

## ANNOTATION

**dissertation work of Uali Almas Bolatula on the theme: «Development of preventive measures to create safe working conditions for operators of production units of oil refineries in order to reduce the risks of industrial injuries and the occurrence of occupational diseases» submitted for the degree of Doctor of Philosophy (PhD) on the educational programme 8D11210 - «Life Safety and Environmental Protection»**

**Relevance of the research topic.** The oil refining industry, the main subjects of which are oil refineries, by the types of their activities are classified as hazardous production facilities that pose a threat both to the operating personnel and to the environment. At oil refineries the main working staff include operators of production units, to create safe working conditions for which, and is devoted to the dissertation work.

The work of operators is connected with the use of various energy-intensive equipment, apparatuses operating at high pressures and temperatures, which are potential sources of possible accidents and emergencies, in which they can suffer injuries, up to fatal cases, and the leading place among harmful production factors in recent years is occupied by the severity and intensity of labour.

In this regard, the issues of reducing the impact of adverse production factors arising in the oil refining process on the professional health of operators, as well as the prevention of technogenic emergencies that increase the risks of occupational injuries, **are currently relevant** in the research to find effective ways to improve the system of industrial safety and labour protection at refineries.

Researchers note that the changed nature of the work of operators of production units of oil refineries, associated with the full automation of production, on the one hand, reduced or eliminated traditional risks, on the other hand, new dangers and risks appeared, the causes of which are due to the so-called «human factor», when an employee, due to an insufficient level of training in the field of labor protection, the inability to quickly make optimal decisions in emergency situations under conditions of time shortage and psychophysiological overload, becomes the culprit of injuries and emergency situations at work.

Obtaining new scientific data on the impact of work environment factors in the conditions of introduction of new technologies, complex equipment, automation of all processes, which have increased the volume of received information several times, and therefore, the possible errors of the employee, poses the task of developing scientifically based recommendations and techniques to reduce the risks of injury and occupational diseases for refinery operators, which was the basis for choosing the topic of the thesis work.

**Purpose of the study** – development of measures to prevent risks of occupational injuries and occupational diseases at the workplaces of refinery unit operators through the introduction of digital technologies and the risk management concept to create safe working conditions.

**Objectives of the study:**

- analysis of the current state of the industrial safety system and the causes of industrial injuries and occupational diseases of workers in oil refineries;
- research of technological and technical features of the isomerization process with identification of hazardous and harmful production factors of the working environment of the isomerization shop with the KCA-1 unit of «PKOP» LLP;
- research on the influence of psychological and psychophysiological factors of the working environment on the risks of injuries and accidents;
- comprehensive assessment of working conditions of operators of production units of the isomerisation shop using the verification sheet method;
- Development of a methodology for creating a human-machine interface for the software (SW) of the system for supporting the activity of operators of production units of the isomerisation shop in emergency situations;
- development of a methodology for assessing the psychophysical state of an operator of production facilities at the workplace using neural networks;

**Object of study:** production units of the isomerization shop with the KCA-1 unit of «PetroKazakhstanOil Products» LLP.

**Subject of research:** emergency response plans and working conditions at operators' workplaces.

**Research methods.** The following were used in the research: methods of comparative analysis in determining and selecting industrial safety and labor protection objects at oil refinery installations, a systems approach to collecting and processing experimental data, the concept of human-machine interface design patterns, forecasting and cause-and-effect methods, deep neural network methodology for assessing the psychophysical state of the installation operator, a checklist method for identifying hazards in the workplace, reliability methods for technical systems and risk management. Statistical processing of experimental data was carried out using the following application programs: Statistika 8.0 and Microsoft Excel 2010.

