ДУ «НАЦІОНАЛЬНИЙ НАУКОВО-ДОСЛІДНИЙ ІНСТИТУТ ПРОМИСЛОВОЇ БЕЗПЕКИ ТА ОХОРОНИ ПРАЦІ»

ISSN 2664-4304

UDC 504.064:629.039.58
DOI: 10.36804/nndipbop.38-3-4.2022.3–10

RESEARCH ARTICLE
OPEN ACCESS

A MANAGEMENT DECISION-MAKING ALGORITHM FOR PLANNING ACTIVITIES TO REDUCE THE PRODUCTION RISK LEVEL

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Received: 03 October 2022; ***Accepted:*** 25 October 2022

Cite as: Tretiakova, L., Mitiuk, L., Ilchuk, O., Rebuel, E. (2022).A management decision-making algorithm for planning activities to reduce the production risk level. *Labour Protection Problems in Ukraine*, 38(3-4), 3–10

It is important to minimize the negative consequences of exposure to hazardous and harmful production factors that constitute a danger to the health of workers, through the introduction of effective technical and organizational measures and personal protective equipment. The aim of the article is to develop a sequence of implementation of safety measures to reduce the risk of occupational diseases among employees of nuclear power plants in Ukraine. The research methodology is based on the analysis of the peculiarities of working conditions, the determination of dangerous and harmful production factors and the choice of an optimization model of support systems in decision making. Statistical data and research findings have confirmed that the poor health and safety of workers is due to inefficiency of available occupational safety management methods, limited implementation of the latest technical and economic arrangements, imperfect methods of limiting the impact of hazardous and harmful production factors, and insufficient funding for such activities. In the general case, the implementation of management methods that provide the safety of life and health of workers and ensure risks are kept at a reasonably low level is to choose the optimal set of technical and organizational arrangements, determine the sequence of their introduction, to control their implementation and evaluation of their results. The article proposes a method of discrete step-by-step optimization of the sequence of implementation of security arrangements. The method involves setting of the most important criterion and a number of limitations. The method modified to the requirements of the set tasks is aimed at choosing the optimal within the framework of the general annual financing of technical and organizational arrangements and means of individual protection of employees and reducing the levels of risk in individual workplaces.

Keywords: safety management, planning, nuclear power plant, occupational risks and hazards, discrete optimization method.

АЛГОРИТМ ПРИЙНЯТТЯ УПРАВЛІНСЬКИХ РІШЕНЬ ЩОДО ПЛАНУВАННЯ ЗАХОДІВ ЗІ ЗНИЖЕННЯ РІВНЯ ВИРОБНИЧОГО РИЗИКУ

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Отримано: 03 Жовтня 2022; ***Прийнято:*** 25 Жовтня 2022

Цитувати як: Третякова, Л., Мітюк, Л., Ільчук, О., Ребуєл, Е. (2022). Алгоритм прийняття управлінських рішень щодо планування заходів зі зниження рівня виробничого ризику. *Проблеми охорони праці в Україні*, 38(3-4), 3–10.

Негативні наслідки впливу небезпечних і шкідливих виробничих факторів, що становлять небезпеку для здоров’я працівників, важливо мінімізувати шляхом впровадження ефективних технічних і організаційних заходів та засобів індивідуального захисту. Метою статті є розробка послідовності впровадження заходів безпеки для зниження ризику професійних захворювань працівників атомних електростанцій України. Методологія дослідження базується на аналізі особливостей умов праці, визначенні небезпечних і шкідливих виробничих факторів та виборі оптимізаційної моделі систем підтримки прийняття рішень. Статистичні дані та результати досліджень підтвердили, що незадовільний стан здоров’я та безпеки працюючих зумовлений неефективністю наявних методів управління охороною праці, обмеженим впровадженням новітніх техніко-економічних заходів, недосконалістю методів обмеження впливу небезпечних і шкідливих виробничих факторів, недостатнім фінансуванням такої діяльності. У загальному випадку реалізація методів управління, що забезпечують безпеку життя і здоров’я працівників і утримання ризиків на прийнятно низькому рівні, полягає у виборі оптимального комплексу технічних і організаційних заходів, визначенні послідовності їх впровадження, контроль за їх виконанням та оцінка їх результатів. У статті запропоновано метод дискретної покрокової оптимізації послідовності реалізації заходів безпеки. Метод передбачає встановлення найважливішого критерію та низку обмежень. Методика, модифікована до вимог поставлених завдань, спрямована на вибір оптимальних в рамках загального річного фінансування технічних і організаційних заходів і засобів індивідуального захисту працівників і зниження рівнів ризику на окремих робочих місцях.

