presented as a complex mixture of congeners and isomers. Dioxins are formed as a result of technological processes of chemical enterprises that produce chlorine, organochlorine pesticides, polychlorobenzenes, chlorinated alkanes and alkenes. In the process of electrochemical production of chlorine, during the interaction of the carbon anode, chlorine and oxygen of the air, dioxins are produced, which are present in the form of impurities in the formed gas, almost simultaneously undergoing chlorination.

The pulp and paper industry is characterized by an exceptionally high ability of environmental pollution with dioxins, in which the mandatory stage is the wood processing with chlorinated reagents in order to remove lignin and the rest of the phenolic part. In this case, a large amount of dioxins is formed. The same thing happens in paper production when chlorine or chlorine compounds are used as bleaching agents.

Dioxins are also formed at high-temperature chemical processes (including garbage incineration) in which organic and inorganic compounds with one or more atoms of chlorine participate [57]. These are also the processes of incineration of municipal solid waste, road transport. 1,2-Dichloroethane is added to fuel in order to reduce lead accumulation inside the engine running on leaded gasoline.

Dioxins, like other polychlorinated compounds, are expose high resistance to intracellular transformation under both, biotic and abiotic conditions. Having a carcinogenic effect and toxic nature of action on living organisms, dioxins pose a real threat to the environment and human health. In case of contact with the skin, they cause chloracne – a disease that is characterized by particularly severe skin damage, because of which non-healing ulcers remain for a long time. Dioxins also cause diseases that damage the endocrine system, disrupt the function of the glands involved in sexual development, and have a detrimental effect on the development of the embryo. Under the influence of dioxins, immunodeficiency develops in the body, resulting in increased susceptibility to infectious diseases.

Due to the exceptional molecular stability of the structures, dioxins are very difficult to biodegrade. Their complete mineralization is possible only in a special case, thanks to the joint actions of anaerobic and aerobic bacteria. It has been established that there is a bacterium capable of destroying these toxicants; this is the anaerobic bacterium *Dehaloccocus* sp., which removes chlorine atoms from the dioxin molecule by reducing dehalogenation [133]. In this case, *p*-dioxin is formed, which is converted under the action of the enzymes: dioxygenases and hydrolases, resulting in cleavage of aromatic core and forming standard cellular metabolites. In eukaryotic organisms, the effect of the dioxins decomposition was found in some strains of basidial fungi, representatives of genera *Phanerochaete chrysosporium* [134]

Some representatives of soil mycelial fungi and actinobacteria are exceptionally sensitive to dioxins. The absence of these microorganisms in the soil could be used as one of the signs of bio indication of dioxin contamination.

2.7 Polychlorinated biphenyls

Polychlorinated biphenyls are a group of compounds characterized by particularly high level of toxicity [57]. Polychlorinated biphenyls (PCBs) combine more than 20 especially toxic compounds. All polychlorinated biphenyls are characterized by exceptionally high thermal stability, do not burn, and are therefore used in electrical engineering, printing, in the production of paper, ink and paints. In the form of additives against ignition, they are used in transformers and technical oils, various heat-transfer liquids, plastics, in packaging materials, as composite fragments of pesticides. Polychlorinated biphenyls practically do not dissolve in water and are characterized by a high boiling point [58]. Despite this, these compounds (PCBs) are abundant in the environment. Due to the exceptionally high stability of their molecular structures in natural conditions, these toxicants remain unchanged for a long time, and due to their high lipophilicity, they are easily accumulated in plant and animal tissues, from where they enter the food chain and pose a great danger to human health.

The stability of polychlorinated biphenyls is largely determined by existing of halogen atoms in their molecular structure. If their molecule contains 30% or less chlorine of total mass, biphenyls are less stable, much more biodegradable and more easily could be removed from the body than biphenyls, in which chlorine content is no less than 60% of the total molecular mass.

2.8 Chlorinated alkanes and alkenes

Among distributed in environment the toxic derivatives of hydrocarbons, chloro-substituted alkanes and alkenes should be noted, which are tetrachloromethane (CCl_4), dichloromethane (CH_2Cl_2), chloroform ($CHCl_3$), dichloroethane ($CH_2Cl–CH_2Cl$), vinyl chloride ($CH_2=CHCl$), trichloroethylene ($CCl_2=CHCl$), tetrachloroethylene ($CCl_2=CCl_2$), etc. These compounds are used in large quantities in organic synthesis both as solvents and as reagents. Chloralkanes and chloralkenes are volatile compounds; their water solubility and volatility are much higher to be compared to the corresponding hydrocarbons.

Trichloroethylene remains unchanged for several months in the soil. It has been established that poplar, aspen, willow, clover, alfalfa, rye, sorghum and some other plants actively absorb and decompose trichloroethylene and other chlorinated aliphatic hydrocarbons. Finally, a part of absorbed trichloroethylene (depending on its concentration in plant cell) undergoes mineralization [53]. Toxic effect of trichloroethylene on the body is similar to carbon tetrachloride. Because of transformations, the formed trichloroacetaldehyde is characterized by mutagenic properties. This compound causes unnatural structural changes in DNA molecules.

Carcinogenic properties of vinyl chloride, the monomer of polyvinyl chloride, have been many times confirmed [53]. This polymer is especially widely used in industry. Linoleum, washable wallpaper, artificial leather, plastic bottles and many other polymer products are made of it.

The vast majority of toxic compounds of the anthropogenic origin are characterized by the ability of active migration in all natural ecosystems.

2.9 Migration of toxicants

Getting in biosphere, toxic compounds migrate between different niches of environment. This is due to the characteristic tendency of substances to be spread in ecosystems, provided by physical, chemical and biological factors, in particular:

– physical-chemical properties of toxicants as molecular mass, water solubility, hydrophobicity, the presence of reactive functional groups (the coefficient of substrate partitioning between nonpolar and polar solvents –*н*-octanol and water, – designated as K_{ow}), vapor pressure – determines the toxic substances volatility
– physical processes of mass transfer of substances, such as adsorption, desorption, diffusion, convection, dispersion, dry and wet precipitation, etc.
– chemical processes, in particular as oxidation, hydrolysis, photolysis, conjugation of toxic compounds or their derivatives with natural raw materials, etc.

– geographical processes of substance circulation, e.g., atmospheric transport (precipitation, wind, hurricanes, floods), ocean flow, river transportation, etc.
– biological processes involved in the global circulation of substances in nature. Such biological transfer ways include bio concentration, bio multyplication, bio accumulation, bio transformation, bio degradation, biotic transfer of substances, etc.

The initial stage of toxic compound dispersion is escape from the zone of their initial occurrence. The rate of this process depends on the method /technology associated with the handling of the chemicals (for instance, in the case of pesticide application, it is very important to know how it was dispersed – from the soil or from an airplane). Geographical factors are important they determine the tendency of the toxicant to spread, as well as fugacity, i.e. the tendency of substances strive to come out of the phase in which they exist.

The stage of toxic substances release from the area of their existence is followed by further heterogeneous distribution in adjacent ecosystems. The most important stage in the distribution of toxicants is the abiotic and biotic transfer of substances between natural environments – soil, water and air, also determined by a number of geographical, physical, chemical and biological factors. Among the wide variety of locally operating ecological technologies designed to eliminate the effects of toxicants action, preventing their spread outside of place of their location, the degradation metabolic potential, primarily characteristic of microorganisms and plants, is especially important. Due to which microorganisms and plants are possessing by unique potential to use in constructive synthesis of regular cellular metabolites the atoms of carbon and other elements liberated during cellular metabolism – toxic compounds degradation process.

The great majority of toxic nature compounds are characterized by different migration ability in separate ecological niches.

In the process of soil contamination with toxic compounds and the possible long-lasting nature of their action, adsorption processes play an important role. Due to the different adsorption capacity of the components, the toxicants trapped in the soil are distributed unevenly. Basically, they are adsorbed on lipophilic organic soil material, by the minerals (clay) layer, and also covalently bind to humic components. In the process of desorption, salt solutions of soil do not completely extract the products of the reaction of toxicants with the humic fraction from the soil, as well as the molecules of toxicants embedded in the layered structure of clay minerals or located in the space of humic macromolecules. Adsorption significantly slows down the mass transfer of dissolved chemicals, which is the main driving force of toxicants migration in the soil. High soil porosity, large molecular sizes, small concentration gradient, etc., are factors that slow down diffusion. Local soil pollution persists for a long time. The reasons for this are both the high adsorption capacity of soils components and the physical-chemical properties of the toxicants themselves, in some cases having extremely high resistance in the natural environment.

The migration of toxic compounds from soil to water is widely spread, highly important natural factor. This process also largely determines the degree of groundwater purity. In the soil, toxicants in most cases are subject to partial or complete transformation by soil microflora, enzymes of exudates of the plants root system, as well as under the influence of sunlight, air oxygen and water itself. Soil minerals (for instance, metal oxides – iron, aluminum, etc.) often serve as catalysts for such transformations.

Binding to humus occurs mainly due to the polar functional groups of toxicants (hydroxyl, amine, carbonyl, carboxyl, etc.). These functional groups, on the one hand, increase the polarity of toxicant molecules and thereby contribute to the formation of hydrogen bonds and Van der Waals attractive forces between the toxicant and organic soil material, and on the other hand, contribute to the covalent binding of toxic compounds with humus components, such as humic and fulvic acids.

Another reason of prolonged soil contamination is the chemical stability of the toxicants themselves. The resistance of toxicants is largely determined by their chemical structure. The stability of aliphatic hydrocarbons is also determined by their resistant to possible soil transformations, by increased number of substituted groups and radicals in the aromatic core, enhancing their molecular stability. Among other compounds of toxic nature, halogen-substituted aromatic hydrocarbons are the most stable, especially in cases when the substituents are chlorine or fluorine atoms.

The total removal of toxic compounds from the environment proceeds only by their mineralization, i.e., when the organic substrates are decomposed to CO_2, H_2O, HCl, NH_3 and some other inorganic substances. Such degradation of toxicants in soil can be accomplished via both abiotic and biotic pathways. Abiotic transformations include photochemical and chemical oxidation-reduction reactions, as well as partial hydrolytic splitting of toxicant molecules. Soil organic matter, metal oxides and minerals participate in these processes. The main pathway of full destruction of toxic organic compounds is their biological mineralization, i.e., degradation by microorganisms and plant root systems, capable of using these substances as nutritional sole carbon source.

The stability, i.e., the persistence of toxic compounds, is estimated by the time needed for transformation of no less than 95% of the toxic molecules. The average period for dioxins, of their 95% decay is 14-15 years, for polychlorinated biphenyls (PCBs) – 10-12 years, for DDT – 4 years, heptachlor – 3.5 years, lindane – 3 years, etc. Widely distributed *sim*-triazine pesticides (simazine,triazine, promethrin) persist in the soil about two years, carbamates – from some months to 1 year, and organophosphorus insecticides (chlorophos, metaphos, etc.) and phenoxyacetic acid derivatives – 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), etc., are destroyed within several months.

Among the minerals, clays are strong adsorbents, in which the ability to adsorb toxicants increases in the following order: kaolin < bentonites < ilites. In humus, in addition to adsorption, often occurs the binding of toxicants by hydrogen and covalent bonds, so toxic substances trapped in the soil are more actively retained by organic material. For example, it has been shown that 29% of the pesticide amibene (2,5-dichloro-3-aminobenzoic acid) introduced into the soil binds to humus, and 9% is absorbed by clays [41].

The rate of microbiological decomposition of toxicants in soil primarily depends on a number of external factors, such as oxygen concentration, temperature, value of pH, the presence of inorganic and organic nutrients of the corresponding microflora, etc. The most significant of all this factors is the oxygen content in soil that limits the intensity of growth of both aerobic and anaerobic microorganisms.

In the aquatic environment, the diffusion of pollutants occurs quite quickly. Local pollution affects not only individual reservoirs or sections of the river where wastewater enters, but ultimately the seas and oceans. The most significant damage to marine ecosystems is caused by pollution from petroleum hydrocarbons. On average annually, about 1.3 million tons of oil and petroleum products fall the seas and oceans [59]. Oil penetrates into different ecological niches in the following ways:

- natural seepage from underwater plumes accounts for almost half of the total oil contamination.
- common tanker operations such as loading and unloading of oil;
- cleaning of tankers, cisterns and reservoirs from oil and oil products;
- tankers wrecks;
- leakage from oil pipelines. Despite its high viscosity, oil penetrates deep into the soil, reaching groundwater and spreads over long distances. For this reason oil

is very often found in coastal wetlands and seas;
- loss of oil during drilling of oil wells located in the open sea;
- rivers polluted with oil or oil product from sewage;
- wastes from refining of crude oil.

Not only direct contact with petroleum products is fraught with harmful consequences for any living organisms. Interaction with hydrocarbons dissolved in water, in particular aromatic and polycyclic hydrocarbons, which quite easily penetrate into the organisms of water inhabitants, is particularly dangerous. It should be noted that these toxicants could cause undesirable changes in the physiology and overall viability of marine organisms, even at very low concentrations (10^{-7}%): at concentrations of 10^{-6}-10^{-5}%, a serious violation of physiological activity is observed, and at a range of 10^{-4}-10^{-2}%, a lethal dose is reached for larvae, marine invertebrates, crustaceans, oysters, snails, shrimps and fish. Only marine plants can withstand concentrations up to 10^{-2}-10^{-1}%.

2.10 Surfactants

The problems associated with water pollution is largely caused by surfactants or detergents (tensides). In practice, they are used as cleansing agents that lower the surface tension of water; their application is accompanied with foaming [35].

Increasing demand for surfactants in industrial enterprises, as well as their intensive use in everyday life, primarily in the washing process, has led to widespread accumulations of foam in riverbeds and reservoirs. Foam hinders navigation, and the high toxicity of surfactants leads to mass death of fish. The negative experience of the use of surfactants in the 1950s compel to search biodegradable surfactants. Relatively easily degradable detergents include unbranched chain tensides, such as nonionic detergents and alkylbenzenesulfonates, which are also characterized by low toxicity to humans and fish [60].

2.11 Explosives

Organic compounds containing nitro groups are often used as explosives. Among them, the most common are 2,4,6-trinitrotoluene (TNT), nitroglycerin, hexahydro-1,3,5-trinitro-1,3,5-triazine (also known as cyclonite, hexogen, or by the British code name – RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), etc. Due to the presence of nitro groups, these compounds are highly toxic pollutants of soils and groundwater (areas of military actions, landfills, military factories and warehouses, etc.) and therefore contaminated areas necessarily require remediation.

2.12 2,4,6-Trinitrotoluene (TNT)

Highly toxic contaminant, TNT is used as an explosive compound and intermediate in the production of dyes and photographic materials. The production and use of TNT for military purposes has led to its wide distribution. This is one of the most toxic explosives in the military arsenal. The massive use of TNT has left behind thousands of hectares of chemically contaminated land. TNT mobility in the soil is limited due to its active adsorption on soil particles.

TNT penetrates the human body through the digestive tract, skin, lungs, and distributing primarily in the liver, kidneys, lungs and adipose tissue, stimulating chronic diseases [61]. TNT is classified as a carcinogenic substance belonging to group C.

In microorganisms, degradation of TNT is carried out in the following ways:

– through elimination of nitrogen in the form of nitrite and further reduction of nitrite by nitrite reductase to ammonium under aerobic conditions

– through reduction of nitro groups by bacterial nitroreductase under anaerobic conditions and subsequent aerobic degradation of amino derivatives.

Individual strains of *Pseudomonas* and some representatives of mycelial fungi can use TNT as a source of nitrogen. For example, the strain *Pseudomonas* sp. JLR11 assimilates almost 85% of TNT nitrogen, including nitrogen of this compound in the composition of other cellular metabolites [62]. This can serve as a classic example of how an atom, which is a toxic factor of a xenobiotic, is used as a building material for the synthesis of intracellular metabolites in the process of metabolism typical for microorganisms, as a result of partial degradation of the toxicant. According to reliable data, TNT can serve as a terminal electron acceptor in the respiratory chain and its recovery is associated with the synthesis of ATP [62].

Phanerochaete chrysosporium and some other basidial fungi completely mineralize TNT. Lignolytic enzymes of basidial fungi, peroxidase, laccase and other oxidases, especially effectively degrade and mineralize TNT molecules.

Some plants also have the potential to absorb and perform TNT transformation. The aquatic plant fescue (*Myriophyllum aquaticum*) and seaweed hara (*Nitella* sp.) are used for the remediation of soils and waters contaminated with TNT. The enzyme nitroreductase, which is directly involved in the reduction of TNT nitro groups, has also been identified in other seaweed, ferns, in monocot and dicot plants, perennial trees (poplar) [63]. Transgenic tobacco (*Nicotian atabacum*), in which the bacterial nitroreductase gene is expressed, has acquired the ability to degrade TNT in quantities required for the neutralization of heavily contaminated military polygons [64].

The variety of chemical structures encountered during soil remediation requires the use of qualitatively novel phytoremediation technologies. The presence of different types of soils and correspondingly contaminants of different structure and stability require special technologies for cleaning soils from toxic compounds, which in turn, creates difficulties. There is no doubt that purposeful selection of plants and microorganisms actively absorbing and assimilating toxic compounds of anthropogenic origin is the main criterion for success in remediation and monitoring of soils contaminated with anthropogenic toxicants.

2.13 Atmospheric air pollutants

Toxic compounds are getting into the air by both ways, directly from emission sources and from contaminated soil and water. The transfer of toxicants at the water-air phase partition is a dynamic process and is carried out in both directions. The process of transferring chemical compounds from an aqueous solution to the atmosphere (volatilization) and in the opposite direction (dry deposition from air to water) occurs as a result of diffusion according to general mechanism.

The rate of transfer of a chemical compound through the water-air surface is directly proportional to the difference of their concentration in the both phases. The flow of substances is directed towards the decrease of its concentration. In the case of chemical contamination of water reservoirs, the concentration of the toxicant in the aqueous solution decays exponentially with time. This is due to the fact that air is a more open system than water, and under natural conditions the concentration of substances in the gas phase is considerably lower than in the water phase.

In the water-air system, the fugacity of toxicants almost completely depends on their volatility, which is determined by the transfer rate in the liquid and gas phases, temperature and the Henry constant (each contaminant has his separate value); the Henry constant parameter shows the ratio of the concentration of the substance in the gas and water phases.

Along with the processes of substance evaporation from water, there are also other ways for the interchange substances between these systems. These ways include wind-driven spraying of seawater, elimination of toxicants from the atmosphere by precipitation (wet precipitation). The share of the transfer carried out in this way in the interchange of chemicals between water reservoirs and the atmosphere largely depends on the geographical location and climatic conditions of environment.

The substance transfer processes between soil and air are the most voluminous in terms of the amount of transferred mass, and complex, since the factors determining the interchange between all three phases – liquid-solid, liquid-gas and solid-gas phases – are of great importance here greatly depending on environmental factors.

As in the case of mass transfer in the water-air system, the processes of substance transport from soil to the atmosphere is carried out through diffusion. The rate of volatilization depends on the molecular mass, temperature, pressure of the saturated vapor of the adsorbed substance and the rate of its transfer in the gas phase. In the case of the substances transfer between the water-air phases, the proportion of each transfer direction depends on the physical-chemical properties of the substance, the type of soil and climatic conditions.

Volatility from a wet surface of soil is much higher than from a dry one. This fact cannot be linked to co-evaporation of substances from water, as firstly, co-evaporation proceeds at higher temperatures and concentrations of contaminants than it occurs under natural conditions. Secondly, the reason for co-evaporation is interaction between the water and the evaporating substance (formation of hydrogen bonds, hydration, etc.), which is not characteristic for most contaminants. Finally, under conditions when the soil surface remains wet, the rate of volatilization of many contaminants does not change, while the water vapors rapidly saturate the surrounding atmosphere and hence its evaporation is rapidly suppressed. Therefore, evaporation of water and volatilization of chemical compounds from soil occur independently. The increase in volatility from wet soil, compared to dry one, is mainly explained by the partial desorption of chemical compounds, which is achieved by their elution (displacement) by water [65]. There is no doubt that the volatility of chemical compounds from the wet soil surface occurs mainly from the liquid phase.

Toxic compounds trapped deep in the soil diffuse towards the surface by different forces. Toxicants with high Henry constant (e.g., insecticides lindane, DDT, organochlorine solvents) move from the lower to the upper layers and their volatilization occurs in the same way as in the case of water. For substances with low Henry constant (for example, the triazine herbicide promethean), upward transport occurs due to convection and capillary forces. This effect is called "wicking" [66].

The volatilization of chemicals from the soil into the atmosphere also depends on other environmental conditions, for instance, on soil type, temperature and wind speed. Another way of substances emission from the soil into the atmosphere is their transfer with dust (wind erosion). Many gaseous substances contained in the atmosphere in above their natural concentrations are dangerous toxicants and cause serious damage to the environment. These compounds include oxides of carbon, nitrogen, sulfur; hydrogen sulfide, methane, chlorofluorocarbon, etc.

2.14 Carbon oxides

Carbon monoxide (CO)

Carbon monoxide, which is always formed by incomplete burning of carbon-containing substances, plays especially dangerous role in the air pollution. The uncontaminated atmosphere contains about 60 million tons of carbon monoxide, which is less than one thousandth of the CO_2 content in atmosphere.

The maximum amount of carbon monoxide in natural conditions is formed as a result of volcanic activity and photochemical oxidation of methane in the atmosphere. Anthropogenic emissions are another important source of CO formation. The optimum condition for fuel oxidation in internal combustion engines is reached only within a definite and fairly narrow operating regime. As a rule, this is equivalent to 75% of the engine capacity, but under other conditions, especially at idle and when starting the engine, the CO content in the exhaust gases increases significantly. In order to purge exhaust gases from CO, companies use special catalysts that contribute to the complete oxidation of fuel to CO_2. On a global scale, the CO exhausted by internal combustion engines of motor vehicles is a small part of its total content, but in large cities, in the presence of a great number of cars, and in the area of high pressure and temperature inversion, the CO content may attain dangerous concentrations.

Carbon monoxide is dangerous to humans primarily because it can bind to blood hemoglobin. Besides, CO can form highly toxic compounds – carbonyls. When interacting with blood hemoglobin, carbon monoxide, like oxygen, occupies a certain coordination position in the haem. The affinity of hemoglobin to CO is 200-300 times higher than to O_2. It was found that the concentration of CO in the atmosphere equal to 0.006% (by volume) is sufficient to bind half of all hemoglobin in the blood [35].