**Main points to be defended:**

- potential sources of emergencies at the isomerisation shop of «PKOP» LLP;
- модель прогнозирования превышения ПДК веществ в воздухе на территории и санитарно-защитных зонах ТОО «ПКОП»;
- methodology for assessing the risk level of hazardous and harmful factors in the working environment of isomerisation shop operators with recommendations on preparing questionnaires, organising the survey and ranking the results obtained;
- methodology for assessing the fatigue of operators of production plants in the process of performing their work functions based on the application of technology for recognising the psycho-emotional state of workers;
- methodology of development of interactive application for training of working personnel to act in emergency situations according to the Emergency Response Plan, by the example of the isomerisation shop of «PKOP» LLP.

### **The main results of the research:**

- technical and technological peculiarities of industrial safety and types of emergency situations at gas, explosion and fire hazardous places of isomerisation processes with identification of places of potential emergencies;

- statistical processing of production data on the maximum permissible concentration of hazardous chemical elements in the atmospheric air on the territory of «PKOP» LLP with a comparative analysis of independent monitoring data from «KAZHYDROMET» RSE with the construction of a trace model of the dependence of the dynamics of variables on emissions for predicting the risks of impact on the environment was carried out;

- the methodology of designing of man-machine interfaces with formation of information system of support of the operator of production units of isomerisation shop in emergency situations has been developed (the positive decision on receiving the patent on useful model «Method of support of the operator of production units of oil refineries at actions in emergency situations» (from 02.10.2024 on application №2024/0016.2) has been received;

- an interactive application was developed to train operators of the isomerisation shop to act according to PLA. The results of the research were pilot-tested at «PCOP» LLP with the receipt of the Act of introduction into production (No. 197 dated 21.10.2024);

- a comprehensive assessment of the risk level of hazardous and harmful factors of the working environment of operators of production units of the isomerisation shop was carried out using the checklist method;

- new scientific data on the influence of psycho-emotional factors on the performance of operators of production plants in the event of emergency situations in the process of work using the methodology of deep neural networks were obtained.

### **Justification of the novelty and importance of the results obtained:**

- locations of potential emergencies at workplaces of operators of production units of the isomerisation shop were identified and a register of hazards was formed.

- it was revealed that the greatest risks for operators at workplaces are psychological stresses, which are caused by an increase in anxiety and stress states in workers due to increased labour intensity, a large amount of information that needs to be quickly processed and decisions need to be made promptly to prevent accidents and other emergencies;

- it has been established that the application of deep neural networks methodology to recognise the psycho-emotional state of the operator at the workplace can solve the problems of emergencies due to wrong actions and erroneous decisions caused by reduced concentration and fatigue of the employee. It was found that the decrease in concentration and the development of fatigue in operators working 12 hour day shift schedules occurs closer to the end of the shift, and in night shifts the decrease in attention coincides with the biological rhythms of the body when the time of deep sleep occurs, between 2 and 5 o'clock at night.

- a methodology for assessing the psychophysical state of a production plant operator at the workplace using neural networks was proposed

- the developed interactive application makes it possible to facilitate both the training process and the operator's actions on the algorithm of liquidation of potential emergency situations in practice, and the simplicity of its installation on all electronic media - availability of any place and time of knowledge testing. According to the results of experimental approbation at the enterprise, it was found that the time spent by the software is on average 15% less than when working with the plan printed on paper, and 30% less compared to the execution of the work plan on a memory stick.

**Theoretical and practical significance of the work** consists in obtaining new scientific data on the influence of factors of the working environment in the conditions of introduction of innovative technologies, complex equipment, automation of all processes at oil refining enterprises, which increased the intensity and tension of labour, and therefore, possible errors of plant operators, which can become the causes of occupational traumatism, injuries and accidents, risks of accidents and emergencies at work.

The paper substantiates the application of digital technologies to improve the system of industrial safety and health protection of working personnel, through the development of a computer application to train operators in interactive mode to prevent and eliminate emergencies in the process of their potential occurrence in the technological scheme of isomerisation. The effectiveness of using such a tool has been confirmed by the results of pilot tests among operators of the isomerisation shop, which showed that the speed of decision-making and correct execution of the action algorithm allows preventing an emergency situation and/or eliminating it before a critical situation occurs.