Ключові слова: управління безпекою, планування, атомна електростанція, професійні ризики та шкідливості, метод дискретної оптимізації.

Introduction

Occupational injury is a cause of great economic losses for countries, which are caused by the reduction in the number of able-bodied workers due to the occurrence of occupational diseases or fatalities. This is because more than 2.7 million workers die from work-related accidents and diseases, over 374 million people suffer from non-fatal accidents and injuries (International Labour Organization, 2017). Challenges in the workplace due to globalisation, latest technology and increasing complexity of technological processes leading to increasing risks (Hämäläinen, 2009). There are also additional production costs associated with

ISSN 2664-4304

attracting and training new employees, medical, insurance and legal expenses (Huizinga et al, 2019). According to International Labor Organization (ILO), every developed country in the world annually loses up to 4 % of total national product as a result of industrial accidents and occupational diseases.

The level of injury, occurrence and development of occupational diseases in Ukraine remains high compared to European countries (Statystychnyy zbirnyk, 2018). The use of outdated technological equipment and processes causes accidents with serious injuries and fatal consequences. Unsatisfactory working conditions and work under the influence of hazardous and harmful production factors (HHPF) are the main causes of occupational and related diseases (Tayrova, 2016). On the other hand, occupational injuries are caused by the low level of effectiveness of industrial safety arrangements.

Nowadays there is a wide range of approaches to safety management, including: laws, standards, procedures and safety rules; assessment of employees' competence and ways to control their activities; ways to limit HHPF (hazards); personal protection systems; security management systems; continuous training and implementation of safety culture (Pillay, 2017). Such measures began to be developed after a careful study of the causes and consequences of major accidents at various industrial enterprises (Pate-Cornell, 1993). Accordingly, approaches in world safety science have improved the practice of safety management of production processes (Pillay, 2010].

However, many of the existing approaches to safety management have not led to significant improvements, as workers die or suffer serious occupational injuries each year. Many methods are outdated, formally implemented and do not correspond to modern approaches to the organization of production. Obviously, innovative solutions need to be introduced to further safety improvement.

For Ukraine, the cost of occupational injuries and occupational diseases annually from 2014 to 2018 is (60…70) billion UAH (Forostyana et al, 2014]. Such costs are caused by the annual cessation of employment of up to 6,000 disabled workers and the deaths of up to 600 people who died in production.

The poor health and safety of workers is due to the inefficiency of available occupational safety management methods, limited implementation of the latest technical and economic arrangements, poor methods of limiting the effects of hazards, and insufficient funding for such arrangements (Kobylianskyi et al, 2018). Making decisions, managers have a set of arrangements and means, so the task of considering and selecting arrangements from a multitude of alternatives arises. Decision making is the choice of a particular sequence of arrangements. The evaluation is based on the subjective opinions of specialists, the available background information and the amount of funding (Shugaliy et al, 2019). The rationale of the choice is usually made using the expert ground and prediction methods based on outdated statistical information (Kruzhylko et al, 2015). In such approaches, the selection of a rational solution involves human participation in the stages of formation of initial parameters and evaluation criteria. Such methods are based on subjective assessments when they use the knowledge and opinions of individual experts at the decision-making stage. Due to such approaches, the regulatory and branch provision of occupational safety arrangements does not correspond to the current European level, and as a consequence it leads to a significant level of occupational injuries.

In the last decade, Ukraine has been trying to implement optimization of mathematical models that are developed on the basis of risk-oriented methods (Kruzhylko et al, 2019). Companies that implement a safety management system based on the use of baseline information from the results of continuous monitoring of hazards and their processing by using formalized mathematical methods have better safety and work productivity than companies lacking such approaches (Shezeen Oah et al, 2018).

