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DETERMINATION OF RISK AS A TECHNOLOGY ASSESSMENT CRITERIA AND ESTABLISHING THE SCOPE OF ITS APPLICATION

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Abstract. The article is devoted to theoretical studies of man-made safety of nature management technologies and risk as a criterion for their assessment.

The development of technologies is considered in the context of the theory of technological orders, which is based on the theory of long waves of M.D. Kondratiev. It is analyzed how the increase of the technological framework affects the level of risk of technological activity. Taking into account the time factor is especially important. It is theoretically proven that mining activity is always associated with the presence of environmental damage, and avoiding the conflict between economic growth and the need to preserve the quality of the environment is not always possible. And therefore, in order to ensure parity between the interests of ecology and the economy, a search for a rational or optimal solution must take place. Life dictates the search for new, often non-standard, technical and technological solutions using known natural phenomena and effects.

With the development of industrial technologies in the historical period, the danger level of impact on natural and social systems also changes. The process of technology development is shown on the example of successive changes in technological orders. The lower group of technological orders was considered on the example of mining technologies, nanotechnology was chosen as the representative of the higher group. Technologies of the lower orders are characterized by the locality of expressions and the insignificant duration of the negative impact on the environment. Technologies of higher technological orders are characterized by other parameters of influence in time and space frameworks. Their influence spans larger global systems and transcends the boundaries of one human generation.

The purpose of this work was to determine the stages of development of industrial technologies, characteristic features of their functioning, and to establish safety criteria and areas of their application.

It was established that the scope of application of the concept of "acceptable technological risk" as a criterion for assessment the effectiveness of the functioning of technological orders is possible only for the first four technological orders. For technological orders of higher technological orders, the application of this assessment criterion without conducting additional research and taking into account parameters of a different order is problematic.

Keywords: technologies of nature management, ecological safety, technological orders, acceptable technological risk.

1. Introduction

Global trends in world development today demand accelerated economic growth of society and forced modernization of industry, but above all, the creation of a system of technologies harmonized with society and the environment. The path of innovative development chosen by the world community makes the economy more dependent on business entities whose activities are related to the creation and development of technological innovations; they acquire strategic importance from the point of view of the efficiency of the economic system and national security. It is their potential that determines the possibility of producing national high-tech goods competitive in foreign markets. Based on this, the goal of the development of the scientific and technical system of the state should be the formation of a new technological innovation system, the basic element of which should be manufacturers of high-tech environmentally friendly products in combination with research, educational and related production structures. It is the focus on manufacturing enterprises that will provide the conditions for maintaining the market orientation of technological innovations, rapid commercialization and application of the results of scientific developments, and the increase of real competitive advantages. Scientific

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and technical development, as well as the solution of structural issues, which for a long time had no solution, are possible only if a breakthrough is made in the creation of a system of technological innovations, where production is chosen as the basis.

Currently, there is a sufficient number of methodological techniques, methods and ways of value assessment of natural resources, technological and environmental costs. Traditional methods of expert assessment, comparative analysis, factor analysis, use of financial ratios, as well as analysis of environmental costs and profits are used in the assessment and analysis of technologies in modern production conditions. The degree of influence of technologies of business entities is determined by a certain list of quantitative and qualitative indicators that act as criteria for assessment the functioning of an industrial enterprise. This is the basis for using a complex and systematic approach to the formation of a system of criterion indicators.

The assessment of technologies is carried out by substantiating the chosen method of production and technologies, taking into account all the environmental and social consequences of the operation of this technology. The general structure of production technology assessment includes the following areas: technological uniqueness according to existing analogues in the world; environmental friendliness of production methods; environmental friendliness of technical means; environmental friendliness of the technological parameters of the main redistributions; environmental safety of products and waste (use and storage); use of the territory; use of resources, emissions and discharges; compliance with sanitary and hygienic standards.

Approaches to the assessment of production, taking into account the mentioned aspects, determine the need to clarify the system of the following principles: systematicity, complexity, periodicity, specificity, scientificity, effectiveness, objectivity, efficiency. The use of these principles makes it possible to evaluate and take into account the ecological and social consequences of the "enterprise-environment" relationship, to form a system of ecological and economic indicators of a modern enterprise. A particularly important place is the determination of the degree of danger (risk) of the consequences of the functioning of technologies in the natural and social environments, which makes it necessary to determine the trends of their development and involve forecasting issues. For this purpose, it is advisable to expand the time frames of research, both in the historical side and towards prognostic predictions.

According to modern views, the development of technologies and their state in society is marked by technological conditions. The theory of technological orders is based on the work of M.D. Kondratiev on the theory of long waves, where he empirically proved the existence of long-term fluctuations, which represent large business cycles. Applying the methods of mathematical statistics, he analyzed economic indicators for a century and a half, starting with the industrial revolution at the end of the XVIII century, in the four most developed countries of that time: the United States, England, France and Germany. This study revealed three major economic cycles: two complete and one incomplete - the first cycle from the end of the XVIII to the middle of the XIX century, the second - from the middle to the end of the XIX century, the third - from the end of the XIX to the middle of the XX century [1].