Carbon dioxide (CO_2)

Unlike CO, carbon dioxide is formed when carbon-containing fuel is completely oxidized. Atmospheric CO_2 is in permanent exchange with soil, water and living organisms, especially with plants (photosynthesis), as a result of which a constant CO_2 cycle is created in nature. The natural sources of CO_2 formation are volcanic eruptions, weathering of carbonaceous rocks, rotting of organic compounds (microbiological processes, biological oxidation), respiratory process, forest fires and fuel combustion. Undoubtedly, all this would lead to a catastrophic accumulation of CO_2 if there were not the processes of its fixation from the atmosphere: photosynthesis, dissolution in seawater, accumulation of carbon-rich compounds, deposition of carbon deposits of combustible minerals, etc.

A known equilibrium state has been established between the processes of carbon dioxide emission and binding in nature, which is typical for both continents and oceans. Nowadays, due to increased technogenic formation of CO_2, only part of the total carbon is included in such an interchange circulation. The unpredictable increase in the amount of burned fuel led to a noticeable increase in the CO_2 content in the atmosphere. Among other reasons, it should be noted the quantitative reduction of soils that fix CO_2 (the result of urbanization), deforestation, especially the elimination of tropical vegetation. All this, intensively carried out by *Homo consúmens*, significantly contributes to the imbalance between carbon binding (mainly biological fixation) and its emission.

2.15. Sulfur dioxide (SO_2)

Sulfur dioxide exerts a clearly expressed direct toxic effect on all organisms. In addition, the reactivity of SO_2 is significantly higher than that of CO_2. Natural sources of SO_2 primarily include volcanoes, forest fires, sea foam and microbiological transformations of sulfur-containing compounds. Sulfur dioxide released into the atmosphere can easily bind with lime, maintaining its stable concentration in the air.

Anthropogenic sulphur dioxide is formed in the process of burning of coal and oil. Another source of its formation are metallurgical processes and the processing of sulfur-containing ores. Most of the anthropogenic sources of SO_2 (about 87%) are associated with power engineering and industry. Total anthropogenic SO_2 comprises more than 90% of the sulfur dioxide existing in nature.

The average residence time of CO_2 in the atmosphere is approximately two weeks. This interval is too small for its global dispersion. Therefore, considerable differences in the content of SO_2 is observed in the atmosphere even in neighboring areas where, in one case, large and, in other case, moderate emissions of sulfur dioxide are determined. Thus, the problem of SO_2 arises primarily in industrialized areas, as well as in the nearest neighbors.

In the atmosphere, sulfur dioxide together with nitrogen oxides (NO_x) undergo a number of chemical transformations, the most important among which are oxidation and acid formation that leads to the formation of so-called "acid rain". These reactions occur in the presence of UV rays, air oxygen or ozone.

It has been estimated that 60-70% of acid rain is caused by sulfur dioxide. SO_2 and acid precipitation induce corrosion of metalware and organic materials such as leather, paper, fabric, rubber and dyes. Sulphur dioxide has a toxic action on organisms, and especially photosynthetic organisms. Hydrosulfite ions (HSO_3^-) are especially toxic for plants, since reacting with peroxides of unsaturated fatty acids in phospholipids, form radicals and destroy biomembranes [35].

Active HSO_3^* and RSO^*radicals, after damage to the membranes of chloroplasts, oxidize and decolorize chlorophyll. Besides, products of SO_2 transformation contribute to a shift in the pH of the cytoplasm to the acidic side, which results in the removal of the magnesium ion from the porphyrin ring of chlorophyll. Under the influence of SO_2, the leaves turn yellow and lose their photosynthetic potential. Sulfur dioxide diminishes the intensity of transport of substances between cell membranes, leading to leaf necrosis.

2.16 Nitrogen oxides (NO_x)

The appearance of nitrogen oxides in nature is connected with electric discharges, forming firstly nitrogen monoxide (NO) and followed by nitrogen dioxide (NO_2).

Anthropogenic nitrogen oxides mainly consist of NO and NO_2 formed by burning fuel, especially at temperatures above 1000 °C. Nitrogen oxides are also formed in the processes of nitriding, during superphosphate production, in the purification of metals by nitric acid, and in the production of explosives and smelting. The main source of NO_x release is motorcar transport. Anthropogenic contamination by nitrogen oxides typically exceeds the critical level in areas with a dense population (big cities).

Monoxide and nitrogen dioxide are involved in a number of photochemical reactions, which contribute to the formation of ozone and peroxyacetyl nitrate $CH_3COO_2NO_2$ (PAN), which are part of smog.

Nitrogen monoxide does not irritate the respiratory tract, and hence humans cannot sense it. If inhaled, NO forms an unstable nitro compound with hemoglobin, which quickly passes into methemoglobin. The Fe^{3+}methemoglobin ion cannot reversibly bind O_2 and is essentially switched out from the process of oxygen transport. The concentration of methemoglobin in the blood, equal to 60-70%, is considered lethal, but such a limiting value of this compound can be observed only in closed rooms.

Further away from the source of emission, NO is transformed into NO_2. This yellow-brown gas strongly irritates mucous membranes. Upon contact with moisture in the organism, nitrous and nitric acids are formed, corroding the alveolar walls of lungs. The walls become permeable and allow blood serum to pass into the lung cavity. Inspired air dissolves the serum forming foam, which blocks exchange of gases.

The action of ozone on the organism is similar to that of NO_2. Ozone also induces pulmonary edema, disrupts the normal movement of ciliary hairs in the bronchi that should remove foreign substances from the bronchi. All this leads to an increase in the risk of cancer.

Nitrogen oxides can directly contact plants via the atmosphere or acid rains, and indirectly affect them via photochemical transformations of active oxidizers, like ozone and peroxyacetyl nitrate (PAN).Acid rain containing nitrogen oxide seriously harms plants in similar ways to SO_2, increasing acidity. Even low concentrations of PAN, which is active under normal conditions, destroy chlorophyll, disrupting the functioning of the photosynthetic apparatus.

2.17 Smog

Smog (the word is derived from the combination of smoke + fog) is a chemical mixture of gases forming a brownish-yellow or brown mist in large cities and industrial centers. There are two types of smog [35]:

1. Smog of the London type is a thick fog with an admixture of smoke and waste industrial gases. It is formed above the cities of mean and northern latitudes in the autumn and winter as a result of a strong air contamination. The smog consists primarily of an aerosol, in which SO_2, H_2SO_4 and soot predominate
2. Smog of the Los Angeles type is shroud-like aerosol with an elevated concentration of caustic gases (without a mist), formed by the Ultra Violet radiation of the sun as a result of photochemical reactions occurring in the gas exhausts from transport and industrial enterprises. This type of smog is also called "photochem-

ical smog". It is characteristic of southern cities in summer. Nitrogen oxides, ozone, peroxyacetyl nitrate and different radicals are present in it.

Smog formation occurs in areas where anthropogenic air contamination is enhanced by geographical features of the terrain (mountains that interfere airflows) and meteorological conditions (temperature inversions in the troposphere that interfere with the distribution of gases in the vertical direction), contributing to the process of smog formation of air pollutants [67]. Smog is usually observed under conditions of weak air turbulence, light wind or calm. Smog reduces visibility, increases corrosion of metals and structures, destroys vegetation, and irritates the respiratory tract. Intense and prolonged smog can cause an increase in morbidity with a fatal outcome.

Photochemical smog has a complex composition. It is a mixture of about a hundred toxic compounds and radicals with a very high oxidizing potential. The sources of photochemical smog are mainly nitrogen oxides and volatile organic compounds (VOCs) such as ethane, propane, butane, ethylene, propene, acetylene, methanol, formaldehyde, acetaldehyde, etc. Photochemical smog also contains other secondary pollutants formed from the primary ones, nitrogen oxides, carbon monoxide, VOCs, etc.

2.18 Chemical accidents, as a source of results of toxicity of anthropogenic activities *Homo consúmens*

Industrial accidents and catastrophes, resulting in a large amount of highly toxic substances enters the environment, have become a real disaster for the *Homo consúmens* civilization. How serious and dangerous this is for the environment can be easily traced from examples of accidents with chlorine – chemical weapons of the XX century. Chlorine poses the greatest danger in a liquefied state. Gaseous chlorine is 2.5 times heavier than air. When liquid chlorine is released, the deadly zone is an area within a radius of approximately 400 m from the point of release. However, the size of this zone can vary significantly, depending on the mass of chlorine, its energy state, the nature of the emergency, geographic and climatic factors [68].

Prognoses for the nearest future indicate that the trend of the probability of chemical accidents will continue in future too. There are a number of reasonable prerequisites for such an assumption:

- increase of novel, more advanced industrial technologies are based on high concentrations energy and harmful substances

– accumulation of particularly large amounts of wastes from various industries that pose a danger to the environment
– inevitable increase of chemical production and, accordingly, an increase in the volume of production, transportation and storage of especially harmful chemicals
– desire to invest in the deployment of harmful industries on the territories of developing, technically underdeveloped countries
– other reasons.

The arenas of military actions, locations and training grounds are characterized by especially high degree of contamination with toxic compounds.

It is especially noteworthy to mention such a “peaceful” source of toxic compounds emissions as motor vehicles, which, without any accidents, daily releases an immeasurable amount of toxic compounds, products of incomplete fuel combustion, else in addition to everything, characterized by high carcinogenic properties.

Toxic gaseous emissions from plants of various profiles operating on almost any type of fuel also contribute to environmental disasters. A great environmental danger, especially in developing countries, is caused by annually increasing industrial waste, often containing toxic compounds.

The existing ecological potential of the planet (mainly plants and microorganisms) is not able to neutralize the annually unpredictably increasing level of eco toxicants, which spread to the entire planet over time. The constantly increasing level of toxic compounds has a significantly negative impact on nature, having an extremely negative effect on such vital biological processes as respiration, photosynthesis, fixation of molecular nitrogen, growth, reproduction and, in general, on the physiology of organisms, etc. Characterized by a rather strong mutagenic effect, increased concentrations of toxic compounds lead to the complete destruction of some species of organisms and the creation of a new mutagenic forms, often degenerative, not characteristic of nature.

The overwhelming majority of environmental studies, as one of the most likely reasons for climate change, in particular global warming, indicate a direct connection of this phenomenon with the carbon cycle. Given the close relationship between air and soil, the carbon cycle, attention is drawn to the violation of the relationship “climate-carbon cycle”, and the increasing excess of CO_2 in the atmosphere, which is not subject to fixation, creates the basis for smog and other uncharacteristic gas accumulations in the air.

The increase of toxic compounds distribution in all ecological niches, sometimes significantly exceeding the maximum permissible concentration (MPC), is largely the result of the action and lifestyle of *Homo consúmens*. This is the result of a general program of industrialization, military actions, agriculture, economic progress, industrial marketing with the aim of increasing the level of well-being, obtaining super profits for multinational companies, globalization of markets, goods, services, etc. What has all this led to?

Evaluating the historical information of humanity, has always suffered from physical disabilities caused by various reasons. Certainly, these were single cases, of course, requiring special attention. However, the current health state of *Homo consúmens* representatives is of serious concern, as indicated by the following data at the tables 8, 9: 25.3% of the world's population (with a total population of 8 billion people) or 2.001 billion people have officially confirmed mental disorders, mental retardation, and other forms of disability. This is an extremely high percentage of disability, in not comparable even with the situation of countries in the post-war years.

The state of health of *Homo sapiens*

Table 8

Types of disorders	Number of patients
Anxiety disorder	301 000 000
Depression	280 000 000
Bipolar disorder	40 000 000
Disorders of the digestive process	14 000 000
Behavior disorder	40 000 000
Substance use disorder (alcohol and drugs)	178 000 000
Total	**853 000 000**

2 - https://www.who.int/news-room/fact-sheets/detail/mental-disorders

Other forms of *HOMO SAPIENS* disabilities

Table 9

Mental retardation, types of disability	Number of patients
Blindness and visual impairment	253 000 000
Deafness and hearing loss	466 000 000
Mental retardation (IQ below 75)[4]	200 000 000
Need for a wheelchair	75 000 000
Schizophrenia	24 000 000

Autism	75 000 000
Dementia	55 000 000
Total	**1 148 000 000**

3 - https://www.inclusivecitymaker.com/disabled-people-in-the-world-in-2021-facts-and-figures/
4 - Forms of mental retardation:
1) Genetic diseases: Down syndrome, Klinefelter syndrome, fragile X chromosome syndrome, neurofibromatosis, congenital hypothyroidism, Williams's syndrome, phenylketonuria (PKU) and Prader-Willi syndrome. Other genetic diseases include Phelan-McDermid syndrome, Mowat-Wilson syndrome, genetic ciliopathy, and X-linked Sideris mental retardation.
2) Maternal infections during pregnancy.
3) Alcohol abuse, including during pregnancy.
4) Drug abuse, including during pregnancy.
5) Exposure of the mother and fetus to toxic chemicals from the environment.

According to the health state in 2000, there were 999 million people with mental disorders, signs of mental retardation and other types of disability. Thus, in a little more than 20 years, the number of such individuals *Homo consúmens* has increased by 50% on the planet. At the same time, the growth of the total population on the planet has been 29.5% (the total population of 2000 was 6,114 billion people).

GREENHOUSE **GAS EMISSIONS (CO_2), IN COMPARISON WITH THE POPULATION GROWTH**

Statistical data of the growth of planet population and greenhouse gas emissions (CO_2) in XX – XXI centuries

1930: Population: 2,085,610,000
Atmospheric CO_2 content: 307.2 ppm
CO_2 emissions: 3.9 billion tons

1980: Population: 4,434,000,000 people.
CO_2 content in the atmosphere: 339 ppm
CO_2 emissions: 19.4 billion tons

2021: Population: 7,920,000,000 people.
Atmospheric CO_2 content: 419.13 pm
CO_2 emissions: 36.3 billion tons

Initial data:

CO_2 content – https://www.eea.europa.eu/data-and-maps/daviz/atmospheric-concentration-of-carbon-dioxide; https://news.un.org/en/story/2021/06/1093592
CO_2 emissions – https://www.statista.com/statistics/264699/worldwide-co2-emissions/
https://www.iea.org/news/global-co2-emissions-rebounded-to-their-highest-level-in-History-in-2021

Thus, in less than a hundred years, the world's population has increased by about 280%, and the amount of greenhouse gas emissions in terms of CO_2 – by more than 830%. The impact of the activity of *Homo consúmens* on the ecology of the planet is reflected in Table 10:

Greenhouse gas emissions (CO_2) by economic sectors

Table 10

Industry sector	Portion of emissions of each economy sector in the total volume, %
ENERGY	**73,2**
Energy consumption in industry	**24,2**
Metallurgy	7,2
Chemical and petrochemical industry	3,6
Food industry	1
Non-ferrous metals	0,7
Paper and pulp production	0,6
Mechanical engineering	0,5
Textile industry	8,1
Other industries (mining, construction, woodworking, automobile manufacturing)	2,5
Transport	**16,2**
Automobile transport	11,9
Aviation	1,9
Shipping industry	1,7
Railway transport	0,4
Pipelines	0,3
Energy consumption in buildings	**17,5**
Residential buildings	10,9
Commercial buildings	6,6
Fugitive emissions from energy production	**5,8**
Fugitive oil and gas emissions (Accidental leakage of methane into the atmosphere during the extraction and transportation of oil and gas from damaged or poorly maintained pipes)	3,9
Fugitive emissions from coal	1,9
Energy use in agriculture and fishing	**1,7**

Undistributed fuel combustion (Emissions from energy production, including electricity and heat from biomass; local heat sources; combined heat and power generation (TPP); nuclear industry; hydraulic accumulators.)	**7,8**
PRODUCTION PROCESSES	**5,2**
Cement	3
Chemistry and petro chemistry	2,2
AGRICULTURE, FORESTRY AND LAND USE	**18,4**
Pastures	0,1
Arable land	1,4
Forestry	2,2
Agricultural crops burning	3,5
Rice cultivation	1,3
Agricultural soils (use of nitrogen fertilizers)	4,1
Livestock and manure	5,8
Waste utilization	**3,2**
Wastewater	1,3
Landfills	1,9

5- https://ourworldindata.org/emissions-by-sector#citation

With the growth rates of the previous century maintained, we will meet the end of the XXI century with a world population of no less than 18 billion and an almost completely poisoned atmosphere. Awareness of the dangerous consequences of a developed civilization based on technogenic principles and maximum satisfaction of their needs has been discussed for a long time. Back in 1820, J. Lamarck wrote: "...It seems as though the man is destined to destroy himself after having made the globe uninhabitable...".

2.19 Environmental consequences of *Homo consúmens* behavior

Domestic animal

Much more data could be presented on this issue, which has become characteristic and sometimes surprisingly close relations of *Homo consúmens* with a variety of animals. Not being able to present even a small part of these relationships, the subject of discussion, within the framework of this monograph, will be the closest domesticated animal species, the number of which is increasing unpredictably, and this has become a separate widespread industry.

Obviously, this is one of the most difficult issues facing the *Worldbiome*: we are talking about pets. Undoubtedly, even in some small deviations from the existing reality, there will be outraged opponents who categorically object to any changes. Frankly speaking, and according to the authors, there is no single concrete solution and the reason is that pets, especially dogs and cats, have long turned into family members, without which the life of these people (owners) is almost unthinkable. Indeed, they give a lot to the owners, often sharing their loneliness, are the reasons for fun for adults and children and are characterized by a number of other properties that have earned the love and respect of the owners. Dogs perform a number of important tasks: they guard houses and other objects, find drugs, are indispensable during hunting for animals and birds, and, finally, are the most loyal animals to their owners. In view of these and a number of other properties, both dogs and cats have become the closest creatures to humans. Despite all this, it would be useful to provide some data related to the costs of keeping pets.

It was only in the XIX century when cats were just beginning to be considered as pets in the USA and Europe. Previously they were considered biological specimen for medical research and mousetraps. In the 30s of the XX century, there were about 70 million dogs and 62 million cats in the world (official statistics do not indicate exact data). With the growth of population over the past years and decades, the number of cats and dogs has increased tenfold! Nowadays, people spend a lot of money on the care and nutrition of their beloved pets.

The volume of pet food production in 2021 amounted to 34.165 million tons. Studying the impact of the pet food industry on the world's fish and seafood stocks, experts have estimated that 2.48 million metric tons of fish are used annually by the industry for the production of cat food. Every year, an area of more than 485 thousand km^2 is used for the production of dry food for cats and dogs, which exceeds the total area of countries such as Germany, Switzerland, the Netherlands and Denmark. Every year, the global production of pet food releases 106 million tons of carbon dioxide equivalent into the atmosphere. Every year, pets consume up to 100 million tons of fresh meat and fish.

On average, 3.7 kg of pesticides are used per hectare of crop area. The area of land used for growing pet food is 49 million hectares. 181,300 tons of pesticides were used to produce 29.33 million tons of feed in 2020.

Today, the total number of domestic dogs in the world amounts to 471 million, domestic cats – 373 million, the number of stray dogs – 429 million, stray cats – 227 million. Total – 1.5 billion animals. This number is given only by countries that register pets, and there are less than half of them. Yes, it should be recognized that dogs, cats, and other pets undoubtedly adorn our lives, and their number is constantly increasing all over the world, but there is another side to this issue: the environmental catastrophe impending on the planet forces us to carefully investigate all possible expenses related to both food and ecology. The authors see their task in presenting this information to society and in discussing the possibility of reducing the number of pets. Data on the number of dogs and cats in most countries of the world are given in Table 11.

The number of domestic and stray dogs and cats

Table 11

Name of the country	2022		Name of the country	2022 (year of)	
	Cats, million	Dogs, million		Cats, million	Dogs, million
USA	103,3	82,2	Philippines	0,5	23,3
India	14,8	79,1	Japan	7,3	12,0
Germany	17,8	10,7	Sri Lanka	no data	3,0
Greece	3,9	1,6	Iraq	no data	1,5
China	140,6	117,2	Iran	no data	1,2
Mexico	10,3	28,6	Pakistan		3,2
Great Britain	12,3	8,7	Israel	2,0	0,5
South AFRICA	4,6	10,3	Singapore	0,09	0,09
Russian Federation	44,1	23,4	Indonesia	30,0	0,5
Norway	0,8	0,5	Turkey	4,1	1,22
Finland	0,9	0,8	Azerbaijan	no data	1,0
Latvia	0,4	0,3	UAE	0,14	0,08
Sweden	1,4	0,9	Ethiopia	0,25	5,0
Slovenia	0,5	0,3	Kenya	no data	6,0
Romania	4,3	4,2	Egypt	5,0	15,0
Hungary	2,3	2,9	Zimbabwe	no data	0,7
Ireland	0,4	0,5	Malawi	no data	1,5
Estonia	0,3	0,3	Uganda	0,6	1,3
Lithuania	0,6	0,6	Tanzania	no data	2,3
Slovakia	0,6	0,9	Ivory Coast	no data	1,5
Austria	2,0	0,8	Nigeria	no data	5,0
Portugal	1,5	2,1	Madagascar	4,0	
Switzerland	1,6	0,5	Morocco	36,0	3,0
Luxembourg	0,1	0,1	Other African countries	no data	62,8
Netherlands	3,1	1,9	New Zealand	1,2	0,9
Ukraine	7,4	5,1	Australia	3,8	5,3
France	15,1	7,6	Canada	8,1	7,7
Italy	7,9	8,3	Puerto Rico	1,0	0,5

Bulgaria	0,8	0,8	Costa Rica	0,37	2,3
Spain	3,8	6,7	Dominican	no data	1,9
Poland	6,8	7,8	Haiti	no data	1,0
Belgium	2,1	1,3	Guatemala	no data	5,0
Czech Republic	1,1	3,2	Cuba	no data	1,0
Denmark	0,7	0,6	Uruguay	no data	1,7
Malta	0,3	0,1	Chile	0,3	3,6
Cyprus	2,0	0,3	Bolivia	no data	1,9
Other European countries	4,7	3,5	Peru	3,6	12,0
Bhutan	no data	0,1	Colombia	2,1	5,0
Cambodia	no data	5,0	Venezuela	no data	3,5
Myanmar	no data	4,0	Brazil	22,0	55,0
Brunei	no data	0,4	Argentina	3,0	9,6
Malaysia	0,8	0,4	Other countries of the world	28,17	174,2
Vietnam	3,8	5,4	**Total world**	**600,0**	**900,0**
Bangladesh	no data	1,6			
Nepal	no data	0,1			
Thailand	4,0	8,5			

***Homo sapiens* waste**

According to the UN, 2.4 billion people in the world do not have regular access to basic sanitation services, including toilets or equipped cesspools (https://www.un.org/development/desa/en/news/sustainable/world-toilet-day-2019.html). In a number of countries, the lack of centralized sewerage contributes to the spread of many diseases and the lack of normal water filtration systems forces about 2 billion people to drink water every day that does not meet basic requirements.

