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Nuclear Risks and Damages in Europe

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ABSTRACT

Methods for improving the safety of nuclear energy production and use facilities, including nuclear power plants (NPP) and other large industrial facilities in various countries, are presented and discussed. According to Concern «Rosenergoatom» data, the operation of all 10 Russian nuclear power plants (NPPs) was analyzed in details. The risks to the population in the region of each NPP were assessed when new reactors are commissioned under the Federal Purposed Program (FPP) for the intensive development of the Russian nuclear energy industry until 2021. It was determined that all of them comply with permissible sanitary standards. Their background radiation levels do not exceed natural one. Measures were proposed to reduce the likelihood of uncontrolled chaos, strengthen favorable social dynamics and the human factor in preventing both natural and man-made disasters. In the context of the rapidly changing global political situation, several possible methods of protection against targeted terrorist attacks and unmanned aerial vehicles (drones) used for these purposes. It was determined that all of them comply with the permissible sanitary standards. Their background radiation levels do not exceed natural levels. Measures were proposed to reduce the likelihood of uncontrolled chaos, strengthen favorable social dynamics, and utilize the human factor in preventing both natural and man-made disasters. In the context of the rapidly changing global political situation, some several possible methods of protection against targeted terrorist attacks and drones used for these purposes were proposed. These methods reduce the likelihood of uncontrolled chaos and enhance favorable social dynamics and the human factor in preventing both natural and man-made possible disasters.

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Abbreviations

ARW: Advance Research Workshop
ASI: Advance Study Institute
ATC: NATO Advance Training Course
FPP: Federal Purposed Program
HES: Hydroelectric Station
IBRAE RAS: Nuclear Safety Institute of Russian Academy of Sciences
ISTC: International Scientific and Technical Center
NPP: Nuclear Power Plants
RSMO: Russia's Special Military Operation
UAV: unmanned aerial vehicles
ZNPP: Zaporizhzhia NPP

Introduction

Today, Europe and the whole world are facing a growing threat of nuclear weapons use due to uncontrolled military actions on their territories, including Russia's Special Military Operation (RSMO) in Ukraine. Major nuclear industry facilities are located there, including the four large NPP and a number of auxiliary facilities, including uranium processing plants. NPP consume large water amounts under its usual exploitation and are therefore located near its near major rivers. This is especially true for all today, Europe and for whole world are facing a growing threat of nuclear weapons use due to uncontrolled military actions on their territories, including RSMO in Ukraine. Major nuclear industry facilities are located there, including four NPP and a number of auxiliary facilities, including uranium processing plants. This is especially true for all Ukrainian NPP. Therefore, they pose the significant risk in the event of accidents and disasters. The greatest danger here is posed by the Zaporizhzhia NPP (ZNPP), with the combined capacity of six nuclear reactors reaching 6,000 MW. It is the largest NPP in Europe, located near the Kakhovka Hydroelectric Station (HES) where the great terrorist attack has been happened on June 6, 2023. The Ukrainian government estimated the damage from the destruction of biological resources at approximately 300 million USD. Any disruption to even one ZNPP reactor may create irreversible pollution not only the Dnieper River basin but also the entire Black Sea. The details of our thematic investigations for many years are presented in References of this article [1-20]. Some important fragments of them are reflected in the presented text of this article

Today ZNPP Situation

Today all Russian NPP operate in the favorable conditions. They are located in seismically safe regions and outside combat zones. ZNPP is the single exception. It has been under Russian control only since 2022 and is located in the combat zone between Russia and Ukraine. Certainly, there are documents on its exploration from previous years beginning in 1980. However, these are now under the control of the National Nuclear Energy Generating Company of Ukraine «Energoatom», and are completely inaccessible to Russian thematic specialists and scientists.

To ensure the normal operation of the water supply systems for other industrial reservoirs in Dnieper river, the special detailed ZNPP monitoring is necessary. Moreover, there have already been attempts to disrupt its operation through targeted terrorist attacks, including the using of drones to create uncontrolled chaos under

the negative and unwanted ZNPP external control under certain EU political structures hostile to Russia. Unfortunately, active military action significantly worsens overall social dynamics and reduces the role of the human factor in preventing both natural and man-made disasters. Although intense military action is currently underway in the Middle East, this our topic under consideration remains highly is relevant and urgent.