At present, six technological orders have manifested themselves in the process of technology development. The article gives their brief definition. These technological orders are conditionally divided into two groups - lower (1st – 4th orders) and higher (5th – 6th orders). For a more complete characterization of the technologies of these groups, a representative technology within each is highlighted and considered in more detail.

The lower group of technological orders is represented by mining production, during the functioning of which negative technological influences and risks, including all components of the natural environment, manifested themselves to the maximum extent.

The highest group of technological orders is represented by technologies of the sixth system - nanotechnology, including genetic engineering, on the example of which the peculiarities of risks in the application of technologies of this group are considered.

Thus, the prerequisites will be established for the theoretical study of risk as a criterion for the functioning of technologies and establishing the scope of its application.

2. Methods

The deepening of environmental problems is exacerbated by the situation observed in the country's mining industry: a massive and largely uncontrolled process of closing mining enterprises, violation of the technological regimes of mining operations at those enterprises whose operational life is coming to an end, but which are still functioning, and this is in complete the lack of a mechanism for maintaining the safety of mining industry facilities in the country in conditions of the inability of their owners to solve these problems.

In this case, one of the most logical options, which lie on the very surface of the problem, is the option of further continuation of the operation of the mining enterprise, provided that its operation is technologically and environmentally safe. But such opportunities, within the framework of the existing regulatory and technological legislation, have exhausted themselves. Therefore, the task of finding a solution to this problem with the involvement of new information resources, primarily those related to the safety of the functioning of technological orders, arises.

The parameters of technological objects, including their service life, are determined and legislated at the design stage, therefore their change (including the extension of the service life) is considered as functioning in the mode of an emergency situation.

A conservative approach should be used when predicting functioning in an emergency situation, which consists in the fact that, based on the characteristics of the object and its parameters, values and limits are accepted that lead to the most undesirable results.

This situation is characterized by corresponding changes during technological processes or the emergence of new modes of operation of the equipment and the state of structures, under which, in order to ensure safety during the elimination of these failures, the transfer of the operation of the equipment to a special mode of operation, different from the mode of normal operation, provided by the project is carried out.

In addition, accidents at industrial facilities (depending on the scale) can often lead to long-term contamination of groundwater, soil, damage to biota and have negative consequences for human health. [2].

All these processes are not characteristic of the nature, they are not involved in modern natural cycles of substances, therefore they cause environmental pollution. And if you take into account that humanity uses only 2% of the mass of raw materials that it extracts from the subsoil, and the rest goes to waste dump and tailings, contributing to the destruction of the ecosphere, then the inefficiency of modern nature management becomes even more obvious. In fact, humanity produces mainly waste, and to an increasingly large extent. This especially applies to mining activities, as a result of which geochemical cycles that have developed over centuries are actively changing, landscapes, hydrogeological and surface water systems, biological groups, and much more are changed or destroyed [3].

Thus, the operation of the mining complex in a critical mode can lead to new threats to the natural environment, people and losses to society and the state. Therefore, the issue of developing new methods for the most comprehensive research and assessment of risks from the use of both traditional and new technological methods and tools is extremely acute today.

The purpose of this work is to determine the stages of development in the historical context of industrial technologies, the characteristic features of their functioning in nature and society, the establishment of technology safety criteria and areas of their application.

3. Theoretical part

According to modern scientific views, the dependence between the scientific and technical state of society and the level of acceptable man-made risks can be determined by examining technological orders. In our opinion, it is precisely the technological orders that correlate with the nature of man-made threats (risks) that may arise in the course of production activities taking into account certain material costs [4].

Based on his research on the theory of long waves, M.D. Kondratiev predicted the coming economic crisis of the 1930s, known as the Great Depression.

For more than 30 years, Kondratiev's ideas were ignored. However, the global economic crisis in the early 1970s forced scientists to turn to them almost simultaneously in several countries [1].

So, the key concept of Kondratiev's theory is «technological order»– a set of technologies and production of the same level. In the transition phase to the post-industrial stage of society's development, the technological system replaces the sectoral division of the economy with a technological division, the development of high technologies in all sectors becomes a priority. However, each technological system has its own leading technologies that form its core. The process of formation and change of the technological structure is manifested depending on the phase of the life cycle – formation, growth, maturity and decline.

Let's consider the characteristics of each of the technological orders in more detail.

The first technological order was marked by the presence of technologies related to the textile industry. The start of the process of formation of this order was the invention of weaving and spinning machines, which led to the transition of the textile industry to machine production. This, in turn, led to an increase in demand for engineering products. Metalworking process were also improved. Similar technological changes, with some delay, occurred not only in England, but also in other European countries, such as France and Germany. Starting from 1790, these processes began their development in the USA. The formation of the first technological order in these countries took approximately 30–50 years.

The second technological order. Starting from about the 1820s, the development of a new technological order took place in the depths of the first technological order. And in the period from 1845 to 1850, the second technological order became predominant in the economy of developed countries. The characteristic features of this system were the rapid development of the machine-building industry, including the production of machines with the help of other machines. International trade has experienced a dramatic increase in importance and intensity. However, the insufficient level of development of transport infrastructure limited the growth of large-scale industry. Therefore, the rapid development of railway construction and the production of vehicles became a key feature of this order. Increasing population concentration in cities and intensive construction in the transport industry required strengthening the technical base of construction and accelerated its mechanization [5].