Urine and feces of some animals and humans have long been widely used as fertilizers with low levels of heavy metal and pesticide content. Organic compounds, mainly cellulose (only ruminants digest cellulose), excreted with feces are degraded into low-molecular weight metabolically active components in the natural environment, under the influence of soil microflora. Urine is rich in nitrogen, whereas feces are rich in phosphorus, calcium and organic matter. Vital elements for the growth and development of plants are nutrients, the amount of which depends on the composition and their amount in the food consumed by a person. As the human skeleton and muscles reach mature size, nutrients accumulate in the body only in small quantities.

Common sewer drains, including industrial waste, does not allow humanity to use the nutrient released by the *Worldbiome*. All this turns into silty sewage sludge. The cycle of turnover of carbon and other components in nature is disrupted, and these components are taken in one place (soil) and fall into a different one. Thus, the possibility of using part of biological resources is lost or significantly reduced.

The existing world water supply system does not provide for the separation of potable water (intended for drinking and cooking) from technical water (for personal hygiene, washing, etc.). As a result, according to some data *Homo sapiens* is deprived of the total savings of clean potable water resources in the amount of 3449.38 km^3 per year or 3.449 quadrillion liters per year.

Methane emissions from animal farming

One of the main sources of methane formation and distribution is animal husbandry. Not touching all animals, which certainly have a definite contribution to the ecology of the environment, we will provide the data on cattle and pigs, as the most common animals in the world. The total number of cattle in the world amounts to 1.5 billion. Considering that one cow produces approximately 400 liters of methane gas per day, the total annual volume of anthropogenic methane emissions is 219 bln m^3. Globally, pigs produce 42 bln m^3 of methane per year. There are 677.6 million pigs in the world. Each pig releases about 170 liters of methane daily.

Poultry wastes and emissions

Unlike herbivorous mammals, birds produce methane in a small amount during digestion, and poultry feces are considered to be of poor quality, despite they are used in the production of gas in anaerobic technologies.

In greenhouse gas inventories, the share of emissions in poultry farming is estimated at 800 million tons of CO_2 due to the manure produced by birds and the energy spent on their breeding and maintenance. One chicken produces 45 kg of manure per year on average, while one turkey – 54 kg. There are 26 billion chickens and 462 million turkeys in the world. Accordingly, chickens produce 1.17 billion tons of manure per year, turkeys – 24.9 million tons. In total, poultry waste amounts to 1.19 billion tons per year, the amount of which, of course, should be taken into account.

***Homo consúmens* Food**

The total world production of food for human and animal consumption in 1975 (FAO data) amounted to 1,752,060,000 tons, in 2022 – 8 685 520 000 tons. For about a 50-year period, the growth of food products amounted to 396%.

The production of food for direct human consumption in 1975 amounted to 1,348,850,000 tons, in 2022 – 5 266 690 000 tons. Growth – 290%. All the above data clearly indicate that the increase in population and, accordingly, food is coordinated. Trying to explain the reasons for the lack of food for most of the *Homo sapiens* population, it should be noted that:

1. The unequal distribution of the planet's food resources is one of the main causes of hunger and poverty
2. Mass migrations and endless wars have led to the displacement of the population and abandoned agricultural lands
3. Insufficient or abundance of precipitation is one of the serious reasons for a significant decrease in yield
4. Insufficient or abundance of precipitation is one of the serious reasons for a significant decrease in yield.

Diseases of *Homo consúmens* caused by excessive consumption of substandard food

According to the WHO, 8.75% of the world's population, 693 million people as of 2022, suffer from obesity. In this case, when analyzing this important factor characterizing the well-being of society, it should be noted that not only the quantity, but also the usefulness of the food quality and the content of uncharacteristic, sometimes toxic components, are important factors determining the process of obesity. 50 years ago, this figure was 2.58% of the population that is 105 million people. To date, the number of overweight people has increased 6.6 times.

Obesity, diabetes mellitus, cardiovascular diseases, hypertension, chronic heart failure, oncology, allergies and other systemic diseases – under the general name "metabolic syndrome" – is the main "disease of civilization" of *Homo consúmens*, generated from overconsumption of substandard food. All this leads to a depletion of the *World-biome* resources. Through excessive food consumption, the habitat of living matter on planet Earth, and primarily the soil, is rapidly degrading. The desert is advancing along the entire front of "cultivated" soils at an average speed of 10 square kilometers per year. This is already a definitely serious danger to a person's life potential.

The farming system used by most countries will lead to serious consequences, such as in the USA. Methods of soil protection farming were developed in the USA back in the 30s of the XX century. According to the memoirs of American scientist Hugh Hammond Bennett: On May 12, 1934, a huge dust storm swept across the southern Great Plains. Hugh Bennett, director of the Department of Interior's Soil Erosion Service, described the storm this way: "This particular dust storm blotted out the sun over the nation's capital, drove grit between the teeth of New Yorkers, and scattered dust on the decks of ships 200 miles out to sea. I suspect that when people along the seaboard of the eastern United States began to taste fresh soil from the plains 2,000 miles away, many of them realized for the first time that somewhere something had gone wrong with the land. It seems to take something like a disaster to awaken people who have been accustomed to great national prosperity, such as ours, to the presence of a national menace. Although we were slowly coming to realize that soil erosion was a major national problem, even before that great dust storm, it took that storm to awaken the nation as a whole to some realization of the menace of erosion."

After such a "natural phenomenon", soil erosion was declared a national disaster, and Hugh Bennett was appointed director of the US Department of Soil Conservation. It took only two or three years for the United States to create new tillage tools and switch to a system of soil-protective agriculture everywhere.

The area of agricultural land on the planet is estimated at 47,954,190 km^2 or 36.90% of the total land area of the Earth. Damage assessment of arable land in the world vary, but the United Nations Convention to Combat Desertification (UNCCD) reports that 52% of the land that is 25 million km^2, used for agriculture is seriously degraded. This figure is larger than the combined territories of Russia and the rest of Europe. An additional 120,000 km^2 of land is degraded annually. https://www.fao.org/in-action/action-against-desertification/overview/desertification-and-land-degradation/en/#:~:text=Land%20degradation%20affects%20almost%202,is%2023%20hectares%20per%20minute!.

The soil is a non-renewable resource, which means that it can be fully remediated in at least 20-25 years. In case of critical ecological situation (pollution), the structure of distribution of agricultural arable soil requires serious attention.

- 80% of all agricultural land or 38,362,741 km^2 is engaged in animal husbandry
- 70.45% of all agricultural land (33 786,813 km^2) or 26% of ice-free land (129,949,283 km^2) is allocated for grazing
- 9.54% of all agricultural land (4,575,928 km^2) is allocated for the cultivation of animal feed.

Dynamics of transport growth for the period 2021-2030

As it was, previously discussed vehicles, being an ecological scourge of modern civilization, emit highly toxic gases: carbon monoxide (CO), benz[a]pyrene, benzanthracene, carbon dioxide (CO_2), as well as other ones in the environment. The number of vehicles worldwide is growing unpredictably fast. Table 12 shows data indicating the existing number of vehicles and the forecast for their increase by 2030. Undoubtedly, the rise in vehicles will result in more environmental issues, such as the increased release of hazardous gas emissions.

Vehicles on a worldwide scale

Table 12

Transport	Quantity as of 2021	Estimated quantity as of 2030	Growth, %
Road transportation			
Motorcycles/mopeds/tricycles	200 000 000	351 200 000	175,6
Cars	1 042 274 000	1 229 883 000	118
Cargo vehicle	389 174 000	652 106 000	167,6
Buses	3 000 000	3 607 500	120,6
Agricultural machinery	1 148 000	1 550 948	135,1
Automotive construction equipment	503 125	693 300	137,8
Railway transport			
Locomotives, motor railcars	558 270	658 755	118
Railcars	3 536 105	5 000 054	141,4
Metro (train)	110 383	140 191	127
Air transport			
Aircrafts	440 000	638 000	145
Helicopters	56 200	84 490	150
Water transport			
Cargo water transport	73 255	106 222	145
Passenger water transport	7 567	10 969	145
Auxiliary water transport	39 177	56 808	145
Military transport			
Aviation	53 418	83 703	156,7
Armored vehicles	384 963	603 231	156,7
Automotive equipment	12 395 832	19 424 265	156,7
Fleet	3 352	5 251	156,7
Total:	**1 653 757 647**	**2 265 852 687**	**144**

Ecology of the textile industry

Among the different industries, the textile industry due to its serious negative ecological inputs requires serious attention. The textile industry consumes a huge amount of natural resources and ranks second in the world in terms of water pollution. The dyes used make water drains highly toxic, which contain sulfur, naphthol, nitrates, acetic acid, chromium compounds, copper, arsenic, lead, cadmium, mercury, nickel, cobalt. Table 13 below provides data on environmental damage caused by the textile industry.

Greenhouse gas emissions and water consumption in the textile industry

Table 13

Stage of textile production	Greenhouse gas emissions, million tons of CO_2 equivalent	Water consumption, bcm
Fiber production	510	54,64
Fabric preparation	931	39,71
Fabric making	395	18,64
Fabric coloring and finishing	1178	47,15
Clothes making	224	13,08
Distribution	41	0,2
Utilization	11	0,12
TOTAL	**3290**	**173,59**

Thus, the contribution of the textile industry to global warming amounts to 3290 million tons of greenhouse gases in terms of CO_2.

Existing technology of *Homo consúmens* thinking way formation

Ecological problems must be discussed across the nation, including special educational courses in all of the university programs, and a wide array of television programs should be dedicated to these problems as well.

Manipulation of mass consciousness in the consumer civilization occurs through television and other media. The market of goods, services, the market of brands, television – they seek to chain citizens to channels advertising all this. Advertising on television creates a virtual world of consumer values. At the same time, people understand that they live among fictional images, but a certain part obeys agitation. By 2010, every fifth person on the planet had a TV, so there were more than 1.4 billion TVs.

From 2018 to 2021, the global production of televisions was annually more than 200 million units per year. Thus, it can be assumed that there are now about 3 billion televisions of various generations on the planet.

Considering the rate of moral and physical depreciation of televisions, models produced prior to the 80-90s of the twentieth century can be found in museums or at individual antiquity lovers. Accordingly, 3 billion televisions are models released in the late 80s and early 90s. Older models (before plasma TVs) make up no more than 10% of the total. Percentage of modern LED and OLED in the current world is about 55-60%, their predecessors – plasma TVs – about 35-40%.

For information. According to experts, the total global energy consumption of televisions of different models amounts to 290.7 billion kW, that is, 290,722.5 gigawatt-hours per year.

This amount of electricity (290 billion kWh) enough to supply power for three years to cities with a population of bigger than 15 million people, such as Istanbul (Turkey), Buenos Aires (Argentina), Calcutta (India), Rio de Janeiro (Brazil). For comparison: one nuclear power plant generates an average of 40 billion kWh per year, whereas a megacity consumes approximately 140 billion kWh per year.

If the indirect cost of extracting metals that are used in the production of televisions and the cost of electricity from the television manufacturer itself is added to the figure of the direct electricity consumption of televisions, this figure will increase by at least 10%.

The products of the film industry, the main categories of which are films, music videos, sports and TV programs shot in studios, are also associated with serious energy costs. Undoubtedly, all costs associated with advertising a variety of products should be regulated, and significantly reduced. The production of a film costs humanity in terms of greenhouse gas emissions, ranging from 391 to 3370 tons of CO_2, which correlates to an average electricity consumption of about 10,000 kWh.

Of course, there are other factors in the life and activities of *Homo sapiens* that affect the ecology and the waste of food products negatively, but in this overview, we tried to outline the most important aspects for the general discussion.

III. A VARIETY OF ENVIRONMENTAL TECHNOLOGIES

The concept of "technology" covers an extremely wide range of activities. Any sequence of actions leading to the achievement of a specific goal (obtaining a product, solving a problem, establishing a mechanism of action, creating an algorithm, developing a training methodology, etc.) can serve as an example of technology. The list and the colossal set of technologies of various profiles is so large that it is impossible to even enumerate all of them on the scale of a large monograph. Each technology is dedicated to a specific task that led to its creation. Among the diverse technologies with a solid history measured over centuries, relatively new innovative ecological technologies have appeared, the essence of which is to protect actively the environment, but the desired effect for the population of *Homo sapiens* has not been achieved so far.

As practice has shown, diverse environmental technologies provide protection of the environment major components – the atmosphere, water bodies, and soil, from the negative effects of pollutants (solid dust particles, liquid aerosols, gaseous substances, often of anthropogenic origin, having toxic and carcinogenic properties), physical fields (noise, vibration, electromagnetic, ionizing and thermal radiation), biological contamination (pathogenic forms of bacteria, mycelial fungi, viruses).

Since the second half of the twentieth century, the development of technological processes in all directions has developed at an unprecedented pace. This revolutionary technological leap was based on the high level of scientific knowledge already achieved by that time, both in the field of natural sciences, engineering and humanities. One of the significant achievements of the last century in the field of scientific and technological progress should be considered the creation of a fundamental scientific and practical base for the development and production evaluation of a wide variety of technological processes.

Among the most important environmental problems of our days, new problems dictated by time have arisen: the fight against the increase in the concentration of CO_2 and methane in the atmosphere, as the main causes of global warming. The change in the carbon cycle is significantly associated with the increased formation of anthropogenic carbon dioxide to a critical level exceeding the photosynthetic potential of the planet. The permanently growing emission of methane, being the result of an increase in the scale of industry, endless wars and agriculture, contributes significantly to global warming, and it turns out that the contribution of methane to warming on the planet was 25% higher than expected. It is important to note that greenhouse gases – methane and carbon monoxide – in the atmosphere can exist unchanged for up to ten years, while the "service life" of nitrogen dioxide (NO_2) is counted in decades.

In the XXI century, the development and evaluation of the effectiveness of innovative environmental technologies having acquired a vital character has become an active field of activity of scientists and specialists of various profiles – politicians, sociologists, engineers, physicists, chemists, farmers and others. When comparing environmental data concerning the main components of nature, it becomes quite clear that atmospheric air, soil and water are closely interrelated ecological niches that determine the degree of each purity.

Biological self-purification of the soil occurs by gradual removal (mainly degradation by rhizospheric microorganisms and the root system of plants) of uncharacteristic substances. This process takes quite a long time, while the speed of pollution processes in the modern technogenic environment significantly exceeds the speed of processes of biological self-purification existing in nature. In this regard, a large number of technologies have been developed that, according to a variety of principles, clean the soil from toxic and other uncharacteristic compounds. At the same time, it is undoubtedly necessary to use the most environmentally targeted technologies that are safe for other organisms, considering both their effectiveness and the financial costs associated with their use.

In 2017, the UN introduced the "Fight against Plastic Pollution" program, [69] the purpose of which is to provide conditions for the environment without pollution due to extremely widespread plastics, and this program is increasingly unfolding. 260 million tons of plastic are dumped annually in the world, 10% of which ends up in the World Ocean. More than two hundred biological species of the marine ecosystem suffer by mistaking plastic for food. Every year, 1 million birds and 400,000 mammals die of this reason. In 2017, the EuRICAA (Europe, Russia, India, China, America, and Africa) project was presented as a worldview ecological revolution. A New Eco Sapiens Code of Civilizational Standards offers ways to resolve this issue. Despite of some achievements in the field of environmental technologies based on completely different principles, in some cases, deeply scientific in their idea and content, both traditional and new innovative environmental technologies are not able to decrease environmental problems on a global scale. The human mentality – to stay at home in any clothing, but to look good and leave a good impression in society – is manifested by *Homo sapiens* in relation to the ecology of the planet.

In order to reduce greenhouse gas emissions, the company SÃO PAULO – (BUSINESS WIRE) – PepsiCo, one of the largest food and beverage producers in the world, has implemented an innovative project at its snack production in Sete Lagoas: a solar thermal power plant that captures sunlight and converts it into energy for heating production water. Thanks to this technology, it has become possible to reduce natural gas consumption by 140,000 m^3, which in turn reduces greenhouse gas emissions (by a total of 280 tons). This is equivalent to planting almost 18,000 trees.

The second largest oil state in the United States is preparing to introduce a bill related to reducing carbon emissions [70]. This will allow reducing greenhouse gas emissions, including carbon dioxide and methane, by up to 50% in the second largest oil-producing state of the United States.

The industrialization of the planet requires the search for new sources of energy, or another alternative is a significant reduction in the *Worldbiome* population. Despite the high capacities that provide energy to more than half of the world, there are different opinions about the actual operating of nuclear power plants.

To date, there is no identified alternative, comparable in scale of usage to non-renewable, fossil energy sources (oil, coal, peat, shale). The first serious data on innovative, environmentally friendly technologies are emerging. One of the most important non-traditional sources of additional energy is solar one. As is known, solar energy has not only outstripped wind energy but also, what is very important, has even partially replaced the use of fossil fuels. According to Bloomberg, unsubsidized solar installations, which are appearing in increasing numbers, are becoming more competitive compared to natural gas and coal. Investments in solar energy are annually and significantly increasing. A huge part of these technologies is very effectively used by China, which is rapidly developing solar energy, being a leader on a global scale. It should be assumed that environmentally friendly technologies for obtaining energy from renewable sources would certainly receive further fundamental development and a real assessment of their potential in the near future. The development of solar energy is possible if the necessary resources are available. Rare earth metals are part of the main elements and components of solar panels, which casts some doubt on the cost-effectiveness and environmental friendliness of their mass use.

Among other possibilities, technologies being studied for the use of hydrogen, an environmentally friendly fuel with practically unlimited reserves, should be noted. Hydrogen is one of the most promising types of alternative fuels, which is explained by its exceptional thermophysical properties, especially important for mobile equipment. For instance, its use in a gas or liquid state in piston engines can be implemented based on the following conceptual approaches:

(1) the use of hydrogen as an additive to the main fuel (gasoline and diesel engines) (2) a hydrogen engine with mixing and forced ignition of a hydrogen-air mixture (3) hydrogen engine with direct injection of hydrogen.

The addition of hydrogen to traditional hydrocarbon fuels improves the environmental and power performance of a piston engine. Undoubtedly, the use of hydrogen engines in terms of increasing engine power, the inexhaustibility of reserves of this fuel, and especially its environmental characteristics, represent advantages that should be widely used in the near future [71].

A wide variety of technologies based on physical (including mechanical), chemical and biological principles has been known for decades, both in the conventional and patent literature [72-75, 31, 32].

The potential of widespread ecological technologies, principles of ecosystem restoration and methods of environmental protection are briefly reviewed below. A separate chapter is devoted to discussing the possibilities, scope and prospects of a new innovative biological ecological concept developed by the authors for 30 years.

In particular, quite effective technologies of catalytic and plasma chemical methods of air purification are well known [76-78]. Along with the existing environmental technologies of a broader profile of environmental purification from pollutants – electrostatic, sorption, catalytic, chemical – plasma-catalytic technologies have been actively discussed in recent years. Plasma is a gas with ionized molecules. It consists of many components including electrons of various energies, positive and negative ions. The degradation process of substances uncharacteristic for nature occurs according to the following principle: polluted air passes through a gas-discharge reactor, in which their destruction occurs under the action of low-temperature plasma. The technology of the catalytic method of air purification is based on the deep oxidation of conversion products formed as a result of the passage of air through a plasma chemical reactor. The technology is designed for the action of a low-temperature catalyst, which works effectively in the temperature range from 20 to 50 °C due to the plasma-chemical action mechanism.

In addition to traditional and innovative environmental technologies, a number of considerations are expressed that are of a social nature, but related to environmental problems. The French philosopher Bruno Latour [79] proposes a new concept of political ecology. However, according to a number of authors, the idea of political ecology, put forward as a fundamental political principle of environmental protection, has no prospects. The persistence, strength and desire of *Homo sapiens* to consume – takes its toll. Therefore, politics cannot protect the interests of nature, as it was created to protect the interests of man, who is its subject.

3.1 Physical technologies

Within the framework of this publication, only a brief overview of the physical principles used in ecology is possible. Even to briefly characterize the physical principles used in ecology, it should be described the complex of technological processes used in practice. Therefore, it would be discussed the main principles of physical technologies being in use.

Physical technologies are based on physical principles such as the action of different rays, the adsorption of technogenic compounds on special sorbents, physical separation, ion and molecular exchange, etc. [80-81]. According to qualitative indicators, physical technologies are quite effective, but require certain instrumental costs (specific materials and equipment), which often makes their use expensive and, accordingly, unprofitable. However, due to their high efficiency, these metodologies are used in conditions where other environmental technologies cannot give the desired result or highly purified water is needed.

Mechanical ecological technologies, representing a variety of physical technologies, are based on purely mechanical effects – pressing, filtration, precipitation, etc. – and are highlighted separately. Mechanical-type technologies include the creation of purification technologies for running polluted water, wastewater; precipitation and pressing of waste, which subsequently facilitates their processing; the use of the principle of mechanical flocculation; the use of mechanical filters of different sizes, differing in power and conductivity. Technologies of this type are actively used at the initial stages of water purification and contaminated aqueous solutions. It should be noted that mechanical filters are quite effective and their effectiveness is based on the ability of different types of sorbents to remove toxic, gaseous pollutants (e.g., sulfur dioxide), as well as small solid particles from industrial smoke.

Physical technologies include the collection of contaminated ground and its disposal. This is the first successful environmental operation that our ancestors used to eliminate environmental pollution. Since the main disadvantage of this technology is that it does not lead to rapid remediation of contaminated ground, soil or any other buried object, but by such action, the contaminated object can be isolated from the environment or a separate ecosystem. There is a risk of spreading any form of buried contamination (e.g., by leaching (extraction), microbiological conversion, changes in the temperature of the microenvironment, etc.). Despite this, hundreds of years ago, when the level of environmental pollution was insignificant and the content of toxic and radioactive compounds was negligible, the contaminated soil was remediated under the influence of the soil microflora surrounding the buried object [82]. In addition to microorganisms, the root system of plants also actively participates in this process. Since burials were relatively rare, the use of this technology did not have any crucial impact on the environment at both, the global and regional levels. Such primitive ecological biotechnology, although rare, is still in use today, especially in developing countries. Undoubtedly, there are more effective and more modern physical technologies for soil purification.

Electrochemical cleaning of soil. Electrochemical purification technology is used to remove chlorine-containing hydrocarbons, various petroleum products, and a number of other foreign compounds containing the phenolic ring from soil. During the movement of electric current through the soil, water electrolysis, electrocoagulation, electrochemical oxidation and electroflotation reactions takes place. According to this technology, the degree of oxidation of phenolic components reaches 90%. The qualitative level of soil decontamination as a result of electrochemical cleaning is approaching 100%, minimal level corresponds to 95%. The use of this technology also allows removing from the soil heavy metals such as mercury, lead, arsenic, cadmium, and cyanides. The disadvantages of the technology include the high cost of the process ($ 100-250 per 1 m^3 of soil).

