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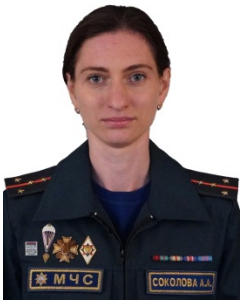

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EMERGENCY RESPONSE IN RESPONSE TO A RADIATION ACCIDENT: HISTORICAL DISCOURSE[1]

The article presents the historical discourse on the use of a «peaceful atom» by mankind, which is relevant in connection with the energy sensitivity of modern states, the prospects for the development of nuclear energy, as well as the japanese Chernobyl and emergency response in eliminating the consequences of a radiation accident that affects the development of the natural economic and economic world system. Nuclear power is closely related to the technical condition and operation of nuclear power plants, which sometimes cause manufactured emergencies with negative environmental consequences for humans, society, and the biosphere, since it is the «peaceful atom» that is a prerequisite for environmental safety for many countries and serves to achieve a high level of competitiveness of the economy.

Keywords: *peaceful atom, environmental safety, control, energy dependence, emergency, global nuclear power.*

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«МИРНЫЙ АТОМ» И АВАРИЙНОЕ РЕАГИРОВАНИЕ ПРИ ЛИКВИДАЦИИ ПОСЛЕДСТВИЙ РАДИАЦИОННОЙ АВАРИИ: ИСТОРИЧЕСКИЙ ДИСКУРС

В статье представлен исторический дискурс применения «мирного атома» человечеством, что актуально в связи с энергозавитсимостью современных государств, перспективами развития атомной энергетики, а также японским Чернобылем и аварийным реагированием при ликвидации последствий радиационной аварии, влияющими на развитие природно-хозяйственной и экономической мировой системы. Атомная энергетика тесно связана с техническим состоянием и эксплуатацией атомных электростанций, иногда являющихся причиной возникновения чрезвычайных ситуаций техногенного характера с негативными экологическими последствиями для человека, общества, биосферы, так как именно «мирный атом» является для многих стран необходимым условием экологической безопасности и служит для достижения высокого уровня конкурентноспособности национальной экономики.

[1]Статья публикуется в авторской редакции.

Ключевые слова: *мирный атом, экологическая безопасность, контроль, энергозависимость, чрезвычайная ситуация, мировая атомная энергетика.*

Introduction. The global processes taking place on our planet actualize not only foreign policy issues, macroeconomics, but also concern the technical sciences: world nuclear energy and emergency response in eliminating the consequences of a radiation accident at modern nuclear facilities. Improving methods for optimizing the operating modes of nuclear power plants (complexes) based on renewable energy sources, as practice shows, is now a basic component and takes into account various factors in the process of organizing the most efficient use of a «peaceful atom». Because of its geopolitical position and the openness of the national economy, the Republic of Belarus is exposed to almost all processes of globalization [1, p. 50].

Global trends in the development of the so-called «peaceful atom» indicate that the nuclear industry is actively developing in modern Kazakhstan and Armenia (planned to build new nuclear power plants, transition to a new power unit, the basis of which will be the prolongation of the service life of the nuclear facility operating in the camp). High growth rates of energy consumption in these countries imply an increase in imports of electricity and gas, which is unprofitable; therefore, in 2024 this issue was actively discussed, at a national referendum, as young people are interested in the dynamic development of nuclear energy. Thus, Kazakhstan has experience in operating nuclear facilities, using modern technologies and the necessary scientific base, which will ensure the country's economic independence in the process of diversifying the energy sector, as well as create new jobs, which is a strategic priority in the near future.

In recent years, Kazakhstan has been widely considering a project to modernize and extend the life of the Armenian nuclear power plant, which is not only a technical prospect, but also the result of cooperation with «Rosatom», the IAEA, and other partners to replace the power unit, taking into account the economic efficiency, safety, nature and characteristics of the national energy system, prospects for developing geographical environmental safety systems in the context of situational modeling [2, p. 311].

In the modern Republic of Belarus, which does not yet fully have its own fuel and energy resources, purposeful work continues to reduce risks to economic stability and energy dependence (import of gas, electricity). The Department of Energy estimates that electricity consumption will increase to around 44 billion kWh by the end of 2025, with a target of 47 billion expected by 2030 [3].