With the exhaustion of the possibilities of mechanization of social production based on the steam engine, and with the saturation of social needs for products of the second technological order, the economic growth of the 1850s and 1860s was replaced by stagnation. Manifestations of overproduction became more obvious, and industrial growth became less intense. In such conditions, the third technological order began to take shape, where the leadership passed from England to the USA.

The third technological order was distinguished by the wide use of electric motors and the rapid development of electrical engineering. At the same time, the specialization of steam engines took place, and the consumption of alternating current became dominant. Construction of power plants began, and coal became the main source of energy. At the same time, an influential place for oil began to appear on the energy market, although it became the leading energy source only in the fourth technological order.

Against the background of this period, the chemical industry achieved significant success. Among numerous chemical and technological innovations, the process of obtaining soda by the ammonia method, the production of sulfuric acid by the contact method, and electrochemical technology were of particular importance.

The fourth technological order appeared at the end of the 1940s, when the technology that was the basis of the third order reached its maximum development and improvement. This new arrangement opened new directions in the development of technologies. At that time, the necessary material and technical base had already been created, which included:

- developed road infrastructure;
- telephone networks;
- development of new technologies and creation of infrastructure for oil production;
- improvement of technological processes in the field of non-ferrous metallurgy.

During the life cycle of the 4th order, the anticipatory development of the electric power industry continued. Oil became the main energy source. Petroleum products became the main fuel for almost all types of transport – diesel locomotives, cars, airplanes, rotorcraft, rockets. Oil has also become the most important raw material for the chemical industry. With the expansion of the 4th order, a global telecommunications system based on telephone and radio communication was created. There has been a transition of the population to a new type of consumption, which is characterized by mass consumption of durable goods and synthetic goods.

The fifth technological order. By the 1980s in developed countries, the 4th technological order had reached the limits of its expansion. From that time, the 5th order began to take shape, which currently dominates in most of the developed countries of the world. This order can be defined as the order of information and communication technologies. Key factors are microelectronics and software. Among the main basic industries, it is worth noting the production of automation and telecommunications equipment.

Thus, the beginning of the 5th order is associated with the development of new means of communication, digital networks, computer programs and genetic engineering. The fifth technological order actively generates the creation and continuous improvement of both new machines and equipment (computers, computer numerical control, robots, various types of machines), and information systems (databases, local and integrated computing systems, information languages and software processing tools information). Among the basic productions of the 5th technological order in the manufacturing industry, flexible automated productions are of great importance. Flexible automation of industrial production dramatically expands the variety of products produced. Another characteristic feature of the 5th technological order is the deurbanization of the population and the associated development of new information and transport infrastructure. Every person's free access to global information networks, the development of global mass information systems, and air transport radically change people's ideas about time and space. This, in turn, affects the structure of needs and motivation of people's behavior.

During the life cycle of the 5th order, the role of non-traditional energy sources increases.

The sixth technological order. Since the beginning of the 1990s, elements of the 6th technological order began to appear more and more prominently in the bowels of the 5th order. Its key areas include biotechnology, artificial intelligence systems, global information networks and integrated high-speed transport systems, computer education, and the formation of network business-communities. These are the industries that are currently developing in leading countries at a particularly fast pace (sometimes from 20% to 100% per year) [5].

Technological orders in Ukraine. Analysis of the technological level of development in Ukraine shows that the technological complexity of production is becoming one of the main structural problems of the Ukrainian economy today. Various types of technological orders exist and are reproduced in parallel and independently of each other. At present, production of the 3rd technological order dominates in Ukraine. This is the development of railway transport, ferrous metallurgy, electric power engineering, inorganic chemistry, coal consumption, universal mechanical engineering, and electric power engineering. In developed countries, the dominance of the 3rd order fell on the 1940s and 50s.

The 4th order is partly present, which exhausted itself in developed economies in the mid-1970s – the development of organic chemistry and polymer materials, non-ferrous metallurgy, oil refining, automobile manufacturing, precision engineering and instrument manufacturing, the development of the traditional industrial complex, the electronic industry, the spread of road transport, widespread use of oil.

As for the 5th technological order, its share is about 3–5% in the overall structure of the national economy. Today, this order defines the actual post-industrial type of production, i.e. the development of sophisticated computer technology, modern types of weapons, software, aviation industry, telecommunications, robotics, and new materials.

According to the data of the Institute of Economic Forecasting of the National Academy of Sciences of Ukraine, almost 60% of the volume of industrial production falls on the 3rd technological order, 38% – on the 4th order [6].

In terms of output, higher technological orders – the 5th and 6th - make up about 4%, and the 6th technological order, which determines the prospects of high-tech development of countries in the future, is almost absent in Ukraine (less than 0.1%). About 58% of industrial production falls on the 3rd technological order (technologies of construction materials industry, ferrous metallurgy, shipbuilding, metal processing, light, woodworking, pulp and paper industry) and 38% – on the 4th.

Almost 70% of the financing of scientific and technical developments today falls on the 4th, and only 23% – on the 5th technological order. 60% and 30% of innovative costs are distributed between the 4th and 3rd technological orders, and the 5th order in innovative costs occupies only 8.6%.