Electro kinetic technology of soil remediation is used to purify the soil from cyanides, petroleum and petroleum hydrocarbons, heavy metals, and organic chloride elements. The types of soils, in relation to which electrokinetic purification can be successfully applied, are clayey and loamy soils, partially or completely saturated with moisture. The efficiency of electrokinetic technology ranges from 80 to 99 percent. The cost is 100-170$ per 1 m^3 of soil.

Heat treatment of contaminated substrates refers to technologies that are intensively and widely used and described in details [80-81]. The object intends to be remediated (contaminated soil, ground or any other object) is treated under high temperature conditions within 1000-1200 ° C, during which the evaporation of toxic compounds, burning and, accordingly, cleaning of the object occurs. Then the soil is cooled, the gases released are collected and used for other purposes. As for the ground (soil), most often it is returned to its original place. This technology is used when the soil is contaminated with stable heat-resistant toxic compounds (for instance, organochlorine pesticides, polycyclic aromatic hydrocarbons, etc.). On an industrial scale, in case of a large mass of soil or ground, the use of this technology is significantly limited. This technology has another negative side, namely, in the process of heat treatment in the processed soil (ground), soil microorganisms of all taxonomic groups characteristic of that type of soil completely die, and it takes up to ten of years to fully restore the soil microbiota, depending on the type of soil and the climate of the region. At the same time, the technology itself is quite expensive, since the transportation of in big quantities of soil biomass and creation of a high-temperature regime during the process for heat treatment of large volumes of soils require considerable energy costs.

3.2 Chemical technologies

All plants associated with the production or processing of chemicals, regardless of their size, existing technology and manufactured products, as well as the emission of pollutants, pose a serious danger to the environment. Any chemical, metallurgical, oil refinery, no matter what modern technologies and equipment it is equipped with, still pollutes the environment with various toxic compounds during production.

Despite the fact that the concentration of pollutants in gaseous emissions and wastewater discharges is insignificant in well-equipped chemical plants, constantly carried out production processes still contribute to the emission of a substantial amount of toxic compounds into the environment. Waste from chemical plants, their storage and processing deserve special attention. Even in the presence of appropriate treatment systems, all plants of these types remain very dangerous to the environment [83].

Chemical technologies of soil purification from toxic compounds are based on the use of surfactants solutions, organic solvents or active oxidants (active oxygen and chlorine, alkaline solutions). These technologies are used to clean the soil from a variety of unnatural components, including hydrocarbons.

Among the negative aspects of chemical methods of soil remediation, it should be noted the destruction of microflora in the treated segment of the soil, long periods of their use (on average from one to four years) and a large amount of washing, polluted water, which necessarily should be processed (additional cleaning).

In order to have at least an approximate idea what kind of environmental problems have chemists to be solved in reality in the process of row material treatment, shows the following example. According to existing data, with an annual amount of processed minerals equal to 100 billion tons, almost 10 thousands of different chemicals are getting in environment, including 60 million tons of synthetic components; 700-800 million tons of mineral fertilizers; 5 million tons of pesticides; 50 million tons of iron; 500 billion m^3 of processed liquid mass [83]. In addition, up to 10 billion tons of solid residues remain because of production process, i.e., 10% of the initial amount of fossils. This is how the average data for processing natural resources look like.

One of the most widespread chemical environmental technologies is the stabilization/immobilization of toxicants in the soil. This technology takes place directly at the site of contamination and does not require soil transfer. Because of the technological process, components capable of binding toxic pollutants are introduced into the contaminated soil. Eventually, complex compounds are formed that are less toxic and, due to their low solubility, are not able to spread widely in the soil. An example is the addition of phosphates to soil containing lead. Stabilization or immobilization technology is often and successfully used in soils contaminated with heavy metals [84].

The sorption technologies are well known, they are based on adsorption or absorption of solid or gaseous technogenic chemicals by their interaction with various chemical compounds, leading to their binding, both in aqueous solutions and on solid absorbers. Heavy metals bound by non-toxic chemicals significantly reduce the toxicity of the formed compounds *in situ* conditions. In some cases, technologies based on chemical and electrochemical separation are used [85].

In general, chemical technologies currently represent the list of the most widely used environmental technologies in practice.

3.3 Biological technologies

Biological technologies are based on biological principles representing a relatively new generation of environmental technologies, the improvement of which is still actively ongoing [86]. As instruments, for their realization, are used microorganisms, plants, viruses, and enzyme preparations. The implementation of environmental technologies, that have common principles with natural processes for the transformation of toxic waste into safe compounds, is a task of exceptional importance. The vast majority of them are based on chemical and biological processes occurring in nature, such as conversion, transformation, hydrolysis, oxidation, synthesis, and mineralization of contaminants.

Ecological biotechnologies are still in the phase of development and improvement, mainly based on the duplication of natural principles. Their practical use does not disturb the ecological balance in nature. It should be noted that environmental biotechnologies have a relatively low level of material costs, including cost price, and technological simplicity of processes.

The authors' investigations, reveal the essence of modern ecological biotechnologies, that consists in genetically determined ability of some organisms (annual and perennial plants and microorganisms of different taxonomic groups), to transform and decontaminate organic contaminants, and in most cases to mineralize them, forming natural inorganic compounds (such as H_2O, CO_2, etc.), participating in the cell requirements and photosynthesis process [72]. A characteristic feature of plants is the absorption and accumulation of heavy metal ions in the intracellular space. This genetically determined feature of a number of plants is one of the main foundation of biological remediation process.

Microorganisms, especially bacteria, degrade organic compounds much faster than any other organism, degradation of their carbon skeleton, and the use of carbon atoms are directed to effective synthesis of regular cellular metabolites [72]. All these reactions are based on the action of enzymes and mainly are carried out based on oxidative degradation of contaminants. Eukaryotes (plants and mycelial fungi) and prokaryotes (bacteria) according to their differing degradation potential effectively eliminate organic toxicants from the environment by deep degradation of their structures, taking part in the characteristic cycle of the carbon turnover.

Plants are characterized by the most extensive, widespread contact with toxic compounds (soil, air, water) [87, 88, 1]. As it is established, they adsorb foreign compounds, after which their further penetration into the intracellular organs of plants occurs. After a certain time required for the adaptation and mobilization of the corresponding enzyme systems, chemical transformations of these compounds begin (oxidation, reduction, hydrolysis, etc.). The initial stage is devoted to the mobilization of plant cell structures: the induction of enzymes involved in the detoxification process, as well as formation of additional energy required for the conversion of toxic compounds. Almost all intracellular plant structures take part in the multi-stage process of detoxification of toxic compounds.

The regular process of metabolism in plants, in comparison with microorganisms, proceeds relatively slowly. During the process of organic compounds degradation, mainly oxidative decarboxylation of the carbon skeleton of organic toxicants occurs – a complex and multi-stage process, which significantly increases the time required for neutralization of toxic compounds [1]. According to experimental data, the process of degradation (or conversion) of stable toxic compounds in plants cell, or their mineralization, can last from hours for several days, depending on the structure of contaminants.

Phytoextraction. The technology of cleaning soils contaminated with non-characteristic substances by phytoextraction is the cultivation of certain plant species on contaminated soil sites. Phytoextraction shows clearly expressed positive results in cleaning the soil from copper, zinc, nickel, cobalt, lead, manganese and chromium. At the end of the phytoextraction process, the plants should be collected and burned. The ash obtained after burning is considered hazardous waste and is a subject to appropriate disposal.

Bioremediation. Represents the technology based on targeted plant breeding and enhancing the activity of the rhizospheric microflora of the soil by introducing into the soil active strains of microorganisms of certain taxonomic groups (bacteria, mycelial fungi, actinomycetes) isolated from the soil and taking part in the degradation of toxic compounds. In the process of bioremediation, due to extensive contact with toxic structures, plants also play an important role. Their joint participation/action in bioremediation processes determines creation a new ecological concept based on the synergistic action of microorganisms and plants.

In case of a relatively low level of pollution, in order to reduce or stop the flow of pollutants from the source of their formation and prevent their spread, as well as long-term preservation of normal natural balance (equilibrium), the use of selectively chosen herbaceous, shrubby and woody plants is especially effective [87]. As has been repeatedly shown, the joint action of plants and microorganisms has a synergistic nature. This means that the effectiveness of their combined action is much higher than the arithmetic sum of each individual action. This process, based on the joint action of plants and microorganisms, is called bioremediation. Currently, bioremediation is recognized as one of the most promising and "friendly" environmental technologies.

The use of these technologies is recommended for any types of soil, even if the concentration of contaminants exceed the MPC (maximally permissible concentration) by 50 times.

3.4 Water and soil remediation technologies

3.4.1 Water

In the XXI century, the water resources of potable water with a low concentration of salt are already significantly superior to oil and gas in vital importance. Today, water is an extremely important social, economic and even political substance that largely determines the health of society, the existence of a normal environment and the development of all types of industries. Unpredictable population growth, intensive urbanization, transport, energy, constantly developing agriculture and industry are the main reasons leading to a catastrophic reduction in the world's freshwater resources. In some decades, water of natural origin on the planet will turn into an exceptionally scarce product. This conclusion allows analyzing the scale of the world's freshwater resources, in comparison with the volume of untreated wastewater, exceeding the natural potential of its self-purification. On all continents of the planet, there are countries having a certain supply of the natural fresh water, and countries that do not have freshwater sources. Water, as already noted above, is one of the most important vital components. For the existence of all non-halophilic organisms and the vast majority of industrial processes, fresh water is required, the lack of which is already an acute shortage, which is especially felt in at least 40 countries that occupy about 60% of the world's land area. The above-mentioned data allows calculating the level of the existing global shortage of fresh water [16, 17, 90].

According to the salt content, water is classified into several categories. According to the salt content, water is classified into several categories. The first one, much bigger than any other, is the saltiest water from the ocean, containing up to 40 grams of salt per liter (in ocean water, in average about 35-40 grams per liter). Lakes, rivers and underground water bodies are, for the most part, characterized by much lower levels of saltiness from 2 grams of salt per liter up to 10 grams.

A completely different situation is with the supply of drinkable fresh water, which should contain less than 1 gram of salt per liter and the amount of which is only 2% of the total amount of water at all salinity levels. For humanity, the supply of fresh water is the most important and increasing problem, requiring special attention [16, 17]. In addition to NaCl (table salt), the main components of seawater are halides and sulfates of K^+, Mg^{2+}, and $Ca2^+$ cations. Some of them, such as bromine and iodine, are even extracted from seawater on industrial scale. This does not exhaust the content of chemical compounds and other individual elements in seawater, among which phosphorus, rubidium, iron and zinc should be distinguished by the amount of their content.

The analysis of the sources of seawater pollution makes it possible to highlight of such industrial enterprises the cause extremely unusual changes to the composition of seawater in large quantities. First, these are enterprises for the processing and use of oil. Water transportation of oil, due to permanently happening crashes, is also connected with a very serious pollution source of water with highly toxic hydrocarbons. There are many other sources of seawater pollution with toxic compounds of different structure and stability pollutants. As a result, seawater without special treatment cannot be used to solve a number of vital and even industrial requirements.

Despite this, the enormous supply of seawater creates the need to consider it as the most real potential substance with constant, averaged characteristics (chemical composition). Seawater, due to the colossal number of dwelling halophilic organisms, including microorganisms, as well as influence the powerful natural factor – solar energy, the oxidative potential of the global aquatic ecosystem, has a tremendous ability of self-renewal. This means that the ocean water over time is able to return to its natural state [73].

Water desalination techniques and technologies are also commonly referred to as demineralization or deionization. As noted above, according to the sanitary and hygienic requirements for potable water, the salt concentration in it should not exceed 1.0 gram per liter, which in rare cases, as an exception, is allowed up to 1.5 grams per liter. However, in some regions of the planet, the concentration of salt in groundwater already exceeds this indicator. Approximately the same pattern is observed in many lakes and reservoirs. Lake Baikal in Siberia, which is a huge reservoir of fresh water with a volume of 23615 km^3, being the largest freshwater basin in the world, is considered to be a unique case.

A number of the most commonly used water desalination technologies [73,16] include heat treatment, membrane technology, chemical electro dialysis methods, ion exchange technologies, and various combinations of physical and physical-chemical methods [73,16]. With the exception of some cases, none of these technologies is used on a large industrial scale. The difficulties of practical application consist in the complex designs of devices and special installations required for technologies, the usage of various ingredients and high financial costs. Despite this, they represent a rather extended theoretical basis for the development of new innovative technologies.

Salt-water heat treatment, as a simple technology, is widely used. Such treatment is the transfer of water from a liquid state to a vapor one with subsequent condensation. The disadvantage of this technology consist in evaporation with steam from seawater organic compounds, with low boiling points. That is why the following step is to perform thermal treatment of seawater in combination with other technologies, which leads to an increase in pure water quality, but simultaneously is increasing the cost of water with a low salt concentration.

For desalination of water in industrial conditions, the method of reverse osmosis and electro dialysis is also used both separately and jointly.

The use of the ion exchange method is advisable in the case when the salt concentration does not exceed 2 grams per liter. In addition, small-scale semi-industrial technologies are based on reverse osmosis methods, especially when high purity water is required. In special cases, deionization methods are used in conjunction with the technologies listed above to obtain high-purity pyrogenic water.

The method/technology of water treatment with ultraviolet rays gives the positive effect relatively rare at low concentrations of salt in water [73, 16]. However, the presence of organic matter in large quantities in some cases significantly limits the use of this method.

The ion exchange method of water purification is also quite common and is used for deionization of water intended for industrial purposes. Partial desalination of water is achieved by Na^+ cations, which cause softening of seawater. Replacing calcium and magnesium cations with sodium and/or hydrogen ions lowers water hardness.

Due to the selection of appropriate ion-exchange resins in this process, it is possible to ensure complete desalination of water with the separation of all macro- and microelements. Desalination technologies on an industrial scale can be used both in single-stage distillation plants and in multi-stage ones to obtain water of a high degree of purity.

In addition to desalination of any source water, special attention is paid to its purification from foreign impurities [17, 96]. As a rule, water treatment with chemical reagents is used for this purpose. Based on the level of water pollution indicators, specially selected chemicals react with impurities present in the water (chemical compounds or elements) and are discharged as a precipitate. Rigid (solid) sorbents of various types are also used to remove impurities. It should be kept in mind that the chemicals used to treat potable water, on the one hand, reduce the hardness of water, and on the other hand, are not completely harmless to human health. From a practical point of view, the use of chemicals is technologically relatively simpler; therefore, water treatment with chemical reagents is often preferred. Based on sanitary and hygienic requirements, the almost absolute antimicrobial properties of most chemicals are certainly important. The technology of chemical treatment of water with any chemical reagent is selected depending on the results of the preliminary analysis, which should carried out in order to determine the type of contaminant, its concentration and the amount of chemical reagent required for purification.

On an industrial scale, the following substances are most often used as oxidizing agents: oxygen, ozone, potassium permanganate, chlorine gas, chlorine dioxide, and hydrogen peroxide. Each of these sanitary compounds has both, advantages and certain disadvantages. Various parameters for evaluating chemical oxidants should be taken into account such as: the amount of reagents required per unit volume of water, the reaction efficiency – the completeness of removal of undesirable components, the time required for the reaction, the cost of the process. As a result, all activities is evaluated by the cleaning efficiency and the cost of the process. During the use of chemical methods/technologies, in order to achieve maximum effectiveness of removing an undesirable component, only a very small excess amount of reagent is needed to be added to the treated water.

Oxygen is most often used as an oxidizing agent. Oxygen concentration has an impact on quality. Consequently, when cleaning water, the amount of dissolved oxygen should be systematically monitored. In addition to oxygen, hexavalent chromium, which is an allergic compound, is subject to control in the used water, and its removal from water intended for any purpose is absolutely mandatory.

In addition to sodium, potassium, calcium and magnesium salts, water (natural or processed), necessarily includes salts of iron, aluminum, and boron. For potable water, the removal of iron compounds is also a prerequisite. Methods based on chemical oxidation are quite effective for this purpose. The reaction proceeds quite quickly, iron compounds in the form of oxides precipitate, and could be easily separated by filtration.

For sanitary and hygienic water purification, the most common reagent is chlorine. This reagent neutralizing bacteria and viruses in water are the most commonly used compounds for the biological disinfection of water. At the same time, it should be noted that chlorine as a chemical is a dangerous compound, its transportation, storage and use require compliance with special safety rules. Chlorine as a chemical component has a quite wide spectrum of action. Depending on the concentration, chlorine acts not only on bacteria and viruses, especially when being used in excess, but also changes the chemical composition of water. Chloroform and chlorophenol are often detected in chlorinated water, which must also be removed. In a number of industries, the concentration of chlorine in used water is allowed from 2 to 5 milligrams per liter of water.

Nano filtration [93] is distinguished by its versatility and allows removing color and halogens connected with organic impurities without using harmful reagents. Although it requires the use of multi-stage pre-treatment, this technology is effective in removing chlorine residues. The technological processes of water purification include the use of different filters and coagulants. If special requirements are imposed on the purity of water, before ultrafiltration microorganisms, reverse osmosis or some other purification steps are used for additional water purification. Due to the large number of preparatory stages, nanofiltration is an expensive method of water purification and is used only for special-purpose water.

The technology of ozonation in water treatment differs from all chemical technologies in that it does not have any toxic or other effect on the chemical composition of water at any stage of use. Approximately an hour after water treatment, ozone evaporates from its surface without any processing. Although it requires rather cumbersome installations, the transportation of which are associated with certain difficulties, this is a well-tested, environmentally friendly technology. Classical, traditional chemical methods of water purification (chlorination, ozonation) to this day, are actively used in practice.

The development of new industries associated with the modern civilization of *Worldbiome* consumption has led to the emergence of many new chemical compounds polluting the environment, which has caused the appearance of new uncharacteristic compounds in potable water. For example, perfluorooctanoic acid, polyfluoroalkyl compounds, polychlorinated biphenyls (PCBs), ammonium ions, heavy metals, in particular ions containing hexavalent chromium, polycyclic aromatic hydrocarbons, new pharmaceutical, veterinary drugs, new forms of surfactants, new pesticides and other substances whose existence has not been earlier detected in water.

Recently, due to increasing distribution, special attention has been paid to perfluorooctanesulfonic acid (PFOS), which is a typical surfactant (Figure 13).

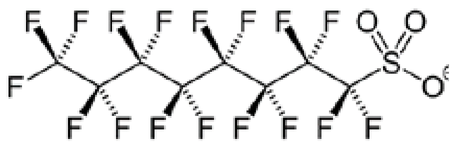


Fig. 13. Structure of the PFOS anion

Intramolecular chemical bonds of PFOS are very strong, which determines the high stability of this compound. Therefore, getting into the water, the PFOS anion practically does not undergo biotic and abiotic transformations. The high surface activity, which is much higher in PFOS than in similar surfactants with a hydrocarbon chain, allows PFOS to spread rapidly in the environment and easily accumulate, penetrating into living organisms, overcoming membrane barriers. Numerous data confirm the carcinogenic properties of PFOS. Once in the body, PFOS causes endocrine disorders, a sharp decrease in the functions of the immune system, a delay in physical development and growth. The removal of such compounds from potable water is necessary and requires the use of appropriate technologies [83, 16, 17, 96].

Discussing the efficiency of water treatment with chemical reagents it should be noted that being in use, chemical technologies allow for the selective removal of undesired chemical components from water, increase water hardness. Iron ions in a soluble state, a wide spectrum of organic compounds, soluble gases, chlorine, ions containing silicon, anions – chlorides, nitrates and nitrites, bacteria, and viruses, in fact, all those components that pose a threat to human health. Therefore, water chemical purification technologies are used most extensively.

At the first stages of purification of heavily polluted water, ecological phyto- (aquatic plants and algae) and bio- (microorganisms) technologies are widely used [89, 72, 73, 94, 95].

In aquatic environments, microorganisms rapidly and actively degrade anthropogenic compounds, often mineralizing them. The process of biological purification of contaminated water could take from hours to a couple of days, depending on the structure and stability of the contaminants. Despite the wide degradation spectrum of microorganisms, the use of appropriate selectively chosen active strains of microorganisms (bacteria and, mycelial fungi), based on their ability to mineralize or transform the carbon frame of organic toxicants to the level of conventional cellular compounds or carbon dioxide and water, is an important advantage in the effectiveness of biological technologies.

Such water treatment is the first stage of purification, during which there is partial demineralization and partial or complete degradation of anthropogenic compounds in the water. The next stage of this process is most often filtering and further processing by differing method. As the industry develops and requires more desalinated water, biological technologies of water purification becoming more important and widely used. Moreover, microbiological methods of partial desalination of salty seawater have been developed, by using consortiums of halophilic (*salt* loving) and halotolerant bacteria have been selected and successfully user.

3.4.2 **Soil**

Compared to water, soil is a much more abundant and complicated complex of multicomponent, biologically active niches created by nature, having many similar characteristics to viable organisms. This is a special biological niche, covering the planet, containing a number of soil organisms with different metabolic activity [74]. Commonly, the fertility of soil is determined by climate, chemical and biological factors such as the type of soil, quantity and quality of existing microorganisms, organic matter, including specific nutrient components, reachable amount of water, cultivated annual and perennial plants diversity, etc. In addition to naturally occurring soil microorganisms, cultivated plants create a variety of rizospheric soil microorganism's diversity required for their specific nutrient needs, growth and metabolism.

Normal soils are characterized by the presence of various chemical components: metal ions, low- and high-molecular organic metabolites (proteins, polysaccharides, nucleic acids, amino and organic acids, sugars and other chemicals), various types of colloids, water, salts and other chemical compounds. Microflora and other soil organisms, together with the chemical part, are the main generators of soil productivity and ecological potential, ensuring the growth and yield of all plants. Simultaneously soil represent a multicomponent niche that is quite sensitive to changes in environmental conditions. Soil, determined by its multicomponent composition, easily and permanently accumulates any foreign (anthropogenic) factors in its structures, leading to biological imbalance [91].

Almost any industrial enterprise located near agricultural plantations negatively affects the natural processes occurring in the soil, contributing to pollution and, depending on the climatic conditions of the region, erosion, desertification, weathering, and waterlogging. As a result, the soil turns into less or completely unsuitable for the cultivation of agricultural crops. Identifying the causes of these violations and carrying out appropriate measures to remediate the polluted soil is the most important task of modern agricultural environmental science. Currently, according to the data of the UN, there are approximately 2 hectares of land per inhabitant of the planet. It should be taken into account that this area, in addition to fertile lands suitable for agricultural plantations, refers to the permafrost regions, deserts, swamps, mountain ranges and other places unsuitable for agricultural purposes, which make up about 64% of the earth's land. Thus, the importance of the condition and the scale of a full-fledged soil oblige humanity to constantly carry out special agro-remediation measures, create new environmentally friendly technologies, to care for a relatively small area of the earth's land corresponding to fertile soil in order to increase its fertility.