The plan of implementation of necessary and sufficient arrangements is formed by the head of the enterprise, based on the planned resources, duration of introduction, limiting factors and other circumstances (Levenets et al, 2017). Availability of information, its accuracy and correctness of use largely determine the rationality of the chosen decisions. However, in addition to numerical and statistical data, the plans for the implementation of occupational safety plans include indicators that are not mathematically formalized. The decision-making process involves focusing on the qualifications of the existing staff, their competence, possible deliberate and unintentional erroneous actions, be ready to accept and comply with the established requirements for job security (Jilcha et al, 2016). For tasks that solve in the context of partially uncertain information, criteria must be offered before decisions are made. In the field of occupational safety, an unreasonable subjective criterion for choosing the option of implementing arrangements can lead to considerable material and financial losses.

The main principle of this article is the choice of security management strategy at high-risk energy enterprises. The article considers the risks during the operation of nuclear power plants (NPPs) of Ukraine, the safety of which is due to the peculiarities of technological equipment and the duration of its use. In the traditional approach to risk management (Dekker et al, 2008), security is aimed at keeping adverse events at a reasonably low level. The main components of the effectiveness of risk management methods should be costs, profits, level of risk and time factor.

In the general case, the implementation of management methods that provide the safety of life and health of workers and ensure risks are kept at a reasonably low level is to choose the optimal set of technical and organizational arrangements, determine the sequence of their introduction, to control their implementation and evaluation of their results. The aim of the article is to develop a sequence of implementation of safety measures to reduce the risk of occupational diseases among employees of nuclear power plants in Ukraine

Methods

Experimental data

In a number of industries, industrial safety is a natural, integral and equal element of production. This approach applies to the electricity sector and its component - nuclear power. In Ukraine, four NPPs have been built and 15 nuclear units have been put into operation, providing up to 52 % of total electricity.

A large number of employees are involved in the work on radiation hazardous objects. The staff at the NPP has more than 35,000 people, of which women make up 34%, and up to 5,000 workers are employed at auxiliary facilities. In Ukraine, according to the recommendations of the International Atomic Energy Agency, a number of legislative documents on industrial safety and health at radiation-hazardous facilities have been adopted (DGN 6.6.1.-6.5.001-98, 1998). The current legislation of Ukraine in this area defines the basic requirements for the protection of workers' health from the possible damage caused by radiation and possible environmental pollution. It is determined that the main direction of the industrial safety improvement of nuclear power plants is planned systematic actions aimed at reducing the level of diseases of workers (Report, 2018).

ISSN 2664-4304

The experience gained in the operation of NPPs in the world practice shows that even the highest requirements for the quality of equipment are not able to prevent emergencies (Arutyunyan et al, 2018). The deterioration and low level of updating of the main production facilities of the Ukrainian NPPs cause a high accident rate, and the outdated technological base leads to the formation of a large amount of waste that is subject to disposal (Vashchenko et al, 2017). At the Ukrainian NPPs due to the implementation of existing engineering and technical arrangements it is impossible to avoid the influence of ionizing radiation from external sources, dust and aerosols with radionuclides. The work is carried out under conditions of elevated temperatures, with aqueous solutions of radioactive substances, under the influence of electromagnetic fields, with biological and chemical substances (1–4) hazard classes (propane-butane, acetylene, oxygen, sulfuric acid, chlorine, acetone, ammonia).

At four NPPs, a high level of employees is annually registered in conditions where the maximum allowable levels or concentrations of HHPF are exceeded. Currently, more than 20 % of NPP personnel work in hazardous conditions, 40 % – in particularly harmful conditions, 69 % of working conditions in the workplace do not meet sanitary and hygiene standards. At the workplace, workers are exposed to two or more HHPF at the same time, including: harmful chemicals (10 %); dust and aerosols (23 %); dust and aerosols with radionuclides (16 %); vibration (3 %); noise, infrasound, ultrasound (32 %); ionizing radiation (36 %); non-ionizing radiation (0.9 %). The number of workers exposed to ionizing radiation is virtually unchanged annually.

In addition to the effects of HHPF, 70 % of NPP employees are exposed to electrostatic risks due to the presence of static electricity in the workplace and 22 % of workers to thermal risks caused by work at elevated temperatures (40–60) ºC. Work at NPPs is characterized by a high level of severity and intensity: up to 27.5 % of employees have a third level of difficulty; 31.3 % – increased level of tension. Every year, (1 600 – 1 750) working days per 100 workers are lost due to illness, and the total number of plants at all NPPs reaches up to 40,000 days each year.