Regarding investments, which essentially determine the future for the next 10–15 years, 95% of all investments are directed to the 3rd and 4th technological orders (75% and 20%, respectively), and only 4.5% of investments are directed to 5th technological order. In the technological part of capital investments (technical rearmament and modernization), 83% dominates the 3rd technological order and only 10% falls on the 4th.

The analysis of the given data shows that the priorities that have actually been formed in Ukraine in recent decades do not meet the requirements of the time.

Considering the fact that today, in the real conditions of a full-scale war taking place in Ukraine, the structure of industry has undergone significant changes, and it is obvious that part of the enterprises of the mining, metallurgical and machine-building complexes of Ukraine, which are located in the occupied territories, cannot be taken into account. Under these conditions, it is rather difficult to analyze and evaluate the distribution of production by technological orders. And, therefore, the above figures can currently be considered approximate.

Analysis of the system of establishing and managing risks within the framework of lower technological orders.

Based on the above historical reference, the dynamics of natural, man-made and social hazards at the initial stage of development was determined by natural factors: climatic (temperature, humidity, etc.), physical (properties of the soil, physico-chemical properties of water, air, etc.), food (low level of protein nutrition – hunger), biotic (intraspecies and interspecies interactions). During this period, the level of danger (population mortality rate) was determined exclusively by the specified natural factors. Improving protection against natural hazards has become one of the main motives of people's activities. This was done by using the achievements of science and technology for the development of the economy and, accordingly, by raising the material standard of living and its quality: nutrition, service, health care, education, sanitary and hygienic conditions.

The causes of risk at lower technological orders were the insufficient level of economic development and the imperfection of social structures. This type of risk can be called socio-economic. The overall mortality rate, which characterizes the level of risk in society, and, therefore, the life expectancy indicator, which characterizes the level of safety, is in many ways a complex criterion not only for the success of medicine, but also the most important indicator of the level of socio-economic development of society.

Previously, the concept of absolute safety dominated, according to which accidents that were considered real had to be completely controlled and localized, ensuring complete safety through the creation of protection systems. However, this paradigm has led to significant losses for the economy, health and the environment, not only in Ukraine but also in the world. Major nuclear power plant accidents such as Chernobyl and Fukushima, as well as natural disasters, have shown the shortcomings of this concept.

The concept of «acceptable risk», based on probabilistic analysis, helped to solve some of the problems mentioned. This approach is based on the empirical fact that no activity can be absolutely safe [7].

The concept of risk associated with a specific technology and the acceptable level of risk determined by economic and social factors are used for the analysis of man-made safety. Thus, the acceptable level of security determines the protection against those threats whose destabilization or destructive influence is the most dangerous for the stability of the system [8]. Knowing the probability of occurrence of threats and expected losses allows avoiding serious disasters, mitigating their consequences and predicting effective compensatory measures [9].

Thus, acceptable risk is a level of risk that is considered acceptable and justified from the point of view of socio-economic conditions. For each type of technical objects, structures and transport systems, an acceptable man-made risk is established. This risk, of course, depends on the level of scientific and technical progress of technologies and industrial systems operating in society, as well as on political, economic and social factors. The amount of acceptable risk represents a certain compromise between the real risk and the possibility of its management, as well as between the level of security and its reach [4].

Therefore, the given concept of acceptable (permissible) risk is real and scientifically justified for the existing lower technological systems

The stages of development in time of technique and technology (within the third technological order) are presented in Figure 1. According to the figure, the ideal technological solution corresponds to a technology with zero risk, and a technology with an acceptable risk is located between the curves corresponding to the existing and the best possible technologies. The area between these curves characterizes the entire possible development of technologies of this order [10].

Traditional safety technology is based on a categorical imperative – to ensure safety, to prevent any accidents. As practice shows, such a concept is inadequate to the laws of the technosphere. The demand for absolute safety, which bribes with its humanity, can turn into a tragedy for people because it is impossible to ensure zero risk in man-made systems.