This is exactly what all-ecological soil remediation technologies serve, the purpose of which is the minimization or complete prevention of the above-mentioned factors disrupting the natural balance [97, 98]. Possible soil pollutions (infections) are listed below, depending on their type, climate and aggregate state:

– soil pollution by various pollutants: solid, liquid and gaseous, which include organic compounds, heavy metals, carbon oxides, nitrogen, sulfur, carcinogenic benz(a)pyrene, benzantracene, carbon monoxide and many other technogenic toxic compounds of anthropogenic origin, released by vehicles moving along highways or near locations of agricultural plantations
– excessive use and/or incomplete assimilation of new and used chemicals (organic and inorganic fertilizers, pesticides, etc.)
– hydrocarbons, other petroleum products partially transformed and settled in the soil at different depths as a result of the extraction, transportation and use of petroleum products
– toxic compounds released in large quantities by energy complexes during the burning of energy resources: gases, petroleum products, coal, peat, shale, and others.

Based on the vital importance of soil quality, various chemical, physical and biological technologies are used to reduce technogenic pollution [99-101].

The simplest are physical (mechanical) technologies, which consist in the removal (cutting) of the top layer of contaminated soil. The thickness of such a layer depends on the type and nature of contamination, on the time of action of the toxicant on the soil and can reach 2 m. The replacement of contaminated soil should be carried out with a new, healthy one, if possible. As for the cut-off layer, it is most often treated with a thermal method under high-temperature conditions (1000-1200°C), or with aggressive chemical solutions. Acids, alkalis, organic solvents are used for the decontamination of cut-off layer of soil to eliminate toxicity. In some cases, the treated soil, free of toxic components, is returned to its original place. The main disadvantage of this type of technology is the complete destruction of rizospheric microflora and all other soil organisms, which takes a long time to recover, on average at least ten years, depending on the type of soil and other climatic factors of region.

Electrochemical technology of soil purification is used mainly to eliminate petroleum products and other organic toxic compounds [99-101].

In this case, partial or complete mineralization of carbon skeleton of organic pollutant is achieved. This technology provides for the installation of specially designed electrodes in the soil with their subsequent movement to the scale of the soil as needed. This operation causes the electrolysis of water in the soil and removes toxic substances such as cyanides, cadmium, and mercury. Despite the high efficiency of soil cleaning, this technology is difficult to implement, since in addition to electricity costs, it requires special equipment, which makes technology complicated for realization and therefore is used only in certain cases.

Chemical technologies of soil remediation differ from physical ones. These technologies are based on the action of various chemical compounds capable of decomposing or binding contaminants. First of all, it is necessary to distinguish a group of chemical oxidizing agents (peroxides, metal ions with variable valence) that are capable to carry out oxidative degradation of organic pollutants, such as petroleum hydrocarbons, polycyclic aromatic hydrocarbons and others. Surfactants capable of removing the vast majority of toxic and other undesirable compounds from the soil are used for the same purpose. Other technologies use chemicals that cause precipitation of heavy metal ions and radionuclides in the form of insoluble compounds (for example, in the form of hydroxides and carbonates). Chemical technologies also provide the formation of non-toxic complexes with pollutants in the soil by addition of some special chemicals. For example, this technology is often used for the remediation of heavy metal-contaminated soils. Immobilization of cyanides, nitrates, and tetrachloride's is carried out on cement, ash, sodium and potassium silicates, bentonite, and cellulose. Assessing, the most commonly used chemical ecological technologies, it should be noted their regulatory role in still existing the ecological balance; however, it should be emphasized that the effectiveness of using technologies is permanently decreasing due to the unpredictably increasing flow of toxic compounds.

3.4.3 **Air**

According to the WHO, air pollution kills about 7 million people annually and is the world's biggest environmental health risk. Every eighth fatal case is associated with air pollution, and 9 out of 10 people in the world breathe polluted air. According to recent data, it has been found that exposure to a heavily polluted environment can increase the potential mortality from viral infections, including COVID-19. There is now strong evidence that there is a close link between global warming and the occurrence of large-scale wildfires, such as the recent fires in California and Australia, which affect many people who are also suffocated by huge amounts of smoke and polluted air.

Silicon Valley scientists developed innovative technologies to solve the growing problems associated with air quality. The Airdog Two Pole Active (TPA) technology has been developed over the past twenty years. Since the products of the Airdog TPA X series were made public in 2017, they have steadily gained popularity around the world.

Air purification

There is a wide variety of pollutants in the air, containing contaminant particles of all sizes, including chemicals such as formaldehyde, benzene, toluene, etc., as well as microorganisms and viruses, for example, e.g., the SARS-CoV-2 virus. It has been proved that improving air quality significantly reduces the risk of respiratory diseases. Air purifiers use a combination of technologies for air circulation and removal of various pollutants, ensuring healthy indoor air quality. There are several key indicators to measure the effectiveness of air purifiers.

● Clean Air Delivery Rate (CADR)

CADR is defined as the volume of airflow per unit of time required to remove all particles in a given size range. The CADR is used as an indicator of the efficiency of air purifiers. It is based on the ratio between the single-pass efficiency of the cleaner and its flow rate and is usually expressed in cubic feet per minute (CFM) or cubic meters per hour. The CADR test is used in a sealed chamber of standard volume. After the contaminant enters the room and mixes with the air space, the CADR test begins with the inclusion of the cleaner; and then the number of particles is counted at specified intervals. CADR is calculated based on the rate of reduction of the number of particles remaining in the room. The CADR value determines how quickly the room can be cleaned with this air purifier. It also determines the recommended room size for the air purifier, i.e. the size of the room that it can clean in an acceptable time. As a rule, the recommended room size in square meters for an air purifier is 1/10 of the CADR number expressed in cubic meters per hour. Similarly, CADR for various gases is defined as the airflow rate from which all gaseous pollutants are removed and is measured in the same test chamber.

● The cumulative net mass (CNM) is an indicator of the total mass of the target pollutants (solid particles and/or gaseous pollutants) that the device can collectively clean under nominal and specified conditions of the required time. This CNM index (mg) together with CADR shows how effectively the air purifier is cleaning the air. CNM can also be linked/converted to another indicator – the "Cleaning service life" (days) of the air purifier – which is important to assess the frequency of the need to change filters and clean the system. Large CNM values mean that you can change the filter or clean the electrodes less often.

● The rate of pathogens removal determines the efficiency of the cleaner to eliminate pathogenic bacteria and viruses. Air purifiers remove pathogens using two mechanisms – filtration and/or inactivation. Most airborne pathogens are adsorbed on aerosol particles. Removing these particles from the air reduces the number of pathogens in the air. Inactivation requires a physical (e.g., plasma, ultraviolet radiation) or chemical (e.g., ozone, H_2O_2) method to kill or inactivate pathogens. Specialized testing agencies can assess the rate of pathogen removal using a standard test chamber in accordance with specific testing protocols.

Variety of air purification technologies

I. HEPA

Air purifiers with a mechanical filter use fans that blow air through a corrugated fibrous filter material. The filter mechanically captures solid particles that are being accumulated on the filter. Sometime later (easy to notice visually), the filter material needs to be replaced. This is an expensive procedure. The frequency of replacement is determined by the size of the room and the level of internal pollution, as well as the ventilation rate between the indoor and outdoor air. However, the size of some pathogenic forms of bacteria, being around 700-800 angstroms, is too small to be removed, and they can pass through air filters. When microorganisms remain on the surface of the HEPA filter, even with low humidity, they begin to reproduce. This is the main source of odor from the air purifier during use. HEPA filters with a higher degree of filtration have an increased resistance to airflow; consequently, a more powerful fan with high static pressure is required. This increases both noise and power consumption.

II. Ionization

There are many types of ionizers on the market. They use a material with a low barrier potential that emits electrons when a high voltage is applied. These free electrons are attached to particles in the air. Ionizers remove some pollutants from the air, but charged particles settle on surfaces such as walls, floors or furniture. Usually, the ionizer index is too low for effective removal of pollutants in the room. They may have limited effects on pathogens when encountered, but without proper collection, their health benefits still need further study and evaluation.

III. UVGI

UV germicidal irradiation (UVGI) is a disinfection method in which ultraviolet light is used to destroy or inactivate microorganisms by damaging their DNA so that they cannot reproduce. However, high doses of UVG have an adverse effect on health, causing cutaneous erythema (superficial redness of the skin) and a painful eye condition known as photo keratitis. UV irradiation can inactivate viral particles in the air, but has a very limited effective zone. The UVGI effect is evaluated by two factors: contact area and contact time. UVGI is effective only in the area with a sufficiently long contact time. If the air movement is carried out too quickly, ultraviolet rays will have a limited effect on the destruction of pathogens, which can retain their infectious and allergenic properties even after limited UV irradiation. In addition, if the virus/bacterium is hidden from exposure to pollutants or other objects, they are not exposed to ultraviolet radiation. Thus, when using even a strong and prolonged UVGI, but without a proper ventilation and filtration system, the rate of removal/destruction of bacteria can also be limited.

IV. Photocatalytic oxidation

Photocatalytic oxidation (PCO) is a series of catalytic materials (such as TiO_2) that can be activated by high-energy photons. PCO is used to purify gaseous pollutants and decomposes many pollutants by passing an air stream through a catalyst. PCO effectively removes volatile organic essential oils, alkanes, and other pollutants. However, the formation of by-products such as formaldehyde is a critical problem for catalytic oxidation. PCO cannot remove aerosols that carry pathogens. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/photocatalysis.

V. Electrostatic Air cleaner (EAC)

The principle of EAC air filtration is as follows:

1. The air passes through the pre-filter, which captures large particles such as hair, pet dander, etc.
2. The air enters the ionization zone. The emitter wires are under high voltage. The particles are charged by emitter wires and accelerated by an electric field between the wire frame and the collecting plates. When a charged particle moves towards the collecting plates, it collides with other dust or particles in the ion field, causing an avalanche effect, thus increasing amount of particles are charged and collected by the collecting plates
3. Charged particles and pollutants move towards collecting plates (oppositely charged) under the action of an electric field. Pollutants are collected by special collecting plates, the ions are neutralized, and fresh air continues to flow
4. The last barrier is a composite catalytic layer. It eliminates the odor and ensures fresh air supply from the air cleaner. The main advantages of EAC compared to traditional HEPA filters are, lower operating cost (no need to replace filters) and reduced energy consumption and noise generation.

EAC are effective for removing all pathogens (bacteria and viruses) from the air, which has been proven by numerous studies conducted for decades, in the USA, China and other countries.

3.5 Innovative technologies based on the action of microorganisms and plants

The basic principle of the nature's constancy and, accordingly of life, is determined by its endless renewal. Actually, all forms of living organisms (prokaryotes, eukaryotes), constituting a vast biodiversity, are subject to renewal, ranging from the most complex in morphological, physiological and biochemical terms (human, animal organisms, plants), up to the simplest microorganisms (prokaryotes, eukaryotes, aerobic, anaerobic) [102, 92]. All these makes great technological diversity and is base for innovative novelties.

The renewal and evolution of all inhabiting organisms are interconnected biological processes that ensure the permanence of the existence of life on the planet. Most commonly, genetically improvements in relation to environmental conditions or other negative factors, with a high probability, takes place during the formation of a new generation. This process, which has been going on for millions of years, continues to this day.

One of the main reasons for the constant biological improvements (modification) of organisms, and, accordingly, vital processes on Earth is nature itself, which to a certain extent is also changeable. Any, even very minor, changes in environmental conditions, whether natural or uncharacteristic toxic compounds or any other, significantly affect the physiology of living organisms, causing spontaneous mutations, violation of the main metabolic pathways, respectively affecting the synthesis of characteristic vitally important metabolites, cell morphology, etc. All these constantly, very slightly, changing, natural factors have an impact on the evolutionary processes of all forms of living organisms, affecting their genetic apparatus, very often causing irreversible transformations.

It should be noted that organisms in their diversity have different resistance to changes in environmental conditions [103]. The sustainability of the genetic apparatus to changing natural conditions is often a factor determining the evolutionary potential of organisms. Existing in nature, malleable forms of organisms (less stable), are subject to changes, including lethal end. More stable forms remain in their original state or gradually undergo sometimes even visually imperceptible changes. Such transformations include climate changes in certain regions of the planet. That occur as a result of complex high-temperature processes, taking place in the bowels of the earth, in particular, constant earthquakes, volcanic eruptions, loss of water resources, prolonged drought processes, waterlogging as a result of large amounts of precipitation and rivers overflowing on a large scale, the multiplication of pathogenic microflora accompanied by increased processes of biological oxidation, etc. Quite often, such natural transformation, are the main reason for the territorial displacement of peoples and nations.

Despite owned all the necessary technologies capable of eliminating almost any unfavorable factors for life, the inhabitants of the planet still have dark spots in the form of inconvenient regions for life. That can be explained by the lack of proper interest of the world community in the environment, mainly due to the maximum use of all natural resources for commercial purposes and, consequently, irrational use of natural resources.

It is impossible not to mention the problems that characterize the super-developed technological world, exactly what our planet is. First, concerning the biggest danger, we are talking about a constantly increasing concentration of toxic compounds of anthropogenic nature, in a number of regions of the planet, more than 30 times, exceeding their maximum permissible concentrations. There is no doubt that because of the prolonged presence of the *Homo sapiens* population under the conditions of increased environmental toxicity (concentration of toxic compounds), undesirable deviations of physiological, metabolic and evolutionary processes are possible and expected.

In some cases, the evolutionary process, being a long path of humanity transformations, leads to the creation of new, more stable forms of life, which are better adapted to existing conditions, compared with their preceding maternal forms. At the same time, it has been repeatedly confirmed [104,105,102,92] that for man, changes in environmental conditions negatively or extremely negatively affect his physiological state, contributing to a decrease in immunity, increased susceptibility to diseases, and disruption of normal metabolism. Each person is connected with the surrounding world, by food, water, air and solar energy, which determine all possible physiological changes. Another invisible connection of man with nature lies in his relationship with plants. Undoubtedly, this is the participation of plants in such vital biological processes as photosynthesis, fixation and assimilation of molecular nitrogen, purification of the environment from toxic compounds uncharacteristic of nature, and without which life on the planet would be elementary impossible.

Being a source of all kinds of food products, phytopharmaceuticals, building materials and many other important for the life products, plants make a significant, simply invaluable contribution to human existence [92,102].

Despite the different attitude of people to the plant world, which resulted in a constant decrease in plant plantations, plants still occupy more than 40% of the earth's land. Plants created and evolved by nature are the main partners of in the process of humanity formation from the primitive prototype to the modern phenomenon. Impossible to forget the historical role of plants in human life. Plants are traditionally used as a material (houses, furniture, furnishings, and all kinds of utensils, ship rigging, paper, fibers, clothing, and weapons). The wood of perennial trees as a source of energy contributed to the survival of our ancestors in the Ancient and Middle Centuries and greatly contributed to the development of the northern regions of the planet for life. Cultivated plants permanently form a harvest without which human life is unthinkable. Plants in cooperation with the soil microflora create special conditions for soil fertility and harvest, etc.

As a unique form of life, plants are characterized by peculiar metabolic pathways of metabolism, which finds expression in the synthesis of numerous secondary metabolites, including a large number of low-molecular compounds (metabolites) [92,106]. According to their functional load, a large number and variety of low-molecular weight compounds, often referred to as the group of secondary metabolites formed by plants during the process of growth and development, serve for physiological purposes and self-protection of plants from phytopathogenic microorganisms, various insects and animals.

It is known that the highest functional activity of plants is expressed in optimal for them climatic conditions. Namely this factor determines the increased activity of plants in tropical and subtropical zones that are almost ideal climatic conditions for growth and development [107,108].

However, being in any soil and climatic conditions that ensure their growth and development, plants largely retain their unique metabolic activity aimed at the characteristic synthesis of low-molecular metabolites corresponding to the plant species and regional soil and climatic conditions. In any climate zones, plants retain their potential to clean environment by both root systems and upper parts via leaves.

It should be noted that, despite the extraordinary diversity of plants, it is almost constantly decreasing under the influence of not only natural environmental changes. Obviously, one should not take into account artificially created genetically modified forms of plants, the number of which is immeasurably less than the natural forms of plants.

In general, not even all the above-mentioned exhausts the contribution of plants to ensuring living conditions. Research and practice over the past three decades have revealed another unique ability of most plants to absorb and assimilate toxic organic compounds, and in most cases mineralize them, i.e., decompose them to elementary inorganic compounds such as water and carbon dioxide [63,109-112].

The uniqueness of plants consists in difference of other organisms, being universal detoxifiers that degrade both natural and a huge number of anthropogenic toxic compounds to standard cellular metabolites, and by this way purifying from pollution all the main components of the environment – soil, water and air.

The reports of large multinational companies indicate the cost associated with cleaning the environment from technogenic compounds, determined by the use of modern environmental technologies as part of remediation measures [113]. Based on the permanently increasing environmental pollution of the planet, this cost is constantly increasing and, according to the authors' calculations for the current period, annually amounts to at least 80 billion US dollars. This does not imply that these measures completely neutralize all environmental components from foreign compounds, often of carcinogenic nature. In order to somehow stop this unpredictably growing process, or at least reduce the extremely negative impact of technogenic factors on the environment, it is necessary to operate with global innovative technologies based on the actions of biological agents, having universal character of action. Currently, plants and microorganisms are precisely such agents, covering the entire terrestrial land and living in water resources.

3.5.1 **Plants detoxifying toxic compounds**

During the last few decades, when interest in ecological biotechnologies has increased significantly and the ecological potential of microorganisms has been realized in a real technology [109, 112, 114, 49], plants have remained practically unclaimed. They were regarded only as organisms capable of absorbing and accumulating toxic compounds in the intracellular space, and it was not assumed even at the intellectual level, that plants could transform toxic compounds into harmless or ordinary cellular compounds (metabolites). Only in the beginning of 70s until 80s of the XX century, a group of scientists for the first time presented data on the possible ecological potential of plants [92, 115, 116, 109, 87].

Subsequently, these data were confirmed in a number of laboratories in different countries. Today, plants are considered as agents, based on numerous data on their ecological potential. Such data gives plants (including agricultural plantations) a global ecological character, representing a permanent ecological biotechnology. Different plants depending on their ability and specificity, significantly differ in detoxification potential; they can play the role of less active than microorganisms, but still important environmental agents. Occupying above 40% of the planet, and having well established property of contaminants detoxification, nothing would diminish their extremely important role in maintaining the global ecological balance [87, 31].

With the establishment of this fact, completely new prospects seems to be opening up in the creation of innovative environmental biotechnologies. In their essence, plants based ecological technologies being friendly to nature, and designed to purify and bring closer to nature, all components of ecosystems. Table 14 presents plants recommended for the implementation of environmental biotechnologies [89], which is not an exhaustive list of detoxifying plants and will undoubtedly expanded.

A list of plants recommended for the implementation of environmental biotechnologies

Table 14

Herbs and herbaceous plants:
Western Wheatgrass *(Agropyron smithii)*
Big Bluestem *(Andropogon gerardii)*
Sideoats grama (*Bouteloua curtipendula)*
Turnip (*Brassica rapa)*
Buffalograss (*Buchloe dactyloides)*
Bermuda grass (*Cynodon dactylon)*
Eastern purple coneflower (*Echinacea purpurea)*
Canada wildrye (*Elymus canadensis*)
Reed fescue (Tall fescue) *(Festuca arundinacea)*
Common sunflower *(Helianthus annuus)*
Italian rye grass *(Lolium multiflorum)*
Perennial ryegrass *(Lolium perenne)*
Birdsfoot trefoil *(Lotus corniculatus)*
Lucerne (*Medicago savita)*
Switchgrass *(Panicum virgatum)*
Rye (*Secale cereale)*
Solidago (*Coldenrods)*
Sorghum bicolor *(Sorghum bicolor)*
Sudan grass (hybrid) (*Sorghum* × *drummondii)*
Woody plants
Black birch, or River birch (*Betula nigra)*
Dicorynia guianensis *(Dicorynia guianensis)*
Eperua *(Eperua falcata)*
River red gum (*Eucalyptus camaldulensis)*
Red mulberry (*Morus rubra)*
Loblolly pine (*Pinus taeda)*
Poplar tree *(Populus sp.)*
Eastern cottonwood (*Populus deltoides)*
Southern live oak *(Quercus virginiana)*
White willow (*Salix alba)*
Bald cypress *(Taxodium distichum)*
Wetland plants:
Sedge *(Carex comosa)*
Bristly sedge *(Carex viridula)*
Green arrow arum *(Peltandra virginica)*
Reed canary grass (*Phalaris arundinacea*)
Reed (*Scirpus sp.)*
Marsh reed (*Scirpus lacutus)*
River reed (*Scirpus fluviatilis)*
Prairie cordgrass (*Spartina pectinata*)
Cattail (hybrid) (*Typha* × *glauca*)

When many other unique, vitally important functions of plants are added to genetically determined detoxification ability, it becomes obvious that plants are a special, technologically very important component of the nature, largely determining its existence [31, 115].

The further development of industry, undoubtedly associated with an increase in toxic pollution, should be normalized by technologies based on *Worldbiome*-friendly principles. The potential for self-renewal of the planet, based on the natural activity of the soil (rhizosphere) microflora and plants existing today, is not able to ensure the diverse activity of *Homo consúmens*. From the point of view of environmental safety of the very near future of the planet, it should be clearly understood that the potential of innovative environmental technologies created and currently being in use, as a rule, has a local character.

The potential for the renewal of vital natural resources, as well as their comparability with environmental safety based on the societal demands is of great interest. When discussing renewable natural resources, it should be noted without fail, that the main driving force of this process is solar energy firstly based on the process of photosynthesis, providing all living, including the plant world, with appropriate energy and nutritional resources. On a global scale, the annual renewability of cellulose, one of the main resource of photosynthetic, in world scale is still approximately 120 billion tons. This is provided that 170-180 billion tons of carbon are annually fixed by plants via photosynthesis. Cellulose is undoubtedly the largest substrate on the planet and, due to its important technological characteristics, is widely used in various industries. According to the above calculations, despite society's not entirely benevolent attitude to vegetation, 25 tons of photosynthetically renewable cellulose per year is still account for every inhabitant of the planet. Whether this annually formed volume of cellulose, having the tendency to be decreased, will be sufficient, at least for the next 20 years, to meet the minimum needs of society, is undoubtedly a very important and that requires a comprehensive analysis.