The existence of not only local but also global, large-scale dynamic chaos in the ZNPP region is undeniable. The development of specialized methods to reduce its sharp turbulence and soften it to its more familiar laminar nature is a very complex and necessary task. Today, innovative terrorism is increasingly being enhanced by the use of biotechnology, which allows for the exploitation of vast regions for terrorist attacks. This is impossible after the use of nuclear technologies in terrorist attacks, which often render territories irreversibly or even almost permanently (for centuries) unsuitable for human habitation. Traditional terrorist methods are already well studied. The use of biotechnologies as a weapon for mass destruction is based on advances in nanotechnology to create new epidemics and diseases. Several countermeasures to such terrorist attacks are discussed here, for example, through strengthening monitoring in transboundary areas with shared waterways, gas and aerosol emissions into the atmosphere. We have extensive experience in international thematic cooperation, for example, within the framework of international and previously approved by the International Scientific and Technical Center (ISTC) projects developed by us in Russia and Kyrgyzstan [1-3].

These weapons are capable of creating not only local but also large-scale uncontrolled chaos among the entire population of the region where they are used. The additional, enormous fear that they cause, combined with the complete uncertainty of their consequences, significantly exacerbate this chaos. An example of this is the disaster at the Fukushima NPP in 2011. It was ultimately categorized as a Level 7 — Major Accident — on the International Nuclear and Radiological Event Scale.

It is undeniable the existence of not only local but also global, large-scale dynamic chaos in the region not only in ZNPP localization, but in the whole Ukraine Zaporizhzhia region.

The development of the specialized methods to reduce its sharp turbulence and soften it at least until its more familiar laminar nature is the very complex and necessary problem. Today, innovative terrorism is increasingly being enhanced by the use of biotechnology, which allows for the exploitation of vast regions for terrorist attacks. This is impossible after the use of nuclear technologies in terrorist attacks, which often render territories irreversibly or even almost permanently (for centuries) unsuitable for human habitation. Traditional terrorist methods are already well studied. The use of biotechnologies as a weapon of mass destruction is based on advances in nanotechnology to create new epidemics and diseases.

Measures to Enhance the Safety of Nuclear Power Facilities

This article presents and discusses several measures to enhance safety not only at NPP but also at other large industrial nuclear power facilities. These include measures to combat terrorist attacks, strengthening the overall safety culture among personnel and the public, ensuring a clear understanding of this culture, ensuring timely and effective information provision, enhancing the safety of NPP, including accelerated retraining of their operators, and educating young people in the spirit of intolerance toward terrorist ideas and their dissemination.

The explosion at the Kakhovka HES in 2023, turned out to be an act of sabotage by Ukraine, which blamed Russia. Conflicting media reports in various countries, including Ukraine and Russia, make it difficult to determine the true identity of those responsible for the explosion. However, it undoubtedly had an extremely negative impact on the safety of not only the ZNPP but also other nuclear power plants in the region with pressurized water reactors VVER), since water supply is a key safety factor for them. This impact is particularly detrimental for the ZNPP, which includes six VVER-1000 pressurized water reactors with a total capacity of 6 GW. After all, a disruption to normal operation of any one reactor negatively impacts the operation of all the others [4-6].

The risks associated with the loss of the required amount of water were calculated in advance. Therefore, the ZNPP personnel were organizationally and technologically prepared for this decision. ZNPP reactor cooling station was not directly connected to the Dnieper River. A backup water supply came from underground wells in nearby small rivers. ZNPP personnel understood the situation perfectly and acted with great competence.

Following the explosion at the Kakhovka Hydroelectric Power Plant, local authorities declared a state of emergency. Under their constant supervision, efforts to prevent strikes by drones of the Ukrainian armed forces were intensified.