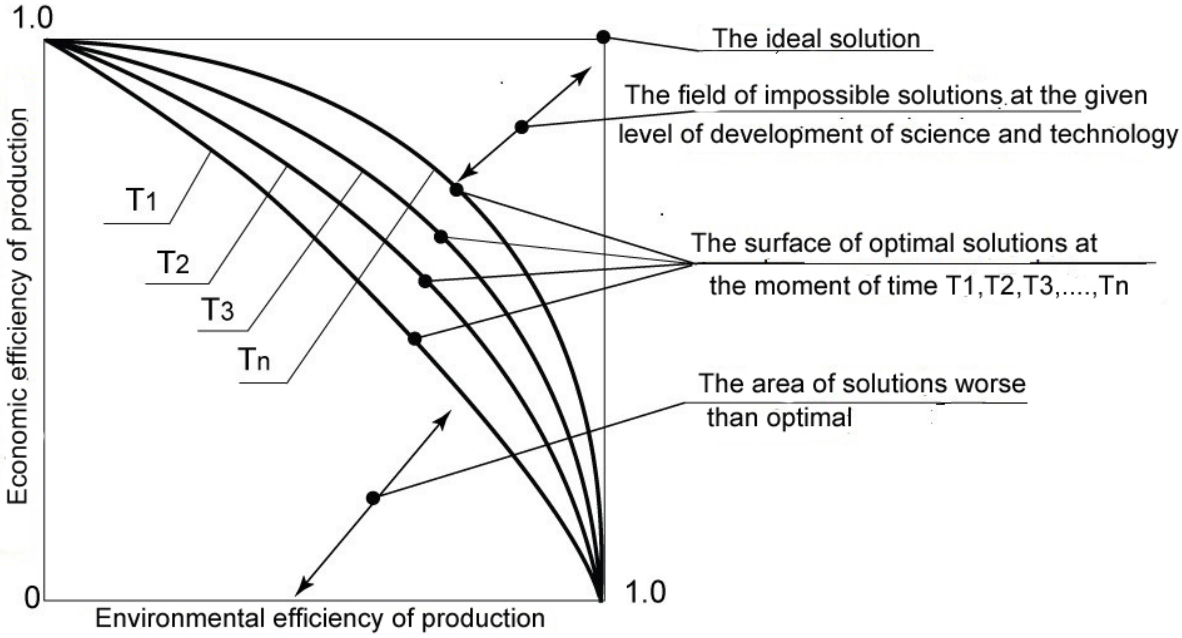


Figure 1 – Stages of technique and technology development over time [10]

The modern world rejected the concept of absolute safety and came to the concept of acceptable (permissible) risk, the essence of which is given above. But it should be noted that the parameters of acceptable risk should be attributed only to a specific period of time. The advantage of using the permissible risk indicator as a hazard assessment is provided by the fact that this permissible risk is realized with the help of technical, economic, social and political directions of human activity that exist in this period of time.

Actually, it is possible to solve (or mitigate) many environmental problems, to achieve relatively quick positive results in the management of the techno-ecosphere by implementing environmental protection technologies.

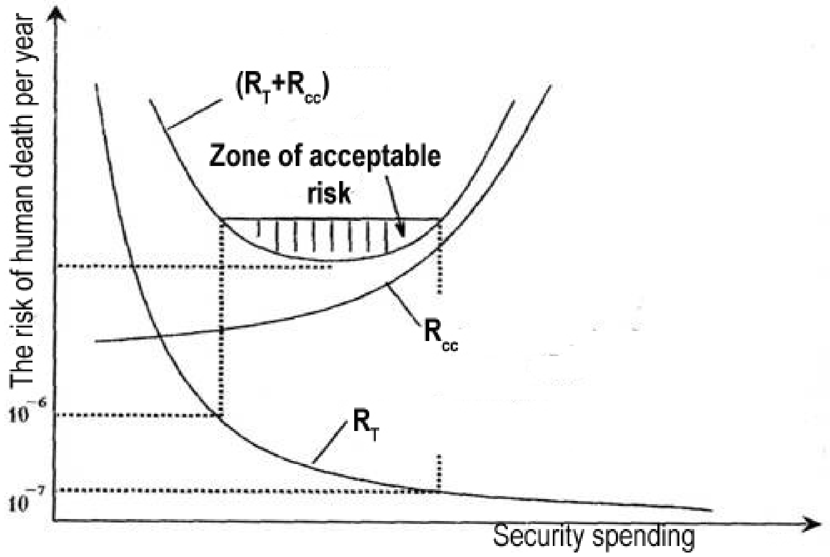
Theoretically, it can be argued that mining activity is always associated with the presence of environmental damage. Satisfying the interests of the parties in the existing conflict between economic growth and the need to preserve the quality of the environment is in principle impossible. In these cases, it is necessary to talk about the search for a rational or optimal solution, which would ensure satisfaction of the interests of both the environment and the economy to an acceptable extent.

This situation in the most general (theoretical) form, for various stages of the development of equipment and technology, is shown in Fig. 1. Optimal solutions that satisfy both ecological and economic interests in the best possible way are located on the curves marked by a solid line for certain moments of time. The less favorable solutions are inside the area bounded by this line and the coordinate axes, the solutions in the area bounded by the optimum line and the point with coordinates (1.1) are impossible.

Economic losses from environmental pollution increase as the load on it increases. At the same time, the first portions of pollution are absorbed by the environment, and the damage to nature, although it exists, is usually not taken into account in economic indicators. Each subsequent portion of pollution usually brings disproportionately greater damage, so the dependence of environmental damage on pollution is non-linear. The loss can be prevented if money is invested in technological measures that reduce the emission of pollutants. The function of these costs is also non-linear, because the costs of technological improvements grow disproportionately fast compared to emission reductions. It is clear that it is possible to achieve complete elimination of pollution only at the expense of infinitely large costs, which is practically impossible [10].

According to modern ideas, the condition of optimality is the equality of environmental damage and costs for reducing pollution, that is, when the total monetary costs of society to solve the problem of pollution control reach a minimum. It is called the point of economic optimum of environmental pollution, and it theoretically achieves the equality of costs and losses. However, in reality, given that the amount of environmental damage, due to its cost expression, is significantly underestimated, this economic optimum is not an ecological optimum, and even more an ecological-economic optimum. It has already been proven, in the problems of ecology, the market mechanism is as imperfect as the mechanism of centralized planning, because many resources, especially shared resources, do not have prices. In addition, in the evaluation process, it is necessary to compare incomparable indicators, and not all of them are expressed in monetary terms. At the same time, the larger the territory, the more difficult it is to find answers [10].