Despite the fact that in the context of growing geopolitical turbulence and constant fluctuations in world energy prices, the Republic of Belarus has achieved serious success and reduced its energy dependence, actively developing alternative energy sources. The fundamental directions today are the construction of the Belarusian nuclear power plant and an increase in the share of renewable energy sources, as well as the transition to local fuels [4]. Everyone knows that the «peaceful atom» today is in great demand in all countries, although the number of natural and artificial disasters does not decrease, which is associated with economic, environmental safety and different-vector trends in the global nuclear energy market [5, p. 154].

The relevance of the historical discourse on the use of the «peaceful atom» is determined, firstly by the fact that it is impossible to stop the spread of the since humanity is constantly increasing energy consumption, and the use of other energy carriers (coal, oil, gas) becomes unprofitable due to the intensive use of natural energy sources, which at the beginning of the XXI century are almost completely exhausted by humanity.

Secondly, in the event of an emergency, radiation impact on objects of economic activity, as practice shows, changes of an economic and environmental nature are observed, which lead to significant, often irreversible consequences, having a devastating effect on the biosphere and sociosphere. Consequently, the organization of material and technical support for nuclear facilities at the stage of their operation, the improvement of quality control tools for technological processes (multi-parameter control

of multilayer structures), the optimization of constants and software tools for monitoring the distribution of energy removal in reactors at a nuclear power plant are becoming a priority. At the same time, it is important to pay special attention to the development of radiation-protective composite materials, theoretical and practical aspects of route optimization of dose loads in a system with radioactive objects, in relation to different stages of the life cycle of a nuclear power plant.

And, thirdly, the need to take into account the ongoing global, regional multidirectional transformations that are directly related to human use of the «peaceful atom», development and substantiation of a design model for safety analysis of a point for deep burial of liquid radioactive waste during operation of equipment for fabrication of nitride uranium-plutonium nuclear fuel, as well as the stress-strain state of destruction mechanisms in the event of an emergency and elimination of the consequences of a radiation accident at high-risk nuclear facilities [6, p. 66].

World practice confirms the fact that artificial accidents and emerging emergencies are characterized by physical, chemical-biological impacts, radiation pollution affecting nature and human health, which is directly related to the culture of economic safety and its strategic importance for nuclear energy [7, p. 105]. Therefore, in the system mode, specialists carry out an examination that establishes the correspondence (inconsistencies) of economic activity, like any other activity of a modern person, which must correspond to the previously set parameters.

The determining factor necessary for the implementation of measures to ensure the safety of nuclear facilities, is the audit, development and testing of the procedure for temporary storage of used radioactive waste of nuclear power plants, which are specific measures aimed at developing the method of scanning contact potentiometry, results of use when monitoring equipment at the station, as well as identification, prevention of violations of environmental legislation necessary to prevent environmental disasters and accidents at nuclear power plants.

Main part. In this regard, the greatest interest today is the effectiveness of the use of a «peaceful atom», a retrospective analysis of the tragic results of accidents at nuclear facilities that prove that the most dangerous are artificial disasters, equipment failures in the power systems of nuclear power plants. If we recall historical facts, then at the end of the 20th century serious accidents were recorded at the plant of an American corporation in 1986 (Bhopal), in Chernobyl (USSR), where radioactive contamination of many territories of Europe, Belarus, Ukraine, and Russia occurred. In March 2011, during the liquidation of the consequences of the radiation accident at «Fukushima-1», the population was urgently evacuated, from the three-kilometer zone around the station, and four days later, the evacuation zone of 164 thousand people was 20 kilometers.

The «Great Earthquake of Eastern Japan» of magnitude nine, which occurred in the waters of the Pacific Ocean northeast of Tokyo, provoked a tsunami (wave height reached 40 meters in height) and an accident at a nuclear power plant, resulting in the melting of the active zones of reactors at three power units. The nuclear facility's systems received the earthquake signal and automatically shut down the nuclear reactors, triggering emergency cooling systems. Despite this, the tsunami wave overcame the barrier, flooding the station and damaging the cooling systems, which, according to the International Scale of Nuclear Events, characterizes this accident as the maximum seventh level. Molten nuclear fuel in the reactors of the power units and the accumulated hydrogen at «Fukushima-1» led to explosions, as well as the release of a large amount of radiation. In this regard, the International Atomic Energy Agency noted that the speed of evacuation became an important factor in the zero number of victims in the aftermath of the radiation accident at «Fukushima-1». And although no one died from radiation, but, in subsequent years, many elderly people died from exacerbation of chronic diseases, nervous shock. As a result, of the explosions, dozens of workers exposed to radiation 2,553 are still missing, and the Japanese earthquake killed 15,893 people. All affected employees of the nuclear power plant hospitalized, but radiation poisoned the water, soil and more than 160 thousand people evacuated, and an increased content, of radionuclides was found in food not only in

Fukushima Prefecture itself and in remote areas of the country. Japanese Chernobyl destroyed the city of Yamada, Iwate Prefecture, and the settlements of Minamisanriku, Sendai, Okuma on the east coast, where the station was located, were also, seriously affected. The tragedy at the Fukushima-1 power plant, which experts believe is inferior to Chernobyl in terms of the scale of the consequences, has demonstrated that a «peaceful atom» can lead humanity to catastrophic consequences [8, p. 194].