In several of our key studies on assessing population radiation doses, we used fully reliable data from Rosenergoatom Concern on the operation of all 10 Russian NPPs over the past 13 years, with annual detailed analyses. Calculations of radionuclide propagation in aquatic environments were conducted using certified methods in the atmosphere, using the Nostradamus and Cassandra programs, developed in Nuclear Safety Institute of Russian Academy of Sciences (IBRAE RAS) and presented on its websites. These calculations utilized the Monte Carlo statistical modeling method [7-9].

In principle, we could use two possible C1 and C2 methods for assessing of damages during normal and emergency NPP exploitations. The first C1method is theoretical character and has not been practically used by us. However, it is presented and discussed here.

1https://dzen.ru/a/ZICjZ_kVrkXyGBvz
2https://studopedia.ru/6_12222_p-ps-nostradamus-ibrae.html
3https://www.ibrae.ac.ru/contents/954

C1 method. Our universal formula for estimate of the total vector of limited damage under NPP exploitation was obtained in [10]:

$$\vec{a}_{lim} = P(1)\vec{a}_{1n} + \sum_{i=2}^{m} \hat{P}_{ij}\vec{a}_j \quad (1)$$

It was used for a fixed time interval under the following assumptions: (1) in the initial state, the facility is in normal (accident-free) operating mode; (2) various types of accidents can occur, i=2, 3, …, m, where m is the total number of possible accidents (m=1 corresponds to normal mode); (3) each accident can create various types of damage. Here j is the type of damage with value a_j. Then j=1,2, …n, where n is the total number of possible types of damage; where P (1) is the probability of generating losses (damages) during normal operation; (4) the implementation of accident i creates damage of the j-th type with prP_{ij},$\vec{a}_{1n}$ty is the vector of limited damage during such operation. The sum

of the values of the coordinate vector P_{ij} is equal to the value of damage of the j-th type when an accident of the *i*-th type occurs. Thus, the loss probability matrix is determined. In the absence of accidents (normal operating mode), is determined only by the first right-hand side of formula (1).

$$\vec{a}_{lim} = P(1)\vec{a}_{1n} \quad (2)$$

The main problem is estimating the values of P_{ij} and a_j. Typically, representative statistical data for their assessment is available only for long periods of normal NPP operation. Such data were and are currently unavailable for non-predictable (unpredictable) NPP accidents, when certain information can only be obtained after the disaster. For this reason, we were unable to use this methodology and its calculations for a specific numerical assessment of risks and damages for the ZNPP. Additional details on this topic are provided in our many articles [11-17].

In reality, the radiation monitoring service of each NPP record annual atmospheric emissions of radionuclides and their discharge into water bodies. For example, suppose R dangerous radionuclide, is released into the atmosphere. All its characteristics, including R half-life and environmental parameters, including weather, are entered into the program. Then, using the "Nostradamus" program, its migration path through the respiratory tract into the human body is tracked in detail. And using the another "Cassandra program, its entry into the body through waterways is monitored and calculated. These programs were developed in IBRAE RAS and subsequently certified. Then, its impact on human life expectancy is determined according to approved sanitary standards. Representatives of the most dangerous group, "fishermen," were chosen as the critical group, consuming the maximum amount of water, air, and food has been estimated in the NPP area.

They ingested the maximum amount of R radionuclide. This is done for each radionuclide throughout the entire NPP monitoring period. The estimates were conservative, based on maximum values of environmental contamination and radionuclide ingestion. The total radionuclide ingestion was then calculated. It was determined that the increased radiation levels from radionuclides at this NPP do not exceed the natural background radiation in the area where it is located (see Figure 1). Thus, the safety of introducing new reactor units under the aforementioned Federal Purposed Program was justified. The previously operating, most hazardous RBMK power units were decommissioned and replaced by VVER-1000 power units. According to Rosenergoatom Concern data, the operation of all 10 Russian NPPs was analyzed. The risks to the population in the area of each NPP were assessed when new reactors were introduced. It was determined that all of them do not exceed permissible sanitary standards. Their background radiation does not exceed the natural background radiation. It has been established that for all NPP within the observation zone, the annual maximum individual radiation doses from atmospheric emissions and water discharges for individuals in the critical population group do not exceed 10 μSv. Such dose levels ensure an unconditionally acceptable level of radiation risk (less than 10-6 year-1) according to Radiation Safety Standards.
The Results are Presented in Table 1.