Acceptable risk combines technical, economic, social and political aspects and represents a compromise between the level of security and the possibilities of its achievement (Fig. 2).



R_T – technical risk; R_{cc} – socio-economic risk; R_T+R_{cc} – total risk

Figure 2 – Determination of the amount of acceptable (permissible) risk for industrial production [11]

In some countries, acceptable risks are established by law. The range of acceptable risks ranges from a maximum of 10^{-6} per year to a minimum of 10^{-8} per year. At the same time, the permissible risk for the ecosystem is equal to the amount at which 5% of the biogeocenosis species may be affected.

Levels of acceptable risk are established taking into account the actual level of accident (achieved safety level) and possible consequences of the accident – the more significant the consequences, the stricter the levels. Failure to accept the risks of accidents with serious consequences, possible at dangerous facilities, leads to the establishment of stricter safety measures for them. Thanks to this, lower levels of risks are ensured at such facilities.

As can be seen from the figures 1 and 2 above, the development of technologies helps to increase the zone of acceptable risk.

Research has established that the scope of application as a criterion for evaluating the effectiveness of the functioning of technological systems of the concept of «acceptable technological risk» concerns only the first four technological orders. This evaluation criterion cannot be applied to technological systems of higher technological orders, and the development of an appropriate evaluation criterion is a separate scientific task.

The above description of technological orders shows that the risks when applying different technologies in accordance with the orders differ significantly from each other. If for the technologies of the first technological orders the risks were local in space and limited in time, then starting from the 4th order, parameters corresponding to the global nature began to appear in their structure. This is primarily caused by the large-scale use of hydrocarbons, which leads to the occurrence of the greenhouse effect and climate change. In the process of using the technologies of the 5th technological order, the risks associated with it expanded their time limits and went beyond the life of one generation. This primarily concerns genetic engineering technologies.

The technologies of the 6th technological order are not subject to any assessment at all. Currently, there is not even an approximate methodology for assessing their danger and determining the man-made risk of implementation.

Analysis of the system of establishing and managing risks within the framework of higher technological orders.

To determine approaches to establishing criteria for evaluating technologies of higher technological orders, we will consider nanotechnology as a representative.

Nanotechnology is a branch of science that deals with technologies on the nanometer scale, which includes the range from 1 to 100 nanometers. Currently, it is most widely used in the computer field, energy production, medicine and biology [11].

Concepts that preceded nanotechnology were first discussed in 1959 by physicist Richard Feynman in his speech There's Plenty of Room at the Bottom, in which he outlined the possibility of synthesis through the direct manipulation of atoms. The term «nanotechnology» was first used by Norio Taniguchi in 1974, although it did not become widely known [12].

Inspired by the concepts expressed by Feynman, Eric Drexler used the term «nanotechnology» in 1986 in his own book Engines of Creation: The Coming Era of Nanotechnology, in which he proposed the idea of a nanoscale «harvester» capable to build a copy of itself and other elements of arbitrary complexity with atomic control. Additionally, in 1986, Drexler co-founded The Foresight Institute to promote awareness and understanding of nanotechnology concepts and their implications [12].

Thus, the emergence of nanotechnology in the 1980s was primarily due to the convergence of the theoretical and public work of Drexler, who developed and popularized the conceptual framework for nanotechnology, as well as apparent experimental successes that drew additional general attention to the prospects for atomic control of matter. In the 1980s, two major breakthroughs sparked the growth of nanotechnology into the modern era.

At the same time, commercialization of products based on achievements in the field of nanoscale technologies appeared. These products are limited to the bulk application of nanomaterials, and are not related to atomic control over this issue. Some examples are: the Silver Nano platform for the use of silver nanoparticles as an antibacterial agent for transparent sunscreens; carbon fiber reinforcement (using nanoparticles from silicon dioxide) for fabric stain resistant carbon nanotubes.

Nanotechnologies are developing in the following main directions:

- creation of materials with exceptional, predetermined properties by manipulating individual molecules;
- construction of nanocomputers that use sets of logical elements from individual molecules instead of conventional microcircuits;
- assembling of nanorobots – self-replicating systems designed for construction at the molecular level;
- nanoantennas for solar batteries;
- genetic engineering – the process of changing DNA in an organism's genome.

Thanks to nanotechnology, scientists manage to achieve better and better absorption of solar energy. One of the progressive companies conducting research in this field is Sandia National Laboratories. Its photo-absorbing films are characterized by a 20% better photoelectric effect. Based on nanotechnology, the American company Engelhard created something like a «molecular gate» through which carbon dioxide molecules pass, while larger molecules (methane) remain in the substance. It finds practical use in the filtration of carbon dioxide from natural gas, as well as in the creation of automobile catalysts.

Hydrocarbon Technologies, a subsidiary of the well-known American company Headwaters, has developed a method of processing coal using nanotechnology at the molecular level to create an environmentally friendly liquid fuel from it. It was the need to replace oil that contributed to the fact that in 2002, the Chinese company Shenua Group became a partner of the Americans and began to use the obtained artificial fuel instead of fuel oil. The NxCat nanomethod, created at another subsidiary, Nanokinetix, allows automotive catalytic converter fillers to capture volatile organic residues in exhaust gases. And the company Nanoforce has made a bet on the use of nanocatalysts for oil purification and on the technology of harvesting using the Poly-Web nanomethod – microscopic algae used for the production of bioethanol.