The basic principle that ensures the safety of using a «peaceful atom» is layered protection, focused on a system of barriers to the spread of radioactive substances, ionizing radiation, organizational and technical measures to protect the population and plant personnel, which implies the creation of successive levels of protection against probable personnel errors and equipment failures at modern nuclear facilities. The emergency as the most destructive patio-temporal change affects all spheres of social life (economic, political, social, spiritual) has specific features and its own special characteristics. Emergencies have a duration in real time necessary to identify sources, consequences and the most effective implementation of measures to minimize damage from nuclear facilities [9, p. 16]. In this regard, the priority today is to provide engineering safety systems at a nuclear power plant, which is a system implementation of effective layered protection (emergency shutdown of the reactor, heat removal from the reactor core, retention of radioactive substances within the specified boundaries of the plant structures).

In the event of an emergency, it is important to clearly implement the planned activities (structuring, aggregation, search for patterns, informing), which actualizes the modeling of algorithmization of management decisions in eliminating the consequences of a radiation accident, a culture of economic and environmental safety, its strategic importance for national nuclear energy, as well as when moving to a new technological platform for nuclear energy [9, p. 3]. Particular attention is required to develop a method for predicting and preventing abnormal growth of vibrations in the equipment of the primary circuit of a nuclear power plant, taking into account the peculiarities of radiation and thermal resistance of steels with a high nickel content, in relation to the operating conditions of high-temperature reactor shells of high-risk nuclear facilities and the prospects for the development of world nuclear energy in the near future [10, p. 174].

It is always important to remember that we must not forget about international cooperation when using the «peaceful atom» and actively develop the creation of databases on natural disasters, radiation accidents, artificial disasters occurring in the modern world, use neural network, statistical, logical-probabilistic methods developed on the basis of statistics of natural and man-made disasters in the process of modeling, probe territories of the polluted environment, algorithmize modeling databases using geographic information, Internet technologies for decision-making, optimization of compensation for environmental damage caused by an emergency at a nuclear facility.

Conclusion. In modern conditions, engineers working in the field of nuclear energy, firstly, it is important to pay special attention to the timely comprehensive work of a specialized scientific institution for integrated monitoring of high-risk facilities, which will expand the range of parameters in real time, and carry out, a better long-term study of the state of the environment (geo-economics', gynecological monitoring), paying special attention to the use of high-temperature superconducting materials, timely detection of electromagnetic damage to synchronous generators based on the analysis of failures of the external magnetic field, as well as the mandatory development and application of a fail-safe control algorithm that increases the efficiency of the operating mode of a high-risk nuclear facility. Timely measures taken to ensure economic and environmental safety should concern the integrated operation of nuclear power plants (nuclear waste, active spent fuel, reprocessing, uranium hexafluoride production, etc.).

Secondly, specialists need to take into account the fact that in the event of an emergency, at a nuclear power plant, it is situational modeling that becomes especially relevant in a situation of a possible destructive effect of radiation on the facility (human, material losses, economic, environmental damage).

Thirdly, to optimize the operating mode and systematically carry out timely comprehensive monitoring of nuclear facilities, apply mathematical, situational modeling, carry out quantitative and qualitative markers to characterize nuclear events and develop ways to eliminate emergency situations, which is important for the prospects for the development of world nuclear energy [11].

And, fourthly, systematically develop methodological grounds for predicting the maximum safe operation of high-risk nuclear facilities, as well as modern designs based on the use of integrated control using artificial intelligence.

Hardware and software complex for monitoring fire safety of nuclear power plants, multiscale modeling, planning of operating modes of an autonomous power system based on a nuclear power source, as well as optimizing the strength of composite structures, nanomodified light-absorbing coatings with improved properties when using an integration platform, as well as an integrated approach to updating solutions for deep burial of liquid radioactive waste will make it possible to implement algorithms for automating organizational control of fire and explosion safety of facilities of the fuel and energy complex of a nuclear power plant.