Table 1: Prognostic Annual Radiation Doses to the Population in the NPP Observation Zone

NPP	NPPs Operat-ing	Power Units VVER	Effective dose for water use (μSv)	Effective dose for air expo-sure (μSv)	Effective dose for all path-ways (μSv)
Kursk NPP	4, RBMK 1000	3	6,69	0.19	6.86
Kola	4, VVER 440	1	7,8	0.014	7.814
Kalinin	4, VVER 440	1	3,4	0.012	3.412
Volgodonsk	1, VVER 1000	1	3,99	0.0026	3.9926
Leningrad	4, RBMK 1000	4	0,62	0.24	0.86
Novovoronezh	2, VVER 440				
1, VVER 1000	2	0,828	0.023	0.851	
Smolensk	3, RBMK 1000	4	5,14	0.1	5.24

Some all NPP are located in regions without possible negative natural influences, such as earthquakes in mountainous regions and tsunamis near seas and oceans. Such a situation is observed at the NPP of Armenia, Japan, California and some others. Serious negative anthropogenic factors with a global threat exist for NPPs located in dangerous conflict zones with a high probability of possible terrorist acts, including the use of ex-plosives and spreaders of epidemics. The application of classical methods of expert assessment of disasters at NPP in these cases is incorrect, and often impossible at all. The necessary data can be obtained from primary virtual computer tests of specific NPPs with simulation of possible disasters. This makes it possible to estimate the risk values, as well as to plan the actions of NPP operators and special emergency and rescue services in case of possible serious accidents at the NPP, in their shutdown or complete prevention. The effectiveness of liquidation of any accident, including an accident at a NPP, is determined by the qualifications and profes-sional actions of special emergency and rescue services. Especially when the identified accident is in the development stage. In some cases, the development of the accident can be completely stopped. But in any case, it will help to minimize and mitigate its negative consequences. It is also often necessary to transform these consequences from a possible irreversible state into a reversible one. The introduction and use of new pro-gressive technologies reduce the risks of nuclear energy. For example, switching to an extended reactor op-eration cycle of 18 months instead of 12 per year allows to reduce harmful emissions of radiation into the atmosphere and water effluents of the environment, which increase significantly during reactor shutdown. The application of classical methods of expert assessment of disasters at nuclear power plants in these cases is incorrect, and often impossible at all. The necessary data can be obtained from primary virtual computer tests of specific NPPs with simulation of possible disasters. This makes it possible to estimate the risk values, as well as to plan the actions of NPP operators and special emergency and rescue services in case of possible serious accidents at the NPP, in their shutdown or complete prevention. The effectiveness of liquidation of any accident, including an accident at a nuclear power plant, is determined by the qualifications and professional actions of special emergency and rescue services. Especially when the

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It has been established that the introduction of new reactor units for all NPPs instead of outdated ones under this Russian Federal Purpose Program is absolutely safe during their normal operation and does not exceed the levels of the existing natural background in the areas where these NPPs are located. The main criterion for their introduction was complete safety for the health and longevity of the population. Great and often in-surmountable difficulties arise when assessing the influence of radiation on human life. Here, not only the type of irradiation is important, but also the intensity of its impact and the absorbed dose. The composition of ra-dionuclides, depending on the type of accident at NPP, has a strong influence. And also very different indi-vidual susceptibility to them of an individual organism, manifested in a wide spectrum of possible ego diseases at different times after irradiation. Therefore, reliable, prompt and detailed information about any accident is extremely important for the entire population. Already happened or expected. To develop preventive measures for its prevention and mitigation of its consequences.

In a similar way, we could calculate the radiation doses during the exposure of the population in the vicinity of the ZNPP, if we had data on the emissions of radionuclides into the atmosphere and their discharges into water bodies, at least for the last period of its operation in 2022-2025, when it was under the management of the Rosenergoatom Concern. But these data are currently classified. It is known only from the materials of the Energia ZAES newspaper, some published data in the mass media and Rosatom, that they do not exceed the permissible limits.