Light-emitting diodes belong to a completely different field of application of nanotechnology. The Japanese company Nichia is currently the leading manufacturer of lighting equipment based on nanotechnology. Their light-emitting diodes are many times more efficient than ordinary light bulbs. And if you take into account that 20% of the world's energy is spent on lighting, it becomes clear – the transition from ordinary lamps to light-emitting diodes will allow you to significantly save energy resources with a greater effect than modern silicon-based solar cells.

Genetic engineering, which is sometimes called genetic modification, is developing at a particularly intense pace. The first genetically modified organism, which was created in 1973, was a bacterium.

- In 1974, the same methods were applied to mice.
- In 1994, the first genetically modified food products appeared.
- Genetic engineering has a number of applications including scientific research, agriculture and technology.

- In plants, genetic engineering has been applied to increase the resistance, nutritional value and growth rate of crops such as potatoes, tomatoes and rice.
- In animals, it was used to breed sheep that produce a therapeutic protein in milk.

Work is underway to create bioengineered plants that could have the following properties:

1) high adaptability to environmental conditions;
2) contain more nutrients necessary for humans;
3) to be stored for a long time without deterioration.

Animal bioengineering is developing rapidly. The ovum is placed in a special mixer along with foreign DNA and small silicon carbide needles. The needles make multiple holes in the membrane through which the DNA enters the cell. Using this technology, bovine growth hormone has been injected into the ovums of many animal species. Thanks to this technology, large fish, cows, pigs, rabbits, and sheep were obtained. Transgenic animals are created for the production of products of medical importance [13].

Through genetic modifications, it is possible to significantly reduce the intensity of field treatment with pesticides and herbicides, since GM plants themselves already have immunity to certain pests or viruses. Genetically modified products can be given medicinal properties. For example, a banana containing analgin and a salad that independently produces a vaccine against hepatitis B have already been created. Food from GM products can be made cheaper, tastier and less picky about storage conditions.

Thus, unprecedented, almost fabulous prospects are opened up for humanity. But... (There is also «but», which is related to the problem of risk and is considered in more detail when discussing the results of the study).

4. Results and discussion

In the process of scientific and technical development of society and the gradual manifestation of global features in it (starting with the fifth technological order), new sources of danger directly appear in the social environment. As the population increases, the danger of epidemics increases. Due to the uneven distribution of benefits in conditions of limited resources of all kinds, the number of social contradictions is increasing. The intensive development of scientific research, their commercialization with the parallel degradation of ethical and moral foundations lowered the personal responsibility of the participants in the process. As a result, and not only that, the nature of the manifestation of risks has changed.

The problem of risk transformation in the modern world is currently important and is actively discussed in foreign scientific publications. The most significant in this regard are the works of the German sociologist Ulrich Beck. His key, most important work is the book «Risk Society. On the way to the second modern» [13–18].

According to the testimony of many scientists, this book is, in the exact sense of the word, an epoch-making book. This work set a new tone in sociology. This book argues that risks, like wealth, are allocable. But here we are talking about another product and another subject of distribution. In the case of benefits, we are talking about profits, goods, chances to get an education. In contrast, risks are a by-product of modernization and are produced in such quantities that it is desirable to prevent them.

Dangers that people often don't notice and don't feel are coming more and more to the fore, dangers that don't manifest themselves during their lifetime, but are passed on to their descendants. The basic principle of economy and modern management is production for the sake of wealth. It is obvious that production cannot exist without appropriate technological knowledge. That is, the more you know, the better you produce, the more significant the profit you get. The best knowledge has to do with power, influence, wealth. Thus, at present, wealth, power and education are closely related to each other.

All of this, according to Ulrich Beck, comes to an end in the "risk society". The place that was occupied by objective knowledge was taken by fundamental insecurity, that is, a feeling of threat or fear. It used to be possible to say that science monitors the objective state of affairs. Science is now complicit in the production of risks. One of Ulrich Beck's striking conclusions is that poverty is hierarchical, smog is democratic. That is, together with the expansion of modernization risks – with the threat to nature, health, food - social differences and borders become relative. [13].

Risks of higher technological orders are not just random events of natural or social origin that pose a threat and must be anticipated for assessment and prevention. They are produced by the entire social system and thus are the product of collective irresponsibility. Risks are not only produced by the system, but also become an extremely profitable business. For example, new chemicals cause new diseases that require new drugs to combat them, which cause side effects that require new drugs to combat. «Thanks to the changing definitions of risks, it is possible to create completely new needs and, therefore, markets» [13]. Thus, «...distribution and multiplication of risks in no way breaks with the logic of the development of capitalism, but rather raises this logic to a new level.