For work in harmful and difficult conditions, employees are granted benefits, additional payments and preferential pension benefits. Information on benefits and compensation for intense work in hazardous conditions at the example of one NPP is given in Table 1.

Table 1 – List of benefits and compensations for NPP employees

Benefits and compensation for work in harmful conditions	Number of employees receiving benefits, [%]	Annual expenses	
		Total, [thousand UAH]	Average per person, [thousand UAH]
Extra days to vacation for work in harmful conditions	23	13 800	11.9
Extra days to vacation for severe and intense work	47	33 300	12.8
Shorten working week	37	22 500	11.7
Supplements for harmful working conditions	64	38 400	11.6
Additional food products	27	6 000	4.0
Medical and preventive nutrition	37	2 100	1.0
Retirement benefits	43	4 200	15.0
Sum total		120 300	

The NPP plans and finances the safety arrangements: certification of workplaces with the presence of harmful factors, training of workers in safe ways of performing work, purchase of hygiene and personal protection equipment. Up to 20.500 million UAH have been spent on such activities in 2019. According to the above information, the cost of implementing security arrangements compared to the payment of benefits and compensation for work in harmful conditions (120.3 million UAH) is no more than 17 %. This confirms the findings of other authors on the ineffectiveness of labour protection arrangements implemented in accordance with state and branch normative legal document (Derengovsky et al, 2018).

As a result of the state of industrial safety analysis, it can be confirmed that the task of improving the level of safety management requires the implementation of organizational and management decisions using multicriteria models of project selection (ICRP Publication 55, 1988). Among the tasks that require detailed analysis and further study are the development of mathematical models, criteria and methods for planning security arrangements at the enterprise level.

Model and method description

The need for decision making on the basis of multicriteria analysis necessitates the application of a comprehensive approach to assessing the level of effectiveness of labour protection management. Under a comprehensive approach, the authors plan for a set of scientific, technical, organizational, and economic interrelated resources and contractors that minimize the damage caused by hazards to maximize impact on occupational injuries.

Analytical models need to be created to apply any quantitative method to decision making. Determination of optimal safety solutions should be combined with a qualitative assessment of the current work to improve technical equipment. The results of this combination must be taken into account during the final decision-making process.

The task of optimizing the means and measures for NPP safety can be formulated as determining the sequence of implementation of such measures within the annual amount of funds, which will reduce risks and decrease the benefits and compensation cost.

To create such a system, the use of a certain mathematical apparatus is required, which will achieve the goals. The article proposes a method of discrete step-by-step optimization of the sequence of implementation of security arrangements (Ehrgott, 2005). The method involves setting of the most important criterion and a number of limitations. (Keeney et al, 1975).

ISSN 2664-4304

The main feature of the planning of optimal arrangements is that the parameters to be optimized are characterized by discrete indicators (cost, time and duration of implementation, protection factor, efficiency).

Task statement formalization lies in grounding the sequence of measures selection from a set of solutions according to the proposed criterion.

The initial data is specified through a discrete sequence of standard event parameters

$$X_i, a_i, b_i (i = 1, 2, ...); Y_i, c_i, d_i (i = 1, 2, ...),$$

where X_i, Y_i are the required variables; a_i, b_i c_i, d_i are the appropriate safety indicators necessary to form the objective function and constraints.

The optimization criterion is written in general terms:

$$KR = min\left[\frac{\Delta F(X)_j}{\Delta H(Y)_j}\right], \quad (1)$$

where ΔF_j is reduction (negative increment) of the objective function at each *j*-th optimization step; ΔH_j is the increment of constraints at each *j*-th optimization step.

It is necessary to note one more reason for the use of the step-by-step optimization method precisely for solving the considered problems. The method does not require the mandatory representation of the objective function and constraints in the form of analytical dependencies. It is important for this algorithm to be able to calculate the increment of the objective function and constraints.

Solving occupational safety problems in uncertainty requires the use of risk-oriented methods (MIL-STD-882E, 2012). In order to assess the risks of injuries and occupational diseases, Ukrainian enterprises contemplate implementation of standard (IEC/ISO 31010:2013, 2015).