It should be noted that the most active development and, consequently, the formation of the diverse technological science as a separate scientific/practical branch began in old centuries, but especially activated no less than 200 years ago. At that time, the world's population was equal to 1-1.5 billion people, during the prosperous ecological state of the planet and the presence of large reserves of natural resources. At that time, just few people were concerned about the calculations related to the distribution of the amount of renewable raw materials per capita. Large deposits of non-renewable raw materials such as petroleum products, coal, peat, shale and other energy resources, with almost complete environmental well-being, provided a completely different orientation to technological processes. With very rare exceptions, the ecological state of the planet did not cause any concerns.

The approach and requirements to the technologies themselves have changed. Nowadays based on existing ecological situation, it is extremely important to introduce knowledge-intensive, environmentally friendly technologies that do not require high-energy costs. There is no doubt that the creation of genetically modified organisms is a forced event, the purpose of which is to provide the progressively growing population of the planet with food, energy and an acceptable ecological environment.

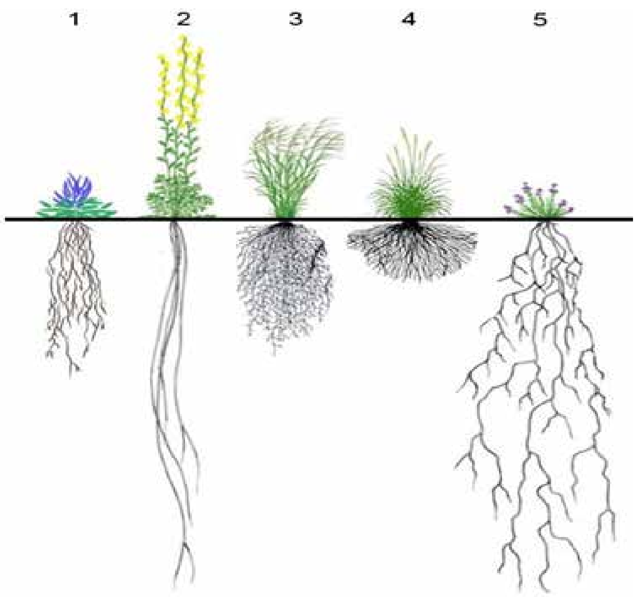
As for genetic engineering, formed in the end of XX century – comparatively new scientific/practical direction, and the expediency of mass production of food and separate food ingredients, by using genetically modified organisms, is not shared by the whole world. However, it may be that for environmental purposes, and in particular, cleaning of the environment from contaminants, the use of highly active genetically modified forms of plants and microorganisms will be acceptable. In this case, their use could be discussed as highly effective action and extremely forced event in areas polluted with especially high concentrations of stable, technogenic compounds that cannot be remediated by conventional eco-technologies.

Taken as the basis of a conceptual approach, the novel discovery potential of plants to degrade unnatural, foreign compounds, including toxic ones, in soil water and air has turned into the first time discussed, environmentally innovative biotechnology of unlimited global scale [63, 112, 72, 89].

Various ecological phytotechnologies, such as phytoextraction, rhizodegradation, phytodegradation, phytostabilization, rhizofiltration and others are already being used for practical purposes. An important factor determining the successful implementation of these technologies is the presence of wide range of vegetation, in particular, plants (previously selectively chosen) that actively assimilate (degrade) compounds of a toxic nature that are uncharacteristic of air and soil. The capabilities of these technologies in their scale significantly exceed all known environmental technologies, mainly having a local or, at best, regional character. The unique detoxification ability of plants is caused by their long-term adaptability to unnatural soil components. This is especially evident in the soil and climatic conditions characteristic of plants. Important ecological characteristics of plants are a well-developed root system, the ability to accumulate abundant biomass and have a solid intracellular volume, the presence of appropriate physiological characteristics (transpiration capacity), and appropriate enzyme systems (Fig. 14). These and, undoubtedly, some other properties determine the ability of plants to degrade organic toxicants and absorb heavy metals and radionuclides in field conditions.

A number of plants transformants have been created through gene cloning, that have an improved capacity for accumulating conjugates of endogenous compounds with toxicants and intermediate products, as an initial step of their biotransformation in intracellular structures. Some of toxicants depending on their structure, which do not undergo to direct oxidative degradation, are stored in vacuoles or cell walls. They are kept there for the time needed for transformation in cell the main part of toxicants and only later, after depletion of toxicants concentration starts their subsequent partial or complete degradation (mineralization). The essence of the process is the same, as in case of regular plants, the difference consist is shortened time needed for the detoxification of intracellular toxicants. These are certainly encouraging results that need further continuation of genetic engineering research.

The possibility of using plants for large-scale purification of soils, grounds, groundwater and reservoirs from inorganic toxicants and other xenobiotics are widely discussed for more than two decades.



1 – Amorpha grayish (*Amorpha canescens*); 2 – Silphium laciniatum (*Silphium laciniatum*); 3 – Porcupine Grass (*Hesperostipa spartea*); 4 – Koeleria macrantha (*Koeleria cristata*); 5 – Liatrice (*Liatris cylindracea*)

Fig. 14. Root system of some herbaceous plants (In a single dimension)

According to the results of experimental data, there is no doubt that *in situ* phytoextraction of heavy metals and degradation of toxic organic compounds is the most cost-effective, environmentally friendly technology that does not require any critical conditions related to soil habitants or soil structure. Transformant plants, characterized by increased phytoextraction and phytodegradation abilities, in addition to other genetically modified plants, are also described in the literature [109, 117, 118]. As follows, investigations of genetic engineering potential aimed the improving efficiency of phytoremediation of plants have been carried out quite intensively over the past 30 years. They were mostly conducted in greenhouse conditions, in small ecologically controlled areas. The first large-scale field studies were carried out in early 2000 in the USA. The list of recombinant plants, created by different technologies, for various environmental problems, have already reached several hundreds.

The poplar family (*Populus*) deserves special attention among the wide variety of plants promising for phytoremediation due to its powerful root system, with the great absorbing capacity. Numerous variants of genetic modifications of this plant convince of the expediency of practical use of some transformants.

In the reviews and publications devoted to the cloning of the cytochrome P450 gene into various plants, transgenic plants with high resistance to herbicides and increased detoxification ability have been discussed. According to this data, duplication of the cytochrome P450 gene in plants that do not contain this enzyme the most often boosts their resistance against the action of herbicides [31, 117, 118].

Glutathione S-transferase is a widely distributed enzyme in plants that participates both in normal metabolic processes of the plant cell metabolism as well as in protecting plants from stressful situations. Quite often, when creating transgenic plants for increased phytoremediation ability, the main target for transformation into other plants is frequently the gene of this particular enzyme.

In a number of publications, transgenic plants have been studied in relation to certain soil and climatic conditions, as well as to degrade foreign compounds including those of toxic nature. Much attention was paid to biological methods of removal widely distributed trinitrotoluene (TNT), one of the most common toxic explosive compounds, and its partial transformation products from the soil [119]. Transgenic plants, carrying out the cleavage of nitro groups and transformation of the carbon skeleton of this toxicant, also remove intermediate metabolites of TNT much faster than conventional plants, whose growth was significantly inhibited on media with TNT [64,109,124].

Transgenic tobacco differed significantly from the usual plant in both tolerance and the ability to quickly absorb and assimilate a significant amount of TNT. Similar data is described in other publications [64,109,124], related to an increase in the ability of transgenic plants to assimilate explosives from the soil by cloning bacterial nitroreductase in them.

Discussing what would be the perfect plant from the point of view of ecological potential, it should correspond to the following requirements: the plant preferably should have long, well-developed root system and a strong transpiration, intensively accumulate biomass, with a certain tolerance towards organic and inorganic toxic compounds and high (measurable) activity of enzymes involved in the detoxification of toxicants. What is about other determined feathers, increasing plants ecological potential, plant must necessarily form conjugates, chemically bound organic toxicants with intracellular metabolites and have the appropriate potential (capacity) for accumulating conjugates and heavy metals in cellular structures and apoplast [120]. The plant should have a robust intracellular oxidizing system of enzymes capable of converting organic toxicants and their intermediate metabolites, regardless of their structure, through biological oxidation. These are the basic requirements that theory and practice currently present in relation to plants intended for phytoremediation.

In the case of inorganic toxicants, a somewhat different picture is created. Incomplete information concerning the molecular mechanisms of plant tolerance to heavy metals, or the lack of data indicating the factors responsible for their intracellular accumulation in a big quantity, creates a well-defined complexity of genetic modification of plants aimed at enhancing their detoxification activity [109,117,118].

Some cases of obtaining transgenic plants with higher tolerance to cadmium and lead (concentrations in the medium of 70-75 mM) are described, which certainly indicates their hyperaccumulative potential. In addition, an important fact is that data indicating a doubling of the copper content in transgenic plants are observed.

As even a cursory review of genetic engineering works shows that, in some cases, there are a significant increase in detoxification abilities in transgenic plants. This is direct evidence that some transgenic plants have an increased ability to assimilate organic toxic compounds and absorb heavy metals. If all aspects of the detoxification process, which is quite complex, in terms of biochemical mechanisms of transformations, were investigated more deeply and comprehensively, it would allow creating a more rational strategy for conducting genetic engineering manipulations with an important applied ecological character. The ecological problems caused by the wide distribution of toxic nature compounds to compel humanity to increase the interest to the naturally occurring detoxification process. Detoxification ability and widespread dissemination of plants covering above 40% of whole planet, should oblige society actively exploit these unique organisms for practical purposes, as a permanently acting, important biological tools, with enormous ecological potential.

It should be noted that microorganisms and plants, both individually and jointly, take a very active part in the natural cycle of organic compounds, including toxic ones [121]. It should be noted that microorganisms and plants both individually and jointly take a very active part in the natural cycle of organic compounds, including toxic ones.

In particular, these organisms degrade foreign compounds, and their constituent carbon atoms are used for the synthesis of characteristic cellular metabolites. It turns out to be something like a natural filter that not only cleans the environment but also uses the carbon skeleton of toxic compounds as a basis for carbon atoms in the synthesis of ordinary cellular metabolites (compounds) according to the principle of low-waste technologies. Despite the biochemical complexity of the process, there is certainly an environmentally friendly detoxification process, in which rhizospheric microorganisms and plants jointly participate, acting as global ecological agents degrading toxic compounds, uncharacteristic of ecosystems.

Table 15 presents a list of plants that are able to assimilate stable highly toxic, carcinogenic compounds such as benzene and toluene from the air via terrestrial organs – leaves).

In addition to ecological and biological safety (preservation of soil structure and microflora), an important advantage of ecological phytotechnologies is the relatively low cost of the remediation process, which is much cheaper than other well-known, traditionally used ecological technologies (Table 16) [63,89].

Ecological phytotechnology, is more time-consuming in comparison with microbial biotechnologies, enable to clean the fertile layer, soil, water reservoirs, and air from uncharacteristic contaminants [63, 12, 114].

Plants potential to absorb atmospheric benzene and toluene through terrestrial organs – leaves

Table 15

Plants	Amount of aromatic hydrocarbons absorbed by per kg of fresh leaves in 24 hours	Plants	
1	2	3	
Strong absorbers	1.0-10.0 mg	Field maple (*Acer campestre*) Oleaster (*Elaeagnus angustifolia*) White locust tree or black locust (*Robinia pseudoacacia*) Wild pear (*Pyrus caucasica*) Walnut (*Juglans regia*) Almond Tree (*Amygdalus communis*) Wild Cherry (*Cerasus avium*) Amorpha **Desert false indigo** (*Amorpha fructicosa*) Sour Cherry Tree (*Cerasus vulgaris*) Chestnut (*Castanea sativa*)	Apple tree (*Malus domestica*) Zelkova (*Zelkova carpinifolia*) Poplar (*Populus canadensis*) Perennial ryegrass (*Lolium perenne*) Lilac (*Siringa vulgaris*) Weeping Willow (*Salix*) Catalpa (*Catalpa bignonioides*) Japanese Sophora (*Sophora japonica*)
Medium absorbers	0.1-1.0 mg	Alder (*Alnus barbata*) Aspen (*Populus tremula*) Elm (*Ulmus foliacea*) Ash (*Fraxinus excelsior*) Tea plant (*Camellia sinensis*) Eastern persimmon (*Diospyros kaki*) Noble laurel (*Laurus nobilis*)	Common Gleditsia (*Gleditsia triacanthos*) Common bean (*Phaseolus vulgaris*) Pine (*Pinus*) Eldar pine (*Pinus eldarica*) Thuja (*Thuja*) Apricot (*Prunus armeniaca*) Grapevine (*Vitis vinifera*)
Weak absorbers	0.001-0.1 mg	Fir (*Picea abies*) Mulberry (*Morus alba*) Linden (*Tilia caucasica*) Reed (*Phragmites communis*) Corn (*Zea mays*) Wild plum (*Prunus divaricata*) Kiwi (*Apteryx australis germanica*) Rose (*Rosa*) Sycamore *(Platanus*)	Cypress (*Cupressus sempervirens* var. *Pyramidalis*) Geranium (*Pelargonium Rroseum*) Privet (*Ligustrum vulgare*) Fig (*Ficus carica*) Pomegranate (*Punica granatum*) Rhododendron (*Rhododendron ponticum*) Peach Tree (*Persica vulgaris*) Potato (*Solanum tuberosum*) Tomato (*Lycopersicon esculentum*) White willow (*Salix alba*) Plum (*Prunus vachuschtii*)

Cost of innovative and traditional phytoremediation technologies

Table 16

Contaminant and matrix	Phytoremediation		Conventional Treatment		Projected savings
	Application	Estimated cost	Application	Estimated cost	
Lead in soil (1 acre)	Extraction, harvest, and disposal	$ 150,000–250,000	Excavate and landfill	$ 500,000	50–65%
Solvents in groundwater (2.5 acres)	Degradation and hydraulic control	$ 200,000 for installation and initial maintenance	Pump and treat	$ 700,000 annual operating cost	50% cost saving by 3rd year
Total petroleum hydrocarbons in soil (1 acre)	*In situ* degradation	$ 50,000–100,000	Excavate and landfill or incinerate	$ 500,000	80%

On the other hand, despite their certain effectiveness, a number of common chemical environmental technologies being applied today do not completely meet the qualitative requirements of the soil. Most of these technologies are detrimental to the soil microflora. It takes years to restore the normal activity of rhizosphere microorganisms after using these technologies and achieving full-fledged yields.

Plants completely or partially neutralize toxic compounds from the environment depending on the structure of the toxicant, the acidity of the medium, the presence of moisture, relevant enzymes and other factors [31,108]. Concepts such as the "Green Filter" or "Green Liver", which serve as the theoretical basis for industrial environmental technologies used to remove or significantly reduce the toxic effect of foreign compounds on the environment, have been developed [89].

The easiest way for plants to avoid the negative effect of toxic compounds is the process of excretion (Fig.15), the essence of which is that the toxic molecules move through the apoplast without any intracellular metabolic transformations and are thus removed from the plant. Although this is the simplest way of toxicant elimination, it takes place only at very high concentrations of highly mobile (phloemobile or ambimobile) toxicants. A serious disadvantage of the excretion process is that the toxicant does not undergo chemical transformations, therefore it completely retains its chemical structure and, consequently, toxic properties. However, as shown in Figure 13, foreign compounds most often penetrate into cells and undergo enzymatic transformations, leading to a decrease in their toxicity. Currently, three successive phases of transformation have been identified, to which toxic compounds in a plant cell are subjected.

Phase I. Functionalization is the process when a molecule of a hydrophobic organic contaminant acquires a hydrophilic functional group (hydroxyl, amine, carboxyl, etc.) due to enzymatic transformations (oxidation, reduction, hydrolysis, etc.). Because of functionalization, the polarity and reactivity of the toxicant molecules are significantly increased. In some cases, this is followed by complete oxidative degradation of the toxicant to standard cellular metabolites and, finally to CO_2 and water. In this way, the plant cell not only completely neutralizes the toxicity of foreign compounds, but also uses their carbon atoms for its own plastic and synthetic necessities.

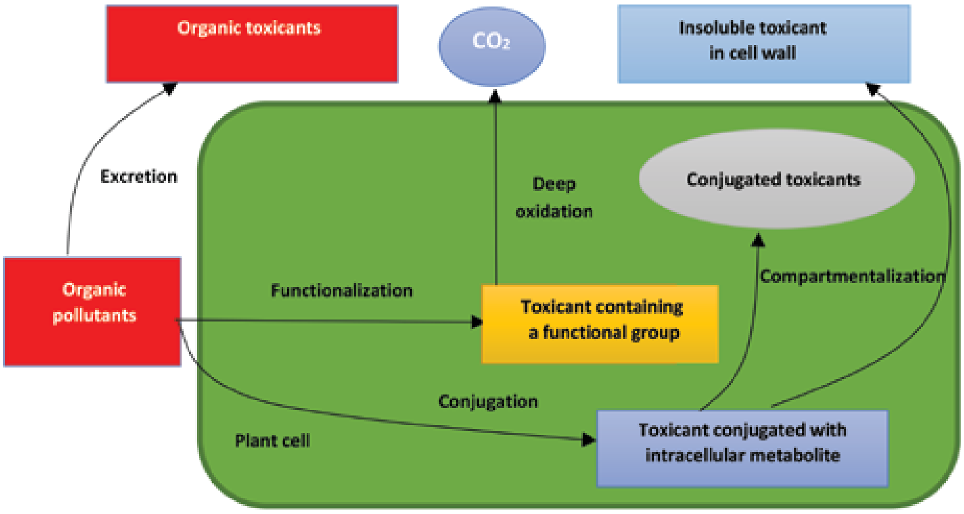


Fig. 15. The mechanisms of transformation of foreign compounds in a plant cell

The totality of such transformations is the essence of plant detoxification processes. However, complete detoxification of contaminants in a plant cell is carried out only at low, metabolically transformable concentrations of toxicants. It takes certain amount of time, and in some cases, the process can last days. Complete mineralization of the toxicant is not achieved at high concentrations, and degradation can be up to a maximum of 10% of the total toxicant in the cell. The rest of the toxic compounds that have penetrated into the cell undergo conjugation.

Phase II. Conjugation is a process during which a chemical bond is formed between foreign compounds (toxicant) that have penetrated into the cell and endogenous substances of the cell (proteins, peptides, amino acids, organic acids, carbohydrates, polysaccharides, pectin substances, lignin, etc.) through the formation of peptide, ether, ester and other covalent bonds. The formation of conjugates leads to a significant increase in the hydrophilicity of the organic toxicant, consequently, increasing its mobility and reactivity, as well as a decrease in the characteristic toxicity. Such transformations facilitate the processes of further compartmentalization of toxic compounds.

Despite the fact that conjugation is one of the most common means of self-defense of plants against the action of toxic compounds, it cannot be argued that this process is energetically and physiologically beneficial for plants. During conjugation, compounds that are functionally important for the cell (regular cellular metabolites) are consumed, which leads to some deficiency of them at high concentration of the toxicant. This reduces the resistance of plants to the action of other adverse factors, including environmental conditions, i.e., it lowers the immune system of plants. Unlike deep degradation, conjugation does not lead to complete neutralization of the xenobiotic, which only partially and temporarily loses or reduces the characteristic toxicity, while preserving the basic structure of the molecule (e.g., the aromatic ring). According to the data of authors, when plants are transferred from a medium with a toxicant to a nutrient medium that does not contain toxic compounds, a gradual mineralization of toxicant residues occurs. This process is typical for the vast majority of plants used in ecological phytotechnologies [120].

Plants having “absorbed” toxicants become their carriers, since most of the toxicants (up to 70-90%) accumulate in plants in the form of conjugates. Such prolongation of the process should be taken into account when using plants in phytotechnologies. Conjugates of toxic substances are particularly dangerous entering the food chain, since enzymes of the digestive tract of warm-blooded organisms are able to degrade conjugates and thus release toxic parts of their intermediate transformation. Therefore, it is extremely important that the plants used in phytoremediation should have as powerful enzyme systems as possible that carry out deep degradation of toxicants.

Phase III. In most cases, compartmentalization is the final stage of the “storage” of toxic substances in certain cellular structures. Usually, soluble in cellular liquid conjugates accumulate in vacuoles, while insoluble conjugates coupled with pectin, lignin, hemicellulose and other cellular polymers are removed from the cell by the exocytosis process and/or accumulated in the cell wall.

The above-mentioned way of utilization of toxic compounds (**functionalization → conjugation → compartmentalization**) is well traced by the example of organochlorine pesticides. Below are some examples of successive transformations of toxicants in plants. After hydroxylation, the herbicide 2,4-D forms a conjugate with glucose and malonyl residue, and then undergoes vacuolization (Fig. 16).

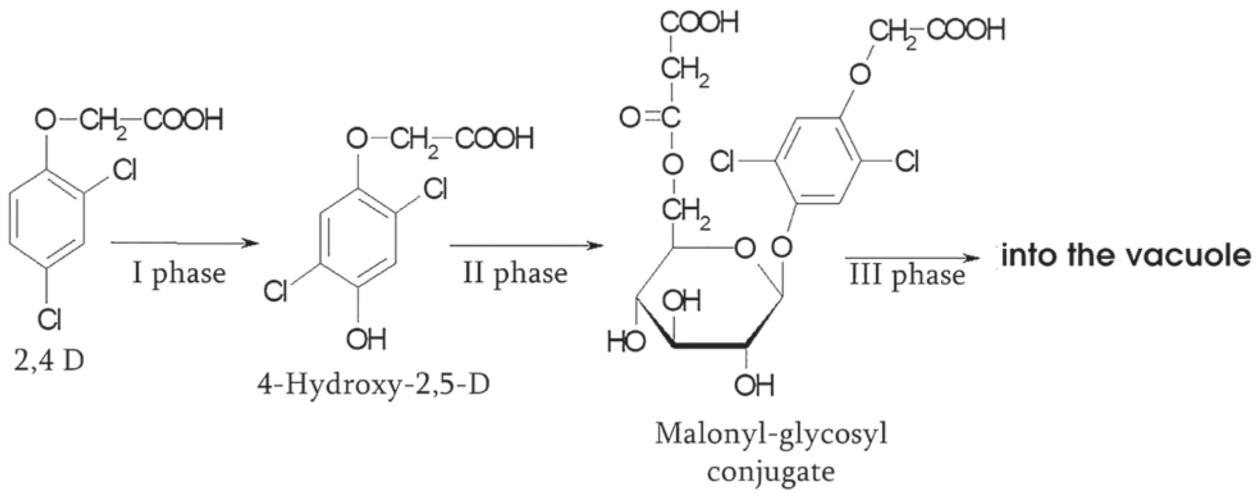


Fig. 16. The mechanism of transformation of 2,4-D in a plant cell

The insecticide DDT, as a result of primary oxidative reactions, acquires a carboxyl group (turns into DDA), which easily forms an ester with glucose and also is stored in vacuoles (Figure 17):

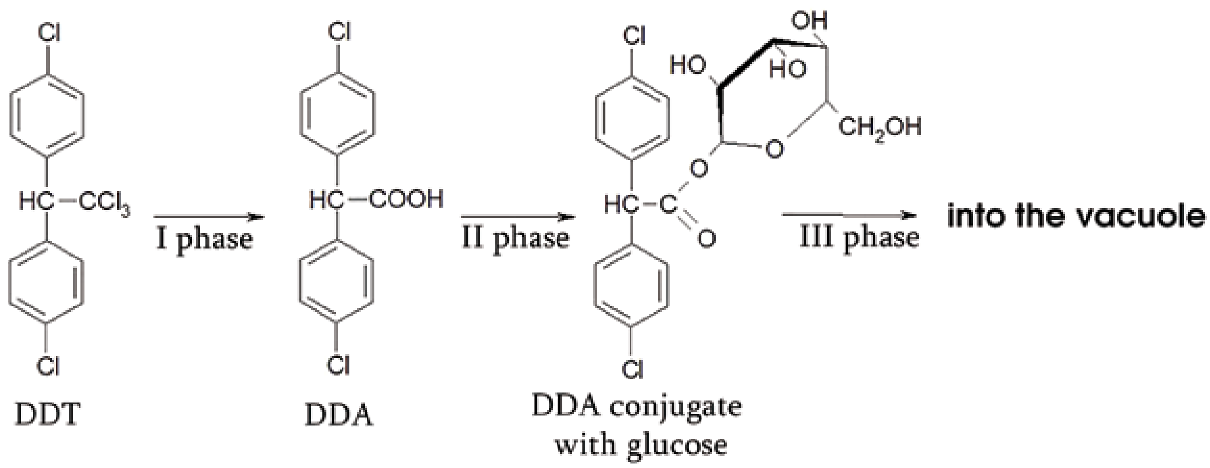


Fig. 17. The transformation of DDT in a plant cell

The biocide 2,3,4,5,6-pentachlorophenol directly forms soluble conjugates in the form of β-D-glucoside and O-malonyl-β-D-glucoside, which migrates in vacuoles. In the case of hydroxylation, pentachlorophenol acquires a second hydroxyl group, and this intermediate binds to lignin, forming an insoluble conjugate, which is then embedded into the cell wall (Fig. 168).