The following European and Asian countries border the Black Sea: Russia, Turkey, Georgia, Abkhazia, Ukraine, Romania and Bulgaria. Therefore, the statements of these governments to the UN about the inad-missibility of violations of the security of the Black Sea, including ZNPP and Kakhovskaya HES, will undoubtedly play a positive role in reducing risks and damages from potential disasters and all disasters in these regions.

It is much easier to prevent such negative incidents than to eliminate the damage caused by them, which can often be irreversible. Examples include the disasters at the Fukushima NPP in 2011 and near the resort town of Anapa on the Black Sea in 2024.

Currently, 4 nuclear power plants with 16 power units are operating in Ukraine. All existing reactors in Ukraine are water-water: 14 VVER-1000 (VVER-1000) and 2 VVER-440 (VVER-400). When analyzing the risks for these stations, it is necessary to take into account their location relative to the combat zones. The situation in such areas is rapidly changing. ZAES affects similar operations in Crimea. This undoubtedly complicates the analysis of possible risks and damages.

But, of course, not all of them will be completely eliminated. The threat of their implementation by means of targeted terrorist attacks remains, especially with the use of explosive devices and special means, such as various bacteriological epidemics and toxins. The increasing use of drones (unmanned aerial vehicles-UAV) facilitates their use and distribution. Some successful methods of artificial intelligence have already been developed to combat such innovative UAV attacks. They are used for group attacks by UAVs. But today humanity still lacks sufficient experience in combating such threats. They are constantly being improved as science and technology develop. That is why we must fight them with all existing world innovative achievements and advanced scientific technologies including space ones [18-20]. But it is always much easier to destroy than to build and create. An example of this is the catastrophic destruction of the USSR. There is no single solution to this problem. However, there are methods of preventing similar terrorist attacks used in international practice. The latter will be minimized after the complete cessation of hostilities. It is necessary to note the existing and growing tendency to increase the intensity of terrorist acts and the widescale of the damage caused by them. Some of them are reflected in numerous thematic domestic events, as well as in global developments of the NATO Program Scientific Committee and its scientific events: NATO ARW (Advance Research Workshop), NATO ASI (Advance Study Institute), and NATO ATC (NATO Advance Training Course). The global large-scale operational experience of combating them and the operational elimination of some of their serious negative consequences is presented in the scientific and practical materials of the NATO ATC for 2011, where the author personally participated and was the single representative from the Russian Federation. Unfortunately, the author's contacts with the scientific activities of NATO were in-terrupted in 2013, an hour before NATO officially announced the break of relations with the Russian Fed-eration in 2014. NATO is not only a militaristic bloc, as it is mistakenly considered in Russia. Tens of thou-sands of scientists around the world work under his funded programs. The tasks set by NATO in its projects are still relevant not only for Russia, but also for the world as a whole, although their financing in our country has been interrupted for an unknown period.

The recent increase in the authorized capital of ZAES by 4.1 billion rubles. https://www.vedomosti.ru/business/articles/2024/11/07/1073612-rosatom-dobavil-zaporozhskoi will go to the introduction of new technologies in its operation, as well as to improve its protection against any external threats (terrorist attacks, drones strike, strengthening the protective shells of its reactors, additional training of personnel in operational counteraction to such threats, the introduction of measures to eliminate possible negative consequences, and others).

The current war between Iran, the USA and Israel has led to the deterioration of relations not only between them, but also between many countries of the Middle East and the EU. However, it should and can be hoped that the Committee on the Scientific Program of NATO will maintain its previous stable positions and continue its important and noble work to strengthen peace, develop science and education, as well as strengthen in-ternational relations and the commonwealth of all nations of the world.

Conclusion

The analysis of possible risks at the NPP must be carried out even before its construction. Both in the design stage and especially in the period of its operation, when the state interests of the country must be respected in the first place. Here, the predominance of the interests of private companies over state ones, as it was before the Fukushima NPP disaster, is unacceptable. Then the private energy company TEPCO convinced the gov-ernment of Japan not to stop

the operation of this nuclear power plant in its current mode in anticipation of the predicted future destructive tsunami in 2011. The underestimation of the tsunami risks for this NPP, located on the ocean coast, including the deliberate and self-serving neglect of them, led to this global disaster. The cost of protective measures, including their development and the costs of their introduction, will always compete.