Risk is an additive function (Kalkis et al, 2005), therefore, in the multiplicative form, which makes it possible to evaluate the simultaneous influence of *M* factors, we write:

$$R = \{\sum_{i=1}^{M} (S_{fi}, P_{di}, D_{fdi})\}, \quad (2)$$

where *R* is the total individual risk; S_{fi} – conditions of occurrence of *f*-th adverse arrangement; P_{di} – the probability that the *d*-accident will happen; D_{fdi} – the possible consequences of a *d*-accident, which will occur in the *f*-th adverse arrangement.

The individual initial risk R_{ri} provided formula (2) can be given in the form

$$R_{ri} = P(A) \cdot P(B) \cdot P(C) \cdot P(D), \quad (3)$$

where *P(A)* – the probability of occurrence of danger (hazard) at A adverse arrangement (accident); *P(B)* – the probability of the impact of this hazard on the employee; *P(C)* – the probability of consequences for the employee from this adverse arrangement; *P(D)* – probability of occurrence of a certain consequence (illness, trauma, death).

It is logical to consider that the costs of occupational safety arrangements in the energy sector help to reduce the incidence of injuries and diseases, reduce the risk level (Tretiakova et al, 2020). The level of residual risk R_{fi} is determined by the formula:

$$R_{fi} = R_{ri}(1 - K_{sf}), \quad (4)$$

where K_{sf} is the safety factor in case of the introduction of a *k*-th procedure or personal protective equipment.

Optimizing priority arrangements

The optimization process is carried out through the selection of volumes and the order of implementation of individual technical, organizational arrangements and personal protective equipment which allow reducing the level of risk.

The task is formulated as follows: to minimize the risks of *M* factors on individual sites of the NPP, using the total annual amount of funds to finance security arrangements:

to minimize the overall risk target function *R*

$$F(R) = \sum_{i=1}^{M} R \to \min \quad (5)$$

to subject to restrictions on the cost of activities

$$F(C): C \in \left[\sum C \le C_0\right], \quad (6)$$

where C_0 is the annual amount of funds.

The optimization criterion is represented as a fraction: in the numerator we write a stepwise decrease in the magnitude of the risk, and in the denominator – an increase in costs.

$$KR = \min\left[\left(\frac{R_{fi} - R_{ri}}{C_j + C_{j+1}}\right)\right] = \min\left[\frac{\Delta R_k}{\Delta C_k}\right], \quad (7)$$

where R_{ri} is the initial level of risk from the *i*-th HHPF; R_{fi} is the residual level of risk from the *i*-th HHPF; C_j – the cost of each *j* optimization step; ΔR_k – the risk level reduction after the *k*-th safety measure; ΔC_k – incremental value of the cost after the *k*-th safety measure.

The incremental value of ΔC_k for each safety measure is calculated by the formula:

$$\Delta C_k = \frac{C_k}{C_0} \cdot 100\%, \quad (8)$$

where C_k is the cost of the *k*-th arrangement.

Risk reduction in view of formula (4)

$$\Delta R = R_{ri} \cdot K_{sf}, \quad (9)$$

Choosing such a criterion involves obtaining reliable background information in accordance with the available technical documentation, which provides guaranteed safety factor and value.

Careful analysis of the substantive formulation of the problem, taking into account the features of arrangement planning, necessitated the modification of the original algorithm to take into account more indicators. Additional metrics can be taken into account in constraint optimization calculations. The choice of personal protective equipment sets can be specified with the appropriate priority of their application.

The following additional restrictions are implemented:

– by the duration of the execution of the T_p project

$$T_{st} \le T_p \le T_{fin}, \quad (10)$$

where T_{st} is the start time of work implementation; T_{fin} – total duration of works, T_{fin} = 5760 h; by the number of arrangements $3 \le k \le 10$.

Results and Discussion

Management decision algorithm

The proposed algorithm was used before the planning of arrangements to reduce the risks of occupational diseases at NPPs. Annual reports have identified a list of HHPF that can lead to occupational diseases. The reasons for exceeding the hygienic standards at certain workplaces are: poor technical condition of production facilities and structures; non-compliance with the requirements of the labour safety instructions; violation of safety requirements when using technical equipment and additional mechanisms; failure to perform official duties.

The current system of assessment at the NPP establishes the following values of individual risk per year: residual risk is equal to 10^{-6}; initial risk – 10^{-4}; accepted risk – (1–5) 10^{-5} (Islamov et al, 2014). A list of alternative arrangements to reduce the level of production risks is given in Fig. 1.