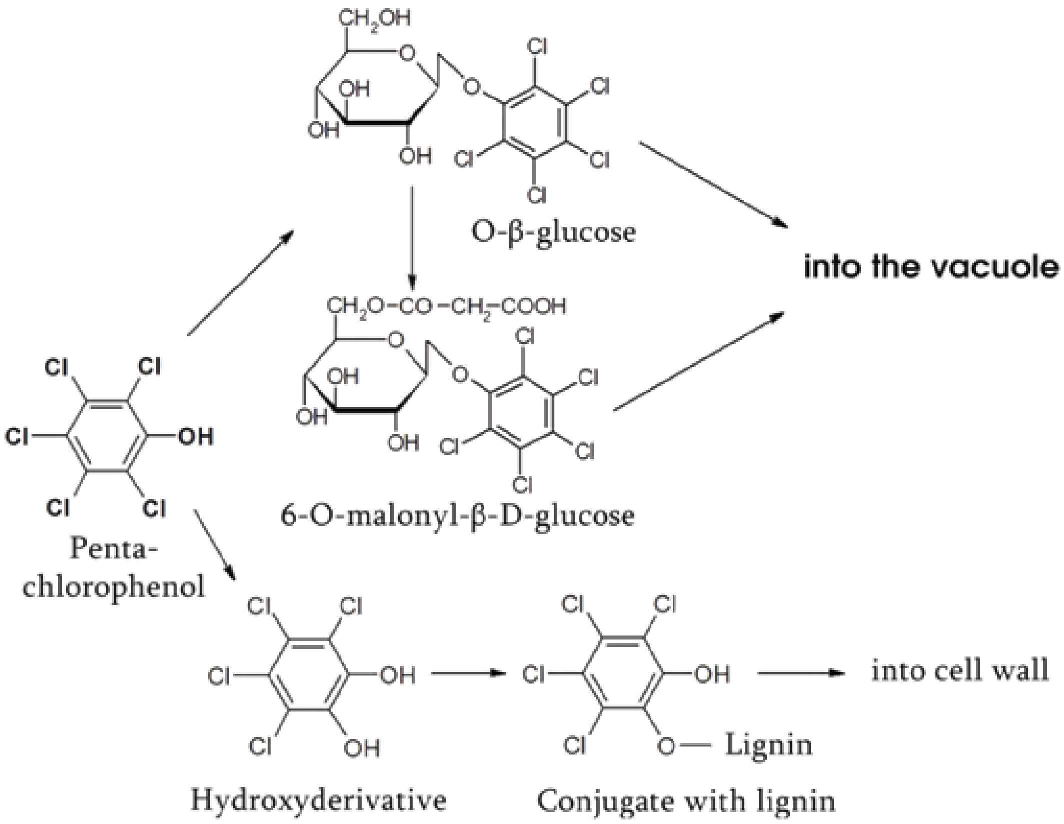


Fig. 18. The transformation of 2,3,4,5,6-pentachlorophenol in a plant cell

Chemical reactions occurring in plant cell during all three phases of contaminants initial transformation/degradation (functionalization, conjugation and compartmentalization) are completely based on enzymes performing their initial orientation [109,117,122,123]. In the absence of toxicants, these enzymes catalase a number of different typical for plant cell physiological reactions characteristic in normal metabolism.

It would give the clearer picture of contaminant transformation to analyze the full set of enzymes participating in this process. At the initial stage, the following enzymes perform the reactions of chemical modification of toxic compounds in plants:

- oxidases catalyzing hydroxylation, demethylation and all oxidative transformations of contaminants: cytochrome P450-containing monooxygenase, peroxidases, phenol oxidase, ascorbate oxidase, catalase, etc.
- reductases catalyzing the reduction of nitro groups (nitroreductases)
- dehalogenases that cleave halogen atoms from polyhalogenated toxic compounds
- esterases hydrolyzing ether bonds in pesticides and other toxic compounds.

The processes of the second phase of detoxification are based on the reactions of conjugation of toxicants (with glutathione S-transferase, glucuronosyltransferase and others). Compartmentalization of conjugates occurs with the participation of ATP-binding cassette transporters (ABC transporters). Depending on the structure of contaminants, other enzymes also could participate in various stages of intracellular oxidation of toxic substances. For instance, conjugates with glutathione localized in vacuoles are easily converted into conjugates with cysteine under the action of peptidases. The long-term process of deep oxidation of toxic substances (foreign compounds) also involves enzymes of plastic, energy and nitrogen metabolism, supplying the plant cell with additional energy and nitrogen-containing metabolites.

Despite the wide spectrum of existing in plant cell enzymes and consequently their broad action, plants do not have a universal detoxification potential [72, 89]. For instance, they are unable to assimilate dioxins, organochlorine compounds and some other structurally stable toxicants. Despite of above mentioned, according to existing experimental data, they are detoxifiers with an exceptionally wide spectrum of action.

Microorganisms as technological agents, representatives of different taxonomic groups, degrading toxic compounds of a very wide spectrum have been well and comprehensively studied [23, 24, 25]. The first data of systematic studies on the processes of detoxification carried out by microorganisms appeared around 40 years ago. In a good surrounding, the ability of rapid dominant reproduction of soil rhizosphere microorganisms is certainly one of the most important factors ensuring the yield and environmental protection of the soil from the possible presence of toxic compounds in agricultural products. According to existing data, on average 1 gram of normal dry soil biomass contains 10^8 bacterial cells, 10^6 actinomycetes and 10^5 mycelial fungal spores. By no means, making this an absolute regularity, it should be noted that, according to the authors, in normal chernozem soils the number of actinobacteria is often almost three orders of magnitude lower, while the number of mycelial fungi is two orders of magnitude higher. The content of microorganisms of individual taxonomic groups in different quantities is quite an acceptable factor, depending on the type of soil and other agro-conditions. Anyway, the number of bacteria (prokaryotes) prevails, although microorganisms of other taxonomic groups (mycelial fungi, actinomycetes) are also abundant, which largely determines soil fertility.

Based on the huge number of publications devoted to microbial detoxification, it should be underlined that microorganisms play a highly important role in the processes associated with the cleaning almost all types of soils. Together with the root system of plants, soil microflora, having a perceptible degradation potential, is the main factor in the process of soil purification, namely degradation and transformation of toxic and other foreign compounds into normal cellular metabolites, in some cases carrying out their mineralization.

Thirty years ago, the authors has started to search and select for active, rizospheric strains of bacteria, mycelial fungi and actinomycetes capable to absorb and metabolically degrade foreign compounds. Based on well-known data on the ability of microorganisms to degrade, up to the mineralization a large number of natural and anthropogenic toxic compounds, a collection of above-mentioned taxonomic groups of rizospheric microorganisms, accounting above 4 thousand strains, has been created. The collection strains were isolated from normal and differing, soil-climatic zones, and contaminated areas with toxic compounds. The selection of sites was performed according to their locations of military polygons and shooting ranges, close to chemical and metallurgical plants, airfields, along highways with heavy traffic, former and operating oil fields, fly-up grounds for planes, thermal power plants and other facilities with a highly probable content of toxic compounds in the soil. As it has been shown despite belonging to the same species and genus, strains of microorganisms isolated from different places significantly differ in a number of physiological parameters and biochemical characteristics, including different degradation potential of toxic compounds. In addition to mesophilic strains, the collection contains several hundred extremophilic microorganisms (halophiles, thermophiles, alkaliphiles, acidophiles, psychrophiles); they carry out contaminant degradation in normal soils and soils differing by extreme conditions. This made it possible to select the technologically important, most active strains that degrade a wide spectrum of contaminants of uncharacteristic nature in almost any possible soil/climatic conditions. In the vast majority of cases, the results obtained confirmed the existing opinion about the characteristic activity of microorganisms aimed at the disposal of unnatural components in the soil and water resources. As a result, high-tech strains of the bacteria and mycelial fungi were identified. The studies conducted using collections of microorganisms, as well as the analysis of a number of publications, have convinced the dominant role of microorganisms in the implementation of the cycle of carbon atoms, even based on toxic compounds.

Bacteria, the most widespread and morphologically simplest single-celled organisms – prokaryotes – inhabit the whole world, all ecological niches and almost all existing organisms. The technological value of these organisms is in their relatively simple structural organization and, accordingly, easy adaptability to different environmental conditions. The main advantage for the ubiquitous spread of bacteria is a very high reproductive ability to double quantitatively in a matter of minutes in almost all, even extreme, conditions. With the exception of lignin and cellulose, aerobic forms of bacteria assure, as a carbon source, almost all natural carbon compounds for growth (accumulation of biomass), and are characterized by an exceptionally wide range of oxidative, hydrolytic, transformational, synthetic capabilities (enzyme systems). That gives to different taxonomic groups of bacteria a universal character of action on the vast majority of natural and a wide range of technogenic compounds.

Since 1970, a group of scientists started to create a special collection of bacteria having high ability to degrade foreign compounds. The main goal of selection was to isolate bacterial strains differing by increased degradation potential. A special attention was paid to strains adapted to different extreme conditions of existence, the diversity of which is especially rich, in relatively Young Mountain of the Caucasus region. As it was conformed, the soils, plants and water reservoirs' mainly are rich by representatives of the following genera: *Bacillus, Pseudomonas, Rhodococcus, Mycobacterium,* and *Nocardia*. The selection of the strains from all unique extreme places allowed creating the collection of bacteria acting in different types of soils even having the signs of extreme conditions. The analysis of individual species and genera of collection bacterial strains, as environmental agents, was carried out based on their ability to decompose the main skeleton of toxic compounds of various structures to physiologically safe metabolites or to mineralize them. Toluene has been chosen as the main test for the selection of bacterial strains acting on contaminants of toxic nature. Studies were conducted mainly with cultures of dominant soil forms of bacteria: *Pseudomonas, Rhodococcus, Nocardia, Mycobacterium* and *Bacillus*. As it was mentioned above, the strains were selected based on their ability to use the toluene as a source of carbon, energy and electron donor.

Analysis of bacterial strains from the various regions of the Caucasus allowed to isolate strains intensively accumulating and degrading toluene, despite the low rate of colony-forming units ($N \times 10^3$), which was three orders of magnitude higher on the medium with glucose.

As a result, of selective chosen, bacterial strains having the sign to degrade a stable to natural conditions contaminant – trinitrotoluene (TNT), were isolated from the collection of bacteria. The possibilities of their usage in soil and water reservoirs have been established [26, 27, 28].

In another series of experiments, bacterial strains were isolated from collection cultures of bacteria, which are characterized by the ability to degrade a toxicant that is stable under natural conditions, such as trinitrotoluene (TNT).

Due to high activity of some strains, they are recognized as suitable for the industrial use in the field conditions. It should also be underlined that, in addition to their high TNT-degrading activity, a couple of strains from this group assimilate mineral oils, using them as the main carbon source.

During studies of the decontamination potential of bacterial strains, in addition to their most widely spread mesophilic forms, representatives of the same genera and family, extremophilic forms of bacterial strains and specially created consortiums could be solely and jointly effectively used in practice. A special increased attention is paid to the application of active extremophiles in contaminated soils and areas requiring remediation and being under extreme conditions [29]. This is important for those regions where soils contain an increased amount of salt, alkaline or acidic pH values; in such cases, it becomes highly desirable to use certain forms of microorganisms that are active under extreme conditions (halophiles, alkaliphiles, acidophiles, thermophiles, etc.).

Dozens of weak and extreme forms of alkaliphilic bacterial strains with the contaminant degradation ability, and optimal values for growth and activity in the pH range of 8.5, and up to 10,5, have been isolated from the collection strains. These cultures were tested to degrade pentachlorophenol, which has an extensive distribution. The most active strains were identified from the genera: *Rhodococcus sp., Mycobacterium sp., Arthrobacter sp.,* and *Pseudomonas sp.*, characterized by intensive growth and degradation of pentachlorophenol and other toxicants under alkaline conditions.

Based on literature and the some author's data, the known list of bacterial strains with detoxifying properties can be significantly, expanded and supplemented, by other genera of bacteria degrading of different structures toxic compounds at wide range of pH. The only exceptions are dioxins, very stable technogenic compounds, microbial degradation of which by rear bacterial strains goes very slowly; a number of halogen-containing organic compounds (e.g., polychlorinated biphenyls) also hardly undergo to the bacterial degradation.

With the aim of broadening of microorganism's degradation potential, a collection of mycelial fungi strains, also famous by foreign compounds high degradation potential, has been created. The collection of mycelial fungi, broadening for 30 years contains above 4.000 strains, isolated in analogous to bacterial collection from differing soil climatic zones mainly of the Caucasus. The collection includes strains, representatives of the following classes of Ascomycetes, Zygomycetes, Deiteromycetes,as well as representatives of the following orders (taxons): *Aspergillus, Penicillium, Mucor, Trichoderma, Fusarium, Sporotrichum, Helmintosporium, Mortierella, Rhizopus, Chaetomium, Gladosporium* et al. Analysis of the collection strains allowed to isolate above 100 strains, the most active destructors of organic toxicants with various structures. In general, characterizing the collection of mycelial fungi strains based on their ecological potential, it should be noted that more than 60% of the collection strains had the ability to degrade toxic compounds of various structures with different activity (from trace level to relatively high activity). Since the degradation ability of any classes of toxic compounds determines the ecotechnological value of microbiological strains, the previous selection of active strains, destructors of toxic compounds, is an absolutely necessary procedure for successful realization of any ecological project. Laboratory and field experiments have shown that under the solid-state and submerged cultivation conditions the selectively chosen active collection strains were more than an order of magnitude superior to other cultures, in terms of their ability to degrade toxicants.

The toxicant degradation potential is the main factor determining the ecological usefulness of microorganisms. According to this indication, collection strains are divided into separate groups by the specificity of their action. For instance, among 15 strains of active explosive destructors (TNT and hexahydro-1,3,5-triazine [RDX]), the most active three strains were selected, which were tested in the field, and it was suggested that they meet all field requirements in terms of their activity and ability to reproduce. As it was detected, all active strains were characterized by high nitroreductase activity. The Table 16 clearly demonstrate the ability of selectively chosen strains of mycelial fungi to carry out deep degradation of the stable carbon frame of TNT, and use the released carbon atoms for the synthesis of important cellular metabolites such as organic and amino acids.

Products of biotransformation of (1-^{14}C) -TNT by mycelial fungi strains

Table 17

Name of the strain	Percentage of radioactivity of separate metabolites from the total initial radioactivity of trinitrotoluene	
	Organic acids	Amino acids
Mucor sp.T1-1	70,20	25,80
Trichoderma sp. N2-6	74,40	21,60
Aspergillus niger N2-2	92,80	5,10

In a separate series of experiments, the effect of a consortium of specially selected strains of microscopic fungi was studied in order to eliminate oil hydrocarbons spilled over the surface of the sea and trapped in chernozem soils. As it was found, the microbial consortium assimilated more than 90% of petroleum products with a concentration of crude oil ranging from 1 to 3%, for five days, which indicates on their high digestibility of oil products.

It has been experimentally proved that by selecting proper strains, detoxification potential of consortia microorganisms could be significantly increased both by consortia representatives, as well as with strains of mycelial fungi and bacteria. Various consortia of microorganisms, which are distinguished by enzymes involved in the degradation of the carbon skeleton of contaminants, and, respectively, by mechanisms of their action, draw nearer to the nature of contaminants, and degrade toxicants more deeply and completely.

Examples of microbiological (mycelial fungi, bacteria, less frequently actinomycetes) degradation of pollutants (both the literature and authors' data) could be significantly extended; however, the exceptional diversity of both toxicants, genera and species of microorganisms does not allow to present data on at least one genus or species of mycelial fungi by their effect even on one class of toxic compounds. It should be limited to the conclusion that the experimentally estimated degradation potential of toxic compounds by selectively chosen strains or consortia of mycelial fungi is so high that it is close to universal.

The combined action of microorganisms and plants to degrade toxic compounds is of great particular interest. Moreover, it was found that this type of degradation process, resembling a double-barreled shotgun, focused at the degradation of toxicants by both microbial and plant divers' potential, is a synergistic by nature.

The technologies based on the use of microorganisms to carry out remediation processes of the environment by deep degradation of toxic compounds is well known phenomena. Within the framework of this publication, the authors have to note that in the studies this ability was unequivocally confirmed. With regard to interaction of plants and microorganisms, it is extremely important to emphasize once again that their joint action has a synergistic character.

Highlighting the extremely important function and role of bio-ecological technologies, in comparison to other remediation measures, should be noted that they differ from any other technologies, because they enable us to carry out remediation and environmental monitoring on a global scale, in nature and *Worldbiome*-friendly conditions, for any region of the planet.

IV. POSSIBLE ECOLOGICAL AND SOCIAL CHANGES BECAUSE OF THE GLOBAL USE OF BIOLOGICAL TECHNOLOGIES

Undoubtedly, on a global scale, geopolitical stability is a factor determining the possibility of coexistence of the peoples inhabiting the planet. However, in his book "Strategic Vision: America and the Crisis of Global Power", (2012), Professor Zbigniew Brzezinski, one of the leaders of geopolitical strategies of our time, emphasizes that "Unfortunately, the major powers have yet to undertake globally cooperative responses to the new and increasingly grave challenges to human well-being – environmental, climatic, socioeconomic, nutritional, or demographic." The assumptions and predictions made more than a decade ago have become even more acute. There are also well-known considerations of other highly authoritative experts that the primary task is not only to take care of the geopolitical stability of the planet, but it is equally important to create a unified environmental concept coordinated with all countries. (Professor Francis Fukuyama of Johns Hopkins University, USA, "The End of History", 1992).

It is increasingly clear that the environmental and geopolitical issues are more and more intertwined. The ecology of the planet has already been significantly deteriorated in the second half of the XX century, and has only been worsening over the time, which was the reason for the statements and assumptions of the above-mentioned and many other well-known scientists and experts on ecology and sociology. There is no even the slightest doubt that the society's concern related to environmental problems has a real, long time basis. Developing this idea, it should be noted that the most acute environmental problems characteristic of the XXI century, have already begun to clearly form due to various geo/bio/ecological changes, expressed in a constant increase in the concentration of toxic compounds in all ecological niches. The non-traditional infectious diseases, including various viral infections, uncharacteristic climatic changes, such as global warming and associated ice melting, a significantly increased number of anomalies among humans and animals, and are not the complete enumeration of the environmental changes. These are only a few examples of the changes that have already visually occurred, and are closely related to the increase in toxicity, radiation and a decrease in the biodiversity of the planet. All of these abnormalities already has an impact on the complex human physiology through effecting on the genome, creating spontaneous mutations and deviations from normal physiology and functional biochemistry. It is impossible to predict what would be the scale of these deviations even in the closest future, but it is quite clear that all of them would be negative and some may turn out to be fatal. Undoubtedly, the prospect of toxic modification of *Homo sapiens* is highly dangerous and undesirable. At the same time, the rate of annual increase in the world's population, amounting to about 1% (up to 100 million per year), has long turned into a serious problem for all humanity. In this regard, the issue should be addressed on the agenda of international organizations from all available positions: what can be done as a long-term prospect of ensuring living conditions adapted for the *Homo sapiens* population?

Let us be honest: in the face of the impending inevitable ecological catastrophe. In order to create a united front of action for all nations and countries, all problems related to the environment should be exposed with absolute directness; these include political, confessional, financial and traditional differences among countries and a number of others, in order to somehow find real solutions to prolong traditional, or slightly change, acceptable living conditions. Undoubtedly, minimal, untapped opportunities to preserve and improve the ecological balance of the entire planet still exist. First, these colossal scientific potential determines the strategy of alleviating environmental stress with different knowledge of innovative technologies that can postpone environmental disasters at least for the coming decades. How can this be achieved? First, how to regulate the unpredictable increase in the population of the planet, which definitely has a limit? This is a mandatory and necessary requirement, without which the basic conditions of human existence, cannot be provided based on the well-studied resources of the planet. Second, every technology being created in any industry, including military, medicine, and agriculture, must pass through an ecological prism to exclude or minimize the probability of technogenic/toxic substances emissions. This, first, mostly concerns multinational companies and individual countries that produce a variety of products on a large scale, associated with the formation of a great number of technogenic products. The issue of minimizing the extraction and use of energy resources such as petroleum products, which are the most massive sources of toxic compounds, should be considered separately. Finally, it is necessary to carefully investigate, still existing possibilities of "ennobling" the planet, the quantitative increase in the scale of fertile lands so far available to humanity, which are still insignificant or not at all used in large regions of the planet as of now. Certainly, this is not the whole list of the reasons for eliminating the ecological imbalance; there are others, which also deserve appropriate attention. Regions with low-fertile soils, or even lean years, and their causes should not be considered as problems of individual countries; rather, all of them, literally every site, should become the subject of international discussion. The role of diplomats and politicians of all countries, first of all, should be to reach consensus on this issue.