Modern mathematical apparatus used in biomedical research, aviation industry, cybernetics, computer science, neurobiology and psychology on automatic recognition of emotions from facial images using the methodology of deep neural networks was first used by us in the development of a methodology for assessing the psychophysical state of the operator of refinery production units at the workplace. The results of the assessment will help in the formation of measures to reduce the risks of occupational injuries and the occurrence of occupational diseases in operators of production plants caused by psychological and emotional sources of stress by improving the physiology of labour at workplaces, changes in the work and rest regime, identifying stress resistance in workers, optimising the duration of the working shift.

**Relevance to science development directions or government programmes.**

The dissertation work was carried out at the department «Life Safety and Environmental Protection» of M. Auezov South Kazakhstan University and is connected with the scientific project AP22688058 №85/ŽF-5-24-26 from 20.06.2024 KN MNiVO of the Republic of Kazakhstan «Zhas falym» for 2024-2026 years.

**Doctoral student's personal contribution to each publication:** The results of research published in 12 scientific articles, including 1 article in an international

journal included in the Scopus database, 1 article at an international conference indexed in Web of Science, 3 scientific publications in journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 7 - in conference proceedings and scientific publications of the Republic of Kazakhstan.

According to the results of researches the positive decision from 02.10.2024 on application №2024/0016.2 on granting of the patent on useful model 'Method of support of the operator of production units of oil refineries at actions in emergency situations' has been received.

1. The article «Estimation of the interrelation between the pilot state and the quality index of piloting» in the journal «Aerospace Systems» - direct participation in experiments on the study of emotional state from facial images, comparative analysis of data, processing of obtained results, translation into English.

2. Article 'Application of modern information technologies to improve the efficiency of actions of operators of production facilities in emergency situations' in the journal «Oil and Gas» - processing and discussion of the results of experiments conducted at the workplaces of plant operators of the isomerisation shop of «PKOP» LLP, design according to the requirements of the journal, submission through the information base of the journal, correction of reviewers' comments, resubmission.

3. Article «Methodology of development of human-machine interface in the system of support of the operator of production plants in emergency situations» in the journal «Bulletin of Bauman Moscow State Technical University. Ser. Instrumentation» - preparation of initial data obtained from the results of experiments of human-machine interface development, statistical processing of the results, construction of graphs and tables, design according to the requirements of the journal, submission through the information base of the journal, correction of reviewers' comments.

4. Article «Recommendations on risk level assessment of hazardous and harmful factors of the working environment of operators of technological units of oil refineries» in the journal «University of Enbekteri - Proceedings of the University: Section «Geotechnologies. Life Safety» of Karaganda Technical University named after Abylkas Saginov» - preparation of initial data obtained from the results of risk level assessment of the working environment of plant operators, processing and discussion of the results, design according to the requirements of the journal, submission through the information base of the journal, correction of reviewers' comments.

5. The article «Investigation of changes in the operator's state by analysing the characteristics of blinking» in the collection of the International Conference IOP Conf. Series: Materials Science and Engineering, indexed in Web of Science - direct participation in experiments on research of the operator's emotional state by facial image, comparative analysis of data, processing and discussion of the obtained results..

6. Positive decision on granting a Patent for utility model «Method of support of the operator of production units of oil refineries during actions in emergency

situations» - search and analysis of analogues and prototype, obtaining experimental data.

**Structure and volume of the dissertation.** The dissertation work consists of 5 sections, including an introduction, a review of scientific and technical literature and patents, objects and methods of research, an experimental part, results and discussions of the conducted research, conclusions, a list of used sources and appendices. The main content is presented on 181 pages, includes 34 tables, 57 figures, 12 formulas and 142 sources of literature of domestic and foreign authors, 6 Applications.