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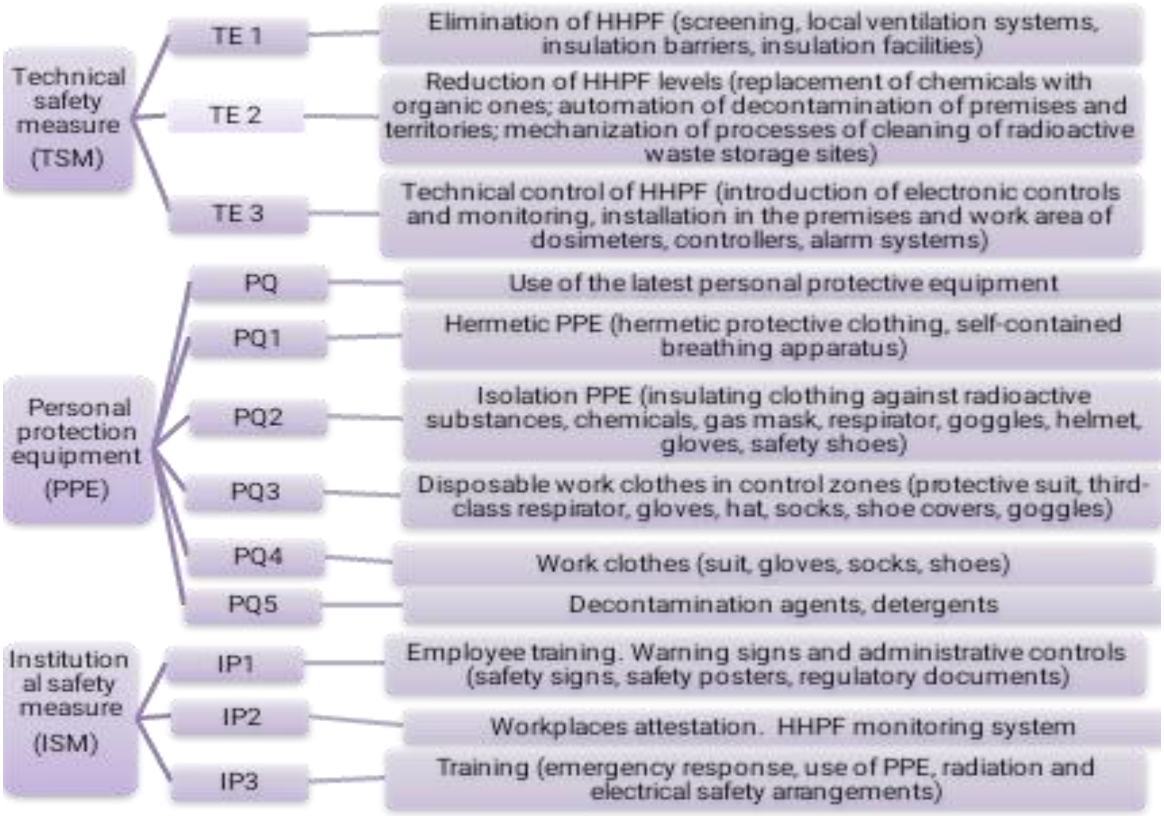

Fig. 1. Alternative safety measures to reduce production risk

The modified algorithm for the problem has the following sequence:

1. Plan an annual amount of material and financial costs to implement arrangements to limit or eliminate existing hazards.

2. Record a discrete sequence of technical and organizational means with an indication of their cost, duration of work and results from implementation in agreement with the chief engineer. The discrete sequence A is represented by its individual components

$$A \supset \{TSM, ISM, PPE\}.$$

3. Write down the list of required sets of PPEs, indicating their number, priority, cost, duration of use.

$$PPE \supset \{PPE1, PPE2, ...PPEn\}.$$

4. Start the first step with the condition R_{ri} = max, $\Delta C_k = 0$.

5. The level of initial risk reduction is determined from a discrete sequence of arrangements depending on a set of technical and organisational arrangements.

6. For each optimization step, we calculate the value of KR_j by formula (7) for the next arrangement or means of improving the safety of work.

7. With KR_j = min, at each step of optimization we select the most effective means of increasing the security and fixing it.