They represent what economists are looking for – requests that cannot be satisfied». Risks that have become global cannot be prevented at the local level. «Only those who understand and conduct national policy in a cosmopolitan manner will survive» [13]. This circumstance puts pressure on the modality of social relations, on the social structures of all countries. On the one hand, «the history of risk distribution shows that risks, like wealth, are distributed along a class pattern, only in reverse; wealth is concentrated in the upper layers, risks – in the lower ones. Probably, risks do not destroy, but strengthen class society» [13]. On the other hand, risks put everyone on the planet in the same social position. «Ultimately, friend and foe, East and West, top and bottom, city and village, black and white, South and North, succumb to the pressure of the growing civilizational risks. Risk societies are not class societies, but that is not enough. They carry in themselves the basic democratic dynamics of development, which undermines borders, with the help of which humanity is driven into a unified situation of civilized self-destruction» [13].

Risks create a special type of management and self-management of people's behavior in modern society – management through fear of a possible future. «In a risk society, the past loses its ability to define the present. In its place, the future is put forward as something non-existent, as a construct, a fiction as the «cause» of modern experiences and actions» [13]. In another place, he wrote: «The specific ontology of risk found its expression in overcoming the differences between reality and representation – and this is a key factor in the perception of reality, which is in the process of becoming» [14].

Based on these works, it is possible to more clearly imagine the development of technologies of the higher 5th and 6th technological orders as those that gradually decrease in size, are minimized to the size of an atom, and then disappear from the field of view altogether. This figurative series includes not only technologies with the prefix nano-, but also psycho-, and in the final version, noo-.

Especially dangerous for society are political technologies, which include the manipulation of public consciousness with the aim of political influence on the population, through the information substitution of concepts, meanings and values.

Thus, it can be argued that the formation of the 7th technological order can be seen in the bowels of the 6th order, the basic basis of which will be nootechnologies.

5. Conclusions

The article describes the historical process of the development of nature management technologies in the context of assessing their safety of functioning in nature and society.

The process of technology development is shown on the example of technological orders. The technologies of the lower orders are characterized by the locality of negative manifestations and the insignificant duration of the negative impact over time. Human life is taken as the unit of risk. Acceptable technological risk is taken as a criterion.

It was established that the scope of application of the concept of «acceptable technological risk» as a criterion for evaluating the effectiveness of the functioning of technological systems is possible only for the first four technological orders. For technological systems of higher technological orders, it is impossible to apply this evaluation criterion without conducting additional research and taking into account parameters of a different order.

Technologies of higher technological orders are characterized by other parameters in time and space. In time, they go beyond the boundaries of a generation, and in space – on a global level.

The properties of nanosystems are significantly different from the properties of larger objects consisting of the same atoms and molecules, therefore the determining point in risk assessment is the establishment of the possible toxicity of nanomaterials. This especially applies to the impact of such neoplasms on biological systems and human health. Given that biological objects are much more complex than technology, some artificial manipulation of biological objects creates the possibility of a breakdown of the biosphere for such a long time that will exceed the existence of any civilization.

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ВИЗНАЧЕННЯ РИЗИКУ ЯК КРИТЕРІЮ ОЦІНКИ ТЕХНОЛОГІЙ ТА ВСТАНОВЛЕННЯ ОБЛАСТІ ЙОГО ЗАСТОСУВАННЯ

Копач П., Якубенко Л., Мормуль Т., Данько Т., Горобець Н., Гальченко З.

Анотація. Стаття присвячена теоретичним дослідженням проблем техногенної безпеки технологій природокористування та ризику як критерію їх оцінки.

Розглянуто розвиток технологій в контексті теорії технологічних укладів, яка ґрунтується на теорії довгих хвиль М.Д. Кондратьєва. Проаналізовано яким чином підвищення технологічного укладу і удосконалення технології в межах укладу впливає на рівень ризику технологічної діяльності. Особливо важливим є врахування фактору часу. Теоретично доведено, що гірничодобувна діяльність завжди пов'язана з наявністю екологічного збитку, а уникнення конфлікту між економічним зростанням і необхідністю збереження якості довкілля не завжди є можливим. А тому для забезпечення паритету між інтересами екології і економіки має відбуватися пошук раціонального або оптимального рішення. Життя диктує пошук нових, часто нестандартних, технічних і технологічних рішень із застосуванням відомих природних явищ та ефектів.

З розвитком промислових технологій в історичному періоді змінюються і масштаби та рівень небезпеки впливу на природні та соціальні системи. Процес розвитку технологій показано на прикладі послідовних змін технологічних укладів. Нижчу групу технологічних укладів розглянуто на прикладі гірничодобувних технологій, представником вищої групи обрано нанотехнології. Технології нижчих укладів характеризуються локальністю проявів та незначною тривалістю негативного впливу на довкілля. Технології ж вищих технологічних укладів характеризуються іншими параметрами впливу в часових і просторових рамках. Їхній вплив охоплює більш глобальні системи і виходить за межі одного людського покоління.

Метою даної роботи стало визначення етапів розвитку промислових технологій, характерних ознак їх функціонування та встановлення критеріїв безпеки та області їх застосування.

Встановлено, що область застосування поняття «прийнятного технологічного ризику», як критерію оцінки ефективності функціонування технологічних систем, є можливим тільки для перших чотирьох технологічних укладів. Для технологічних систем вищих технологічних укладів застосування цього критерію оцінки без проведення додаткових досліджень та врахування параметрів іншого порядку є проблематичним.

Ключові слова*:* Технології природокористування, екологічна безпека, технологічні уклади, прийнятний технологічн ий ризик.