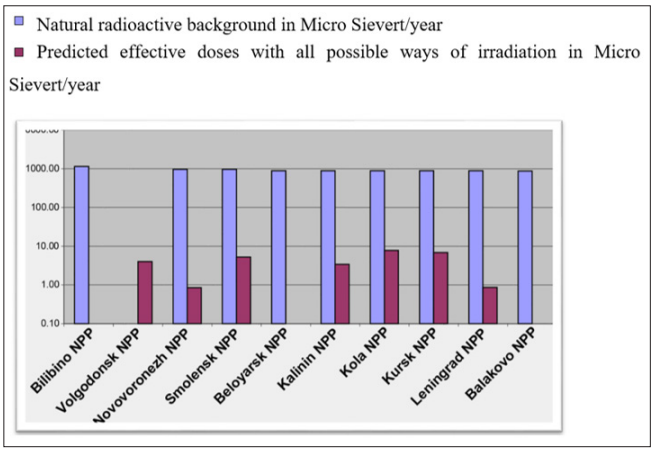


Figure 1: The Natural Radioactive Background at the NPP Localizations and the Conservative Predicted Effective Doses of Irradiation for the "Fishers" Critical Group of Population on Russian Federation Territory.

The political situation in the area of localization any nuclear energy objects is also important - the stability of the political regime, its social dynamics and the role of the human factor. The negative existence of the pop-ulation's disunity in terms of religious affiliation. The presence of dissatisfaction with the authorities among working employees, for example, due to the high level of unemployment, is negative. Without the correct reaction of the population, any instructions and recommendations of the authorities on correct behavior, es-pecially in a critical situation, are almost impossible to implement. It is inadmissible to present to the population knowingly false information. It is normal when the information itself can change and be clarified during the course of the risk event.

According to the author of this article, some of the main factors influencing and complicating risk analysis for the object under consideration (O) and some others are as follows:

Although all of them are aimed at weakening and possibly removing negative consequences in the event of the development of an undesirable critical situation, they arise due to the complexity of the characteristics of the object itself, which often has a complex, rapidly changing space-temporal character. This is O geographical location. Proximity to natural disasters and cataclysms. And also the presence of many anthropogenic factors - proximity to the zones of frozen conflicts and the front of hostilities. Influence of state O on their progress. The time of year and the state of the weather also affect the possibility of using covert acts of terrorism at O. The location of other risk objects relative to the object under investigation and their proximity to it affects the organization of O protection. The essential affiliation of O to significant objects of the state structure affecting the national security of the country requires additional attention and measures to organize its protection. The O history, such how long and how long he has been researched, is also significant. What is the attitude of the employees working on it to the study of its condition? They have motivation and interest. Their general culture and willingness to follow the developed recommendations and instructions to reduce or completely avoid undesirable events on O.

Special difficulties in calculating risks and damages arise in the nuclear power industry, which requires a particularly careful attitude. They are detailed in this article. Earlier in the USSR there was some neglect of the NPP operation. They mistakenly believed that NPP should be treated like other objects of conventional energy, for example, hydro or coal energy. This led to the appearance of the Chernobyl disaster in 1986. It is necessary to avoid its repetition. To do this, develop preventive measures. Some of them are discussed here. Damage from nuclear disasters with far-reaching, unpredictable negative consequences is often impossible to com-pletely eliminate. It is even a huge problem to fill them somehow. In addition, they cause many different problems. For example, with safe storage of long-lived radioactive waste. There is an additional cycle of research on the development of technologies for their as complete processing as possible with the goal of repeated waste-free use in the production of nuclear energy.

We have provided relevant confirmations for each of the closely related factors.

Conclusion

The methods and methodology described and used in this article are universal and applicable to many other regions and countries of the world where there is nuclear energy, which is actively used in their economic activities.

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Author Contributions

Valyaev Alexander: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Conflicts of Interest

The authors declare no conflicts of interest.

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