8. Check the conditions specified in the restrictions.

9. Review all arrangements and measures to improve safety and limit the impact on employees of certain HHPF. If all the conditions are fulfilled, we proceed to point 10. If the conditions are not met, we return to point 4.

10. Completion of calculation and printing of final results on the list of safety measures.

The use of the proposed algorithm of planning arrangements to limit the impact of hazards makes it possible to select the most effective safety measures within the framework of the annual determination of material and financial resources.

Mathematical model of making managerial decision on reducing industrial risk

As an example, the proposed algorithm was used for planning at a NPP, whose budgeted financial resources for occupational health and safety amounted to 21 million UAH per year. The list of alternative projects to reduce production risk at individual work sites, their cost and duration of implementation, as well as the estimated values of the criterion are given in Table 2.

The proposed algorithm was used to select the optimal set of arrangements within the planned resources. The calculation consisted of six iterations. The obtained results are presented in table 2, indicate that six optimal measures with a minimum criterion have been selected, which can be implemented during the year within the provided funds. The sequence of planned measures aimed at reducing the impact of HHPFs and risk levels reduction is

$$A1 \supset \{TE1, PQ, IP3, IP1, PQ5, IP12\}.$$

The course of the optimization process step by step is shown in Fig. 2., Fig. 3, which presents a graphical interpretation of the results.

ISSN 2664-4304

Table 2 – List of alternative projects

Reference selection character	Planned safety measures	Arrangements indices			The estimated values of the criterion
		Work duration, T [hour]	Additional cost, ΔC [%]	Safety factor	
TE1	Workplace screening with ionizing radiation	1300	23.1	0.03	$1,3\cdot10^{-3}$
TE2	Installation of electronic controls during deactivation	1000	17.6	0.1	$5,7\cdot10^{-3}$
TE3	Equipment of premises by stationary dosimeters	850	15.8	0.8	$6.9\cdot10^{-3}$
TE11	Installation of local ventilation systems	850	18.6	0.05	$4.2\cdot10^{-3}$
PQ	PPE purchase	560	70.1	0.5	$2.9\cdot10^{-3}$
PQ5	Purchase of decontaminating equipment	280	3.6	0.9	$8.7\cdot10^{-3}$
IP2	Workplaces attestation	1500	0.8	1	$9.9\cdot10^{-3}$
IP1	Employee training	250	0.7	0.8	$8.0\cdot10^{-3}$
IP3	Training in the application of PPE	860	2.3	0.4	$3.9\cdot10^{-3}$
IP11	Provision of production facilities with information stands	450	0.6	0.9	$8.9\cdot10^{-3}$
IP12	Purchase of regulatory documents for the labour protection service	160	0.3	0.9	$9.0\cdot10^{-3}$
IP21	Installation of air pollution monitoring systems	850	20.6	0.6	$5.0\cdot10^{-3}$