It is well known that in order to somehow reduce the hotbed of the main environmental problem – the usage of traditional non-renewable energy sources, it is necessary to significantly strengthen all the possibilities of natural sources: hydroelectric power plants, plant biomass, geothermal waters, solar and wind energy. Such technologies are already finding more and more widespread use, but despite the cost of some of them, it is necessary to use literally all of the possibilities, especially since such options really exist. For instance, the same category of innovative technologies should include the production and use of electric motors, especially cars, which significantly reduces emissions of toxic compounds.

Entrepreneurs are working on creating batteries that can accumulate a large amount of energy, and use it for various purposes, including heating of the houses. Elon Musk's solutions are as bold as they are simple. All nations can significantly reduce the use of fossil fuels as an energy source by using the energy of the sun, getting enough renewable energy for the system, and smoothing the production and use of energy between peak and off-peak hours.

The unpredictable growth of population and decrease in agricultural plantations requires qualitatively new technologies in a food production. For example, a new technological direction involves "upward movement", i.e., the organization of vertical farms, which, undoubtedly, in addition to novelty and saving space for cultivated plants, suggests great prospects in terms of not only saving energy and acreage, but also plant protection in specially organized greenhouses for this purpose. The technology is so impressive that it is necessary to give an appropriate example of its practical implementation – vertical farms. Vertical Harvest in Jackson, Wyoming, is a three-store 9×45 m hydroponic greenhouse that can annually produce 16 tons of vegetables, 2 tons of greens and 19 tons of tomatoes. Standard farms require a hundred acres to produce a similar crop, http://www.facepla.net/.

It is impossible to ignore the research of Professor Teruo Higa (University of the Ryukyus, Okinawa, Japan), who created the special microbiological consortium, which not only cleanses and remediates the soil, but also has a positive impact on the environment. According to his conclusion, dozens of different forms of microorganisms are effective, since they use their regenerating function, contributing to a significant intensification of characteristic soil processes, metabolism, and increased digestibility of mineral and organic substances. Because of effective collaboration of soil and plants, the efficiency of plant fertility is significantly enhanced.

Professor T. Higa's effective consortia of soil microorganisms' consist of synergistically acting aerobic and anaerobic microorganisms. The consortium of the microorganisms includes lactic acid and photosynthetic bacteria, as well as microorganisms from all taxonomic groups, bacteria, yeasts, actinomycetes, and fungi having an exceptionally wide spectrum of action. These microorganisms, being antagonists of pathogenic microflora, inhibit their growth, and thus significantly ennoble the soil. These works have been widely distributed, and are available at: https://agriecomission.com/base/teruo-higa-i-ego-effektivnye-mikroorganizmy [125].

The breeding of a new highly productive animals and plants, whether genetically modified or created by classical technologies, should also be considered as an opportunity to increase food production and environmental preservation through energy-saving technologies, and the rational use of already limited natural feed resources.

The amount of solar energy, as permanent source, has direct contact with the earth's surface (soil) in regions with a moderate or moderately hot climate equal up to 10 billion kilocalories per hectare annually. The lack of a large-scale technology for solar energy conservation, it become highly desirable to strengthen the natural forms of conservation of this gratuitous form of energy, expressed in the form of accumulated plant biomass, simultaneously strengthening the immune system of the soil. This is achieved by increasing the intensity of photosynthesis, active fixation of molecular nitrogen, and increase of reproduction of ecologically extremely important rhizospheric microflora. Following to the greening of the planet, it would be extremely profitable form of using solar energy and at the same time a great contribution to the environment.

Undoubtedly, one of the most important problems of nowadays is purification and desalination of potable water. Despite the lack of real large-scale technologies capable of fundamentally solving this crucial problem, there are some certain successes in technological solutions. Scientists from the SLAC National Accelerator Laboratory of the US Department of Energy and Stanford University have developed a device that is activated by the sun and kills 99.999% of bacteria in water in 20 minutes, getting microbiologically absolutely clean water. (www.slac.stanford.edu).

It is necessary to carefully analyze and widely use all kinds of economical technologies for spending natural resources in all industries, and this should be done by authoritative international organizations. This is an involuntary, but certainly progressive stage in the formation of new principles of technological security of society. Researches in this direction are continued intensively, and a number of original technologies and high-tech patents on environmental issues have been published.

Nevertheless, the question is raised: against the background of a significant increase in "toxicity" in all ecological niches, have these new innovative ecological technologies brought any significant improvement in the sense of the ecological balance of the environment? Of course not, because the systematically increasing emission of toxic compounds outstrips the potential of their useful action, and they are all limited to regional scales. Novel, more revolutionary global technologies, approaches, and solutions are urgently needed to stop or minimize the ecological imbalance growing at a catastrophic rate.

How realistic is the creation of revolutionary technologies that can seriously affect the ecological picture of the entire planet in modern conditions? There are no obvious solutions, which would can solve the problem immediately and unambiguously. Therefore, it is necessary to solve comprehensively the unpredictably rapidly increasing technogenic contamination of the entire ecosystem of the planet by all available means. At the same time, it should be taken into consideration that the technology itself should not serve as a source of infection of any ecological niche. In this regard, especially increased interest is paid to biological principles and ecological technologies, which are actually environmentally friendly.

According to the FAO (Food and Agriculture Organization of the United Nations), the demand for food by 2050 will increase by 60% and by almost 100% in developing countries. All this should be realized when 33% of the soil is degraded to a degree from moderate to deep erosion, as a result of depletion of food resources, salinization, lack of moisture and chemical contamination with toxic substances. The rate of degradation of such a valuable natural resource as soil is so high that in the future they call into question not only the possibility of using technologies of global scale affecting food production, but also the implementation of elementary sanitary ecology. It is estimated that because of irrational use, up to 2 billion hectares of productive land resources have already been lost, more than the entire modern area of arable land. The main factors of soil degradation are undoubtedly the constantly increasing number of toxic compounds, irrational technologies for the use of land resources. Water erosion, which leads to the destruction and demolition of the soil cover, should be noted first among the natural factors that degrade the soil. Undoubtedly, wind erosion causes great damage to the soil, especially in steppe regions and places where dust storms are characteristic. Under the influence of these factors, in addition to erosion, depletion of the remaining soil is observed, that significantly weakens its immune system. Thus, the lack of any of the nutrients required by plants for growth and a full-fledged harvest can lead to a significant decrease and deterioration in the quality of the products produced. According to the FAO data, soil as a constantly in demand, depletable and non-renewable resource, in case of deep erosion, takes a long time to fully recover, and in some unfavorable soil-climatic zones – almost a period corresponding to the life-span of one generation. Despite the very high authority of any FAO information, it should be noted that the restoration of eroded soil can be solved in a much shorter time by artificially enriching the soil with elementary organic matter and introducing selectively chosen soil microbial consortia (bacteria, mycelial fungi, actinomycetes), based on existing climatic conditions.

The degree of soil degradation is very different. The common classification includes the following four degrees of gradations: light (weak), moderate, strong and extreme. According to the UN, the extreme degree at which the soil cover is destroyed, is not widespread. However, it should be borne in mind that even 1% of very heavily degraded arable land on a global scale is 16 million hectares. Almost 2/3 of arable land are subject to strong and moderate degradation (see Fig. 19).

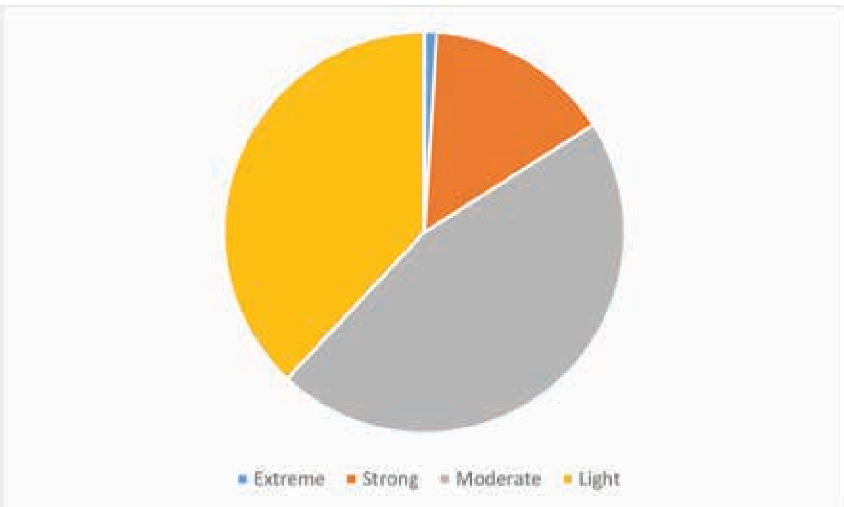


Fig. 19. Global extent of soil degradation

Fig. 17 shows another potential for the ecological safety of the planet. These data clearly indicate that problems related to the ecology of the entire planet should be solved comprehensively at the level of international organizations such as the UN. Undoubtedly, soils on all continents are the most important for all humanity by their importance.

Taking into account all the above mentioned, the authors proposed a biological concept developing over 30 years as a permanent acting ecological biotechnology, designed to restore eroded soil, monitor and improve ecological imbalance by degrading toxic (foreign) compounds, intensifying the metabolic processes of the soil, by using the detoxification potential of rhizosphere microorganisms and the root system of plants. There are numerous examples proving the efficiency of both, their individual and combined use, in cleaning the soil from contaminants of various structures. In fact, the proposed concept represents a significant intensification of the natural biological process based on the synergistic action of microorganisms and plants to jointly degrade anthropogenic contaminants of toxic nature in natural conditions. A significant increase in the efficiency of the technology is achieved through the selection of both plants and microorganisms that actively assimilate contaminants in the soil. According to the authors' calculations, the effectiveness of joint detoxification potential of microorganisms and plants occurring in nature, as a result of their joint co-existence, does not exceed 5-7% of their maximum capacity. This potential can be increased to at least 40-50% by introduction in soil selectively chosen active consortia of microorganisms and plants (root systems), thereby strengthening the immune system of the soil, and using them in the form of environmentally friendly technology under unlimited global conditions. To emphasize the significance and importance of the proposed biological principles as remediation biotechnologies, it would be reasonable to discuss the data presented on the Fig. 18, where just schematically is shown the planet in a section that makes it possible to assess its technological value.

The soil is an extremely thin layer, in different parts of the planet ranging in thickness from 20 to 150 cm, surrounding the entire terrestrial land and bearing a colossal, incomparable responsibility related to the realization of photosynthesis (source of organic matter), diverse harvest, ecological balance (metabolically degradation of foreign compaunds by different ways hited in soil) and, in general, the well-being of all mankind. In different parts of the planet, the functional activity of the soil varies significantly. From a natural technological point of view, assessing the biological functions of land layers located even deeper (2 meters or more), it should be noted that at these depths, there is a certain transformational action (activity) of the subsurface layer, mainly due to the action of microorganisms (mostly anaerobs). Assessing technologically the ecological function of this layer, ranging from 4-6 to 10 meters in depth, it should be noted that there is the boundary which divides almost the entire universe into a viable, upper part, still metabolically active, and a deeper, much more inert part, possibly having trace amount of biological transformation activity. Modern views on the functions and characteristics of individual soil layers are schematically shown in Fig. 20.

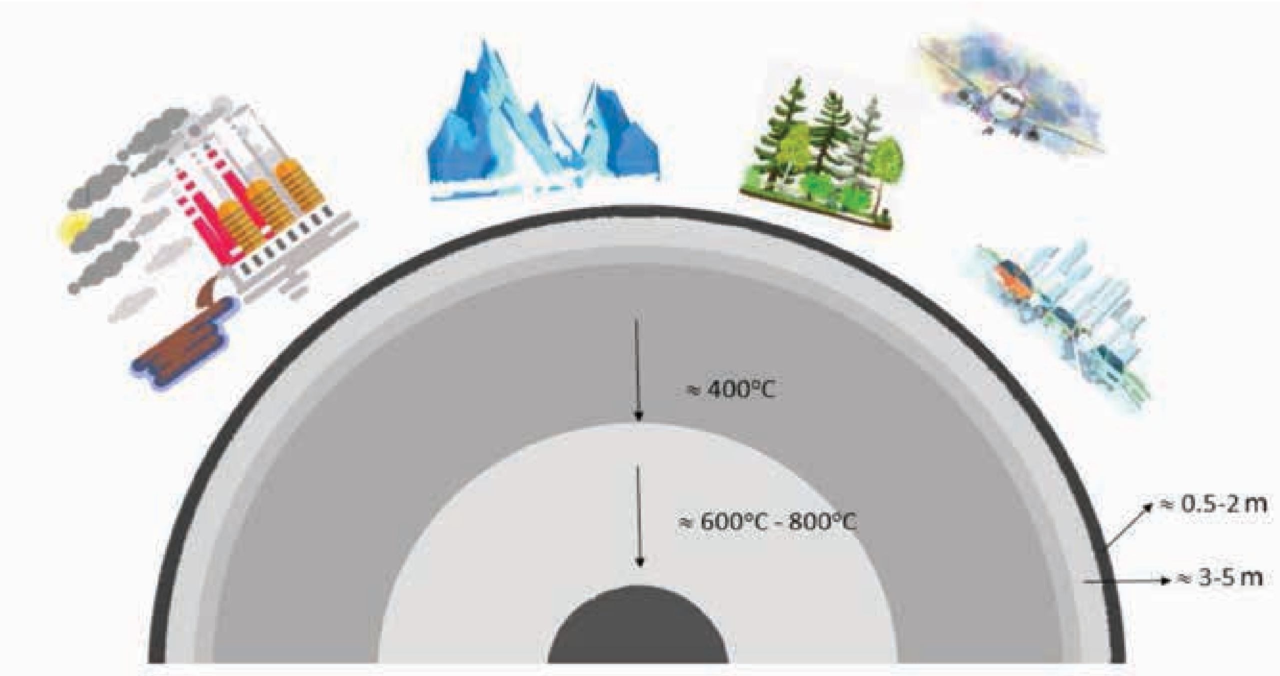


Fig. 20. The cross section of the planet

The soil mainly consists of humus (organic part), microorganisms and some other organisms, plus minerals in different ratios. However, due to the permanent increasing deterioration, it is necessary to emphasize, extremely important function of the soil and the subsurface part of the earth's crust, which should metabolically eliminate a large number of a wide variety of toxic compounds. Having a thorough understanding of the functional activity of soil, it should be noted that there is its permanent enrichment with a number of uncharacteristic, toxic in nature, stable technogenic compounds from both sides: the deeper and the upper layers of the soil.

Deeper part of the soil represents a high-temperature bubbling mass with a colossal potential for chemical synthesis, with temperature 600-800 °C, and up to 1200 °C in the asthenosphere. This part of soil is a powerful source for the formation of a new, stable and uncharacteristic for the upper part of the nature compounds. These, mostly stable compounds, formed in the bowels of the earth under conditions of high-temperature regime, reach the soil cover. The decontamination potential of the soil is the main power to bind and transform most of them into harmless compounds. If not such preservation, they could significantly affect the chemical composition of the upper layer of the Earth's crust and even the near-Earth part of the lithosphere.

When technologically assessing the exceptional role of the soil cover, it should be noted that the soil transforms most of these compounds into ordinary natural components. This vitally important process is carried out in soil mainly by soil microorganisms of all taxonomic groups, as well as by the plants root system; a small part of compounds entering the upper part of soil undergo natural oxidation. A number of these compounds are characterized by high stability, being products of high-temperature regime synthesis; probably, some small part of them still leak through the soil cover and become components of the lithosphere. Undoubtedly, most of soil organisms take part in the transformation processes of these compounds, although microorganisms and the root system of plants conduct the lion's share of transformations. Thus, the soil is the main component of nature, assimilating and transforming compounds formed in the deep bowels of the earth and in the aboveground atmosphere.

What happens outside (above) the soil is a fairly well studied process, in which the soil is assigned a unique role in maintaining a vital ecological balance. Toxic compounds, products of emissions from transport, energy, agriculture, etc., due to their heavier specific gravity in comparison with air, are mainly located in a distance of up to one and a half meters (150 cm) from the earth's crust (soil). All these compounds eventually turn out to become cellular components of plants, rizospheric microorganisms and other living organisms. It becomes quite clear that the soil, having a certain transformational potential, could not decontaminate permanently, significantly increasing concentrations of toxic components.

The selection of highly active soil microorganisms (bacteria, mycelial fungi, actinomycetes), active destructors of toxic compounds, and their introduction into the soil, jointly with the root system of also selectively chosen plants, actively assimilating toxic components, significantly increases the decontamination potential of normal soil, into nature-friendly ecological biotechnology. Thus, the proposed biotechnology copies and accelerates the natural process of the carbon containing compounds circulation, including those forming toxicity, through significantly enhancing soil decontamination process.

Undoubtedly, any scale of use of ecological technologies would be only benefit for various regions on the planet, although it is especially advisable for those places where the concentration of a toxic nature compounds is higher than the maximum permissible concentration (MPC), creating critical living conditions. There are quite a lot of such regions on the planet. The technologies are also of interesting from the point of view of continuous monitoring of environmentally hazardous regions. As for the global scale of their use, it is quite obvious that they are not limited, since the cultivation of plants and the introduction of appropriate forms of microorganisms into the soil are possible and desirable under any conditions. Especially important is the fact that the microorganisms and plants being previously adapted to various conditions of existence, including extreme ones, is a guarantee of its successful implementation on a global scale.

The proposed technology, being used with maximum efficiency, is planetary in nature, and the success of its implementation is determined by the collaboration of all or most countries, regardless of their faiths, confessions, political orientations, traditions and any other factors, and consists in completely peaceful, large-scale selective landscaping of all feasible land regions. The implementation of this technology should include land resources of all categories: agricultural plantations, forest fund, settlement lands, and recreation areas as specially protected territories, places of former and present military dislocations. Special attention should be paid to the lands of post-war countries, which are likely to contain toxic, explosive substances, or toxic products as intermediates of their partial transformation. Despite a number of difficulties of a very diverse nature, it should be kept in mind that this is a forced event to preserve the conditions and the form of life to which the world community has been long time adapted.

What benefits could the use of the biological concept described above bring to the entire planet?

First, a more efficient use of free solar energy and light for the accumulation of plant biomass as a form of energy conservation, increasing the immune system of the soil as the most important environmental niche. Undoubtedly, in the search for alternative energy sources, solar energy is the main form that has no analogue, the action of which is directly connected to the formation, existence and increasing of the immune system of the whole nature.

Second, a significant increase in the dangerous areas inhabited by active, artificially introduced varieties of selectively chosen plant species and rhizosphere microorganisms. This will not only be the environmentally friendly technology that helps to clean soil from toxic and other uncharacteristic compounds, but it will also, promote the involvement of unused soil reserves of the planet. As well as the creation of new sources of water resources, which are critical for humanity, and will become an extremely friendly form of strengthening the multicomponent soil segment. Obviously, due to unpredictable growth of the world population, shortage of food, and increased toxicity, a new way of humankind's existence should be found, that leads to the planet turning into a joint, single system of analysis and planning all available agricultural and ecological potential and this is not far off. The implementation of environmentally friendly technologies, without disturbing the ecological balance, will become an important factor in the development of large areas of desert and the gentrification of low-yielding lands. The analysis of the amount of desolate lands in the north of Africa and the adjacent part of Asia alone equal to 11,630,400 km^2, which convinces that this region is vital, but still untapped potential of the planet. Egypt (with population 102.88 million) is a good example: once on the scale of the entire occupied area, the flourishing country has turned into a desert, and nowadays, 80% of the country's economy is located in the delta of one of the most abundant rivers in the world, the Nile, which is almost 700 kilometers in long. The presence of a tropical and subequatorial climate, as well as one of the most full-flowing rivers in the world, the Nile, with a colossal water basin, are prerequisites that can ensure the improvement of soils and the creation of conditions such as tropical ecology along the entire length of the Nile River from Lake Victoria to the Mediterranean Sea. Considering that the Nile River basin is 3,349,000 km^2, the flow rate is 2830 m^3/sec, and only one third of it can be presumably used for agricultural purposes, it is obvious that the Mediterranean Sea, for which the Nile is the main supplier of water, is not threatened by the danger of the Aral Sea type. Moreover, the water level in the Black Sea, into which a number of high-water rivers flow, exceeds the level of the Mediterranean, which ensures the overflow of water from the Black Sea to the Mediterranean Sea. In addition, the Strait of Gibraltar connects the Mediterranean Sea with the Atlantic Ocean, and this is a guarantee of the inviolability of this large and ecologically important water basin. The presence of normal fertile soil, water and living conditions in the region would dramatically affect the geopolitics of Africa, Asia and even Europe. What all this would mean:

-first, the large-scale landscaping, which would change the ecology of vast, now desert regions south of the Mediterranean Sea, positively affecting the climate mitigation of the entire north of Africa, as well as the emergence of additional water resources

-second, new regions for large-scale agricultural production would be created improving the food shortage in the entire planet scale

-third, normal, attractive living conditions would be restored in the north Africa, and the endless flow of migrants from Asia and Africa to Europe would stop. Undoubtedly, there will be a number of other political, economic, and ecological advantages from the implementation of this project that cannot be foreseen.

Since the ecological catastrophe affects the entire population of the planet, removal of land factors that hinder the population and the effective use of land, should become a universal task concerning the participation of all nations in the rehabilitation processes. Based on the unfavorable environmental prospects of society, it is almost certain, that in the very near future environmental well-being will have a serious impact on a geopolitical relations. The factor of ecological safety of the planet that should be the guiding vector when all countries and nations of the world will be forced to agree to place environmental welfare at the forefront of both politics and economics.

This mega-ecological project is an expensive undertaking, the first stage of which is to improve the land resources of the planet that are unfavorable for life and agricultural purposes. In the future, bioecological technologies should be implemented on a global scale, which will be an extremely important step that will allow maintaining the stability of the world community for at least many decades, even under the conditions of a difficult-to-predict increase in the population of the planet.

The creation of environmental and social projects related to the solution of pressing vital problems is necessary stage. Nowadays we are considering land areas of around 12 million km^2, which would, certainly imply a significant expansion of the territories of agricultural plantations, and the creation of new environmentally friendly hubs. Within several years, or maximum one decade, would be turned into normal high-yielding plantations and environmentally safe regions by applying modern agricultural technologies, the availability of water and a suitable climate, allowing improvement of untreated soils.

We accept messages at the address:

apotemkin@t-online.de

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Prof. Giorgi Kvesitadze,
Georgian National Academy of Sciences

Dr. Alexander Potemkin,
Hamburg, Germany

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