In the near future, it is necessary to specify the criteria for the method of assessing the characteristics of the radiation background of the surface atmosphere near a nuclear power plant, to determine the relationship between the properties of a high-temperature gas-cooled water-cooled power reactor and the state of the environment to ensure economic and environmental safety and the prospects for the development of a «peaceful atom» and world nuclear energy [12, p. 106].

Thus, in the modern realities of a multipolar world, situational modeling requires special attention, necessary for the most efficient implementation of emergency rescue operations, organization of financing of material and technical services in the event of a radiation accident at a nuclear facility, what is necessary for the subsequent rehabilitation of infected areas, ensuring safety at high-risk facilities, emergency response in eliminating the consequences of a radiation accident in the event of its occurrence at a nuclear power plant [13, p. 106].

References

1. Kovalenia A., Archakov V., Bankovsky A. Obespechenie naczional`noj bezopasno-sti v kontekste tendenczij razvitiya so-vremennogo mira [Ensuring national security in the context of trends in the development of the modern world]. *Belarusskaya dumka* [Belarusian thought]. 2021, no. 9, pp. 50–55. (In Russian)
2. Binenko V.I., Donchenko V.K., Rastoskuev V.V. *Riski i e`kologicheskaya bezopasnost` prirodno-khozyajstvenny`kh sistem* [Risks and environmental safety of natural and economic systems]. St. Petersburg, St. Petersburg State University, NICEB RAS, 2019, 352 p. (In Russian)
3. *Belorusskaya e`nergetika: sostoyanie i trendy`* [Belarusian energy: status and trends]. (In Russian). Available at: https://dzen.ru/a/Z2Vqtjr1MkR0dmYl?ysclid=m9yn9642jj509082127. (accessed: 26.04.2025).
4. Shishko E. L., Shumskaya V. V. E`nergeticheskaya nezavisimost` Respubliki Belarus` i razvitie al`ternativny`kh istochnikov e`nergii [Energy independence of the Republic of Belarus and the development of alternative energy sources]. *Gumanitarny`e nauchny`e issledovaniya* [Humanitarian scientific research]. 2025, no. 1 (In Russian). Available at: https://human.snauka.ru/2025/05/55568 (accessed: 25.08.2025).
5. Osetskaya M. M., Ukraintsev V. F. Tekushhie tendenczii na mirovom ry`nke yadernoj e`nergetiki [Current trends in the global nuclear energy market]. *Prostranstvennaya e`konomika* [Spatial economy]. 2018, no. 1, pp. 154–169. (In Russian)
6. Tikhonov M. M., Sokolova A. A., Sokolova S. N. Algoritmizacziya i modelirovanie upravlencheskikh reshenij v chrezvy`chajny`kh situacziyakh [Algorithmization and modeling of management decisions in emergency situations]. Annali d'Italia: is a peer-reviewed European journal. 2021, no.15, vol. 1, pp. 66–70.

7. Golovko M.V. Kul`tura e`konomicheskoj bezopasnosti i eyo strategicheskoe znachenie dlya atomnoj e`nergetiki [Culture of economic security and its strategic importance for nuclear energy]. *Global`naya yadernaya bezopasnost`* [Global nuclear safety]. 2015, no. 2, pp.100–105. (In Russian)
8. Sokolova A.A., Sokolova S.N. 电厂安全的理论问题 Theoretical aspects of safety of nuclear power plants. Proceedings of the International Conference «Scientific research of the SCO countries: synergy and integration». Reports in English. 2023, pp. 188–194.
9. Orlov V.V., Ponomarev L. I. Yadernaya e`nergiya i chelovek [Nuclear energy and man]. *Priroda* [Nature]. 2011, no. 3, pp. 4–16. (In Russian)
10. Adamov E.O., Lopatkin A.V., Muravyov E. V., Rachkov V.I., Khomyakov Yu.S. Naczional`naya strategiya razvitiya yadernoj e`nergetiki: dva podkhoda k novoj tekhnologicheskoj platforme yadernoj e`nergetiki [National Strategy for the Development of Nuclear Energy: Two Approaches to a New Technological Platform for Nuclear Energy]. *Izvestiya RAN. E`nergetika* [Izvestia RAS. Energy]. 2019, no. 1, pp. 3–14. (In Russian)
11. Sokolova A.A., Sokolova S.N. Yaderny`e ob`ekty` povy`shennoj opasnosti i perspektivy` mirovoj atomnoj e`nergetiki [High-risk nuclear facilities and prospects for world nuclear energy]. *Nauchny`j dialog: teoriya i praktika* [Scientific dialogue: theory and practice] Ed. D.R. Khismatullin. Moscow, Infinity Publishing House, 2025, pp. 174–179. (In Russian)
12. Kessler G. *Yadernaya e`nergetika* [Nuclear Power]. Ed. Yu. I. Mityaev. Moscow, Energoatomizdat, 1986, 261 p. (In Russian)
13. Sokolova A. A., Sokolova S. N. Bezopasnost` na ob`ektakh povy`shennoj opasnosti i avarijnoe reagirovanie pri likvidaczii posledstvij radiaczionnoj avarii [Safety at high-risk facilities and emergency response in eliminating the consequences of a radiation accident]. *Nauchny`j dialog: teoriya i praktika* [Scientific dialogue – theory and practice]. Ed. D. R. Khismatullin. Moscow, Infinity Publishing House, 2025, vol. 1, pp. 106–112. (In Russian)