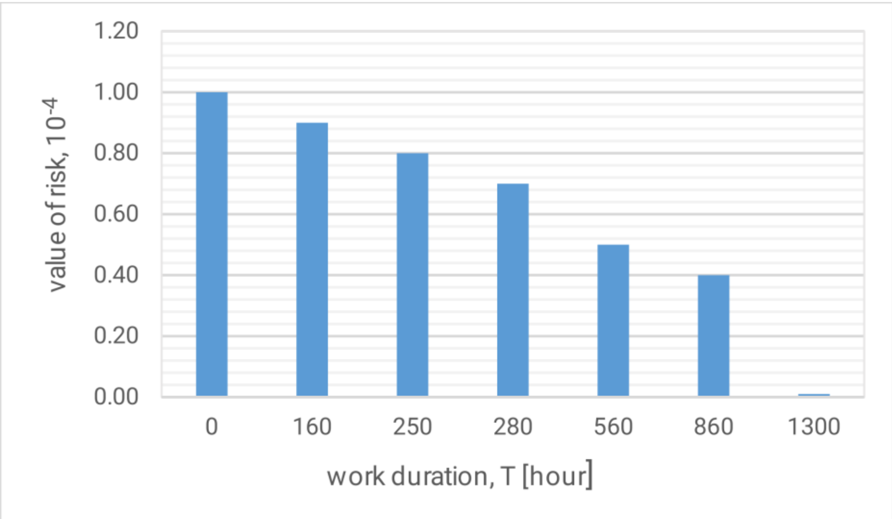

Fig. 2. Change in risk after the implementation of measures A1

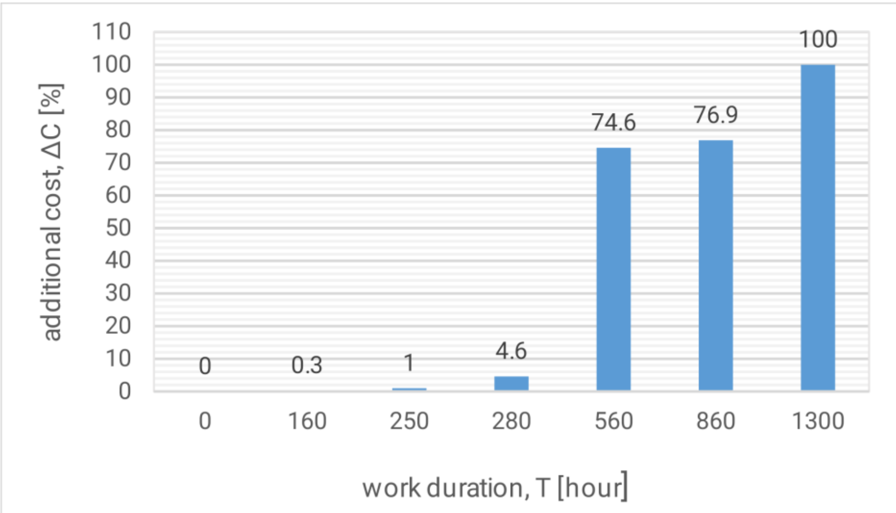

Fig. 3. Sequence of measures implementation A1 and use of planned funds for the year.

ISSN 2664-4304

The analysis of the initial information showed that the most effective protection measures are technical, which require significant investments in obsolete and worn-out production assets of Ukrainian NPPs. The introduction of screens at workplaces with ionizing radiation allows 10 % of NPP employees to ensure residual risk at an acceptable level. Other technical security measures were not implemented due to restrictions (6) on the total cost. As practical experience and planning results show, large amounts of money are used to purchase, decontaminate and store PPE, which is a mandatory means of protection for all employees.

PPEs allow workers to be protected from existing HHPF in the workplace, subject to additional organizational arrangements. Training for workers who work in hazardous conditions is obligatory at NPPs, but is often formal.

Conclusions

The researches results presented in the article made it possible to substantiate the necessity of introduction of optimization mathematical models in the course of planning of arrangements for safety improvement at production and to state. A theoretical analysis of the available methods of planning security arrangements indicates the current deficiencies in the functioning of the safety management system, which lead to the choice of inefficient security arrangements and incorrect planning of material and financial resources. Based on the analysis of the statistical information on the working conditions at the NPP, it is shown that in the presence of a large number of dangerous and harmful production factors, 20 % of employees work in hazardous conditions, 40 % – in particularly harmful conditions, 36 % – under the influence of ionizing radiation. Under these conditions, annual funding for occupational safety arrangements is up to 13 % of the funding for benefits and compensation for harmful working conditions.

Despite the availability of annual reporting documentation and funding, the solution to the problems of improving occupational safety is developing slowly in Ukraine. Obviously, this is caused by the lack of monitoring system of parameters of hazardous and harmful production factors, imperfection of technical and organizational arrangements to limit or eliminate their influence, inefficiency of spending material and financial state resources.

The algorithm of discrete optimization was developed, designed to solve multicriteria problems with nonlinear objective function, discrete source information and multidimensional constraints. The algorithm modified to meet the requirements of the given tasks is aimed at choosing the optimal within the framework of the general annual financing of technical and organizational arrangements and means of individual protection of employees and reducing the levels of risk in individual workplaces.

Implementation of the developed method during the planning of safety arrangements at Ukrainian NPPs allows to gradually reduce the impact of dangerous and harmful production factors, which will lead to reduction of accidents and occupational diseases, improvement of working conditions and, as a consequence, reduction of additional production costs and financial state losses.

Acknowledgments

The authors' team is grateful to the administration of the enterprise «NVP Ikar» and its director Oberemok Olecsandr for help in verifying the modelling results. The authors would like to express sincere gratitude for advices in the preparation of this paper to prof. Denyciuk Sergii.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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