Список использованных источников

1. Коваления, А. Обеспечение национальной безопасности в контексте тенденций развития современного мира / А. Коваления, В. Арчаков, А. Баньковский // Белорусская думка. – 2021. – № 9. – С. 50–55.
2. Биненко, В. И. Риски и экологическая безопасность природно-хозяйственных систем / В. И. Биненко, В. Кю Донченко, В. В. Растоскуев. – СПб.: СПбГУ, НИЦЭБ РАН, 2019. – 352 с.
3. Белорусская энергетика : состояние и тренды. – URL: https://dzen.ru/a/Z2Vqtjr1MkR0dmYl?ysclid=m9yn9642jj509082127 (дата обращения: 26.04.2025).
4. Шишко, Е. Л. Энергетическая независимость Республики Беларусь и развитие альтернативных источников энергии / Е. Л. Шишко, В. В. Шумская, // Гуманитарные научные исследования. – 2025. – №1. URL: https://human.snauka.ru/2025/05/55568 (дата обращения: 25.08.2025).
5. Осецкая, М. М. Текущие тенденции на мировом рынке ядерной энергетики / М. М. Осецкая, В. Ф. Украинцев // Пространственная экономика. – 2018. – №1. – С. 154–169.
6. Тихонов, М. М. Алгоритмизация и моделирование управленческих решений в чрезвычайных ситуациях / М. М. Тихонов, А. А. Соколова, С. Н. Соколова // Annali d'Italia: is a peer-reviewed European journal. – 2021. – №15. – Том 1. – С. 66–70.
7. Головко, М. В. Культура экономической безопасности и её стратегическое значение для атомной энергетики / М. В. Головко // Глобальная ядерная безопасность. – 2015. – №2. – С. 100–105.
8. Sokolova, A. A. 电厂安全的理论问题 Theoretical aspects of safety of nuclear power plants / A. A. Sokolova, S. N. Sokolova / Proceedings of the International Conference «Scientific research of the SCO countries: synergy and integration». – Reports in English. – 2023. – P. 188–194.

9. Орлов, В. В. Ядерная энергия и человек / В. В. Орлов, Л. И. Пономарев // Природа. – 2011. – № 3. – С. 4–16.
10. Адамов, Е. О. Национальная стратегия развития ядерной энергетики: два подхода к новой технологической платформе ядерной энергетики / Н. О. Адамов, А. В. Лопаткин, Е. В. Муравьев [и др. // Известия РАН. Энергетика. – 2019. – №1. – С. 3–14.
11. Соколова, А. А., Соколова, С. Н. Ядерные объекты повышенной опасности и перспективы мировой атомной энергетики / А. А. Соколова, С. Н. Соколова // Научный диалог: теория и практика : сб. науч. ст. по итогам работы Международного научного форума ; отв. ред. Д. Р. Хисматуллин. – М.: Издательство Инфинити, 2025. – С. 174–179.
12. Кесслер, Г. Ядерная энергетика ; пер. с англ. под ред. Ю. И. Митяева / Г. Кесслер. – М : Энергоатомиздат, 1986. – 261 с.
13. Соколова, А. А. Безопасность на объектах повышенной опасности и аварийное реагирование при ликвидации последствий радиационной аварии / А. А. Соколова, С. Н. Соколова // Научный диалог: теория и практика : сб. науч. ст. по итогам работы Международного научного форума ; отв. ред. Д. Р. Хисматуллин. – М.: Издательство Инфинити, 2025. – Том 1. – С. 106–112.

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