Occupational Risk Assessment for Workers of Aluminum Production Using the Example of RUSAL Bratsk OJSC

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Abstract. Aluminum is considered one of the most commonly used materials and has a wide range of applications in various industries. However, the production of aluminum is associated with a significant negative impact on the health of workers engaged in technological operations to produce it. In this regard, the aim of the work was to assess the occupational risks of workers in aluminum production. As a result of the analysis, it was found that the technological process for producing aluminum has a complex of negative effects on the health of workers, which includes industrial noise, general and local vibration, gas and dust contamination of the air in the working area, exposure to electromagnetic fields and radiation, adverse microclimate parameters. The totality of dangerous and harmful factors in working conditions and negative indicators of injuries and occupational morbidity for aluminum production workers requires carrying out a procedure for assessing occupational risks. Of the whole set of methods, we selected the three most informative and easy to use methods, i.e. the method of scoring occupational risks, the method of assessing the IOR level and the Fin-Kinney method. The object of the study was RUSAL Bratsk Aluminum Smelter OJSC. Based on the results of the assessment, it was established that the general level of occupational risk in RUSAL Bratsk OJSC corresponded to the “medium” and “high” values of these methods, which is considered unacceptable. To reduce the risk, it is necessary, in particular, to implement additional or modernize existing labor protection measures.

1. Introduction

Aluminum is the most common of the metals of our planet (more than 7% of the mass of the Earth), an active industrial production, which began relatively recently - from the middle of the last century [1]. But in nature, aluminum is represented mainly in the form of various chemical compounds. Due to its unique properties, aluminum occupies a significant position in global production and consumption. The main consumers of aluminum are mechanical engineering and construction, electric power industry, transport engineering, consumer goods, etc. (Fig. 1) [2].

Global production and consumption of aluminum is growing steadily every year and in 2019 amounted to approximately 69.5 and 70.9 million tons (Fig. 2) [3]. Today, high consumption can be seen in countries with developed mechanical engineering, namely in the USA, Germany, Japan (Table 1). A special place in the world market is occupied by China - it is the largest producer and consumer of aluminum [4]. The People's Republic of China produces and consumes about half of global aluminum. Therefore, China is completely independent in terms of this resource [5].
Figure 1. Global aluminum consumption by separate industries in 2019.

Figure 2. Global aluminum production and consumption 2015-2019.

| Country of production | Volume of aluminum production, million tons |
|-----------------------|--------------------------------------------|
|                       | 2015 | 2016 | 2017 | 2018 | 2019 |
| North America         | 4.47 | 4.59 | 4.55 | 4.51 | 4.47 |
| South America         | 1.33 | 1.21 | 1.02 | 0.83 | 0.64 |
| Europe                | 7.57 | 7.40 | 7.30 | 7.19 | 7.09 |
| Africa                | 1.69 | 1.74 | 1.74 | 1.74 | 1.74 |
| Asia (without China)  | 8.11 | 8.43 | 8.99 | 9.54 | 10.09 |
| Australia and Oceania | 1.98 | 1.96 | 1.91 | 1.86 | 1.81 |
| China                 | 31.67| 35.17| 38.27| 41.38| 44.49|
| Total                 | 56.82| 60.5 | 63.78| 67.05| 70.33|

In 2019, about 4163 thousand tons of aluminum was produced in Russia, the main producer of which is the United Company RUSAL, the largest aluminum supplier in the world [6, 7]. RUSAL unites enterprises engaged in the extraction of primary raw material - alumina, and its processing at aluminum smelters. RUSAL's geography is diverse and has about 14 aluminum enterprises, but the main production facilities are located in Siberia, namely Bratsk, Krasnoyarsk, Khakass, Irkutsk, Sayanogorsk aluminum smelters.

However, the process of aluminum production is associated with increased negative impact on the organism of workers engaged in basic technological operations. Therefore, the aim of this work is to assess the occupational risks of workers in aluminum production.

2. Study objects and methods
Initially, it is necessary to understand what negative effects exist and what consequences they have for a person.
When preparing a batch of aluminum ores, a huge amount of dust containing alumina, silicon oxides, various alkali metals, in concentrations exceeding the maximum allowable levels, is emitted into the air [8]. In addition to dust, processes are associated with noise and vibration at workplaces, as well as an unfavorable microclimate - enormous heat radiation from furnaces with a significant temperature difference in the winter season [9]. During the electrolysis process, the decomposition of alumina is accompanied by the release of compounds of fluorine, carbon monoxide and nitrogen, sulfur, tarry fumes, and benzapyrene. Also, electrolyzers are sources of constant magnetic fields [10].

Accordingly, during the technological process for producing aluminum from aluminum-containing ores, workers are exposed to a complex of negative effects, which includes industrial noise, general and local vibration, gas and dust contamination of the air in the working area, effects of electromagnetic fields and radiation, and adverse microclimate parameters [11, 12].

Later on, the impact of negative labor factors contributes to various occupational diseases in workers. Statistical information on cases of morbidity indicates the prevalence of respiratory diseases in the general gradation of diseases - about 73% of all cases [13]. They are followed by diseases of the musculoskeletal system associated with exposure to fluorine and its compounds (39%). Over the past year, a total of 28% of occupational lung diseases have been reported; 26% of hearing diseases; 5% of diseases associated with overstrain of organs and systems; 2% other diseases. The structure of occupational diseases includes mainly fluorosis and osteopathy, dust bronchitis and pneumoconiosis [14].

In addition to the harmful factors of working conditions at workplaces, there are various sources of hazard that can lead to injuries. In 2018 alone, the Federal State Statistics Service recorded 93 cases of injury to workers in the aluminum industry, of which 2 were fatal [15].

The totality of dangerous and harmful factors in working conditions and negative indicators of injuries and occupational morbidity for aluminum production workers requires carrying out a procedure for assessing occupational risks. Currently, the assessment of occupational risks means a set of interrelated activities, including measures to identify, assess and reduce their levels [16]. There are various methods for assessing occupational risks: synthetic (integrated) method, quantitative method and method based on the study of subjective assessments. Most of these methods are complex and cumbersome for practical application or require a significant list of informative data [17]. Of the whole set of methods, we selected the three most informative and easy to use methods, i.e. the method of scoring occupational risks, the method of assessing the IOR level and the Fine-Kinney method. Let us consider the nature of these methods in more detail [18].

In 2009, the Klin Institute of Occupational Safety and Working Conditions developed a method for assessing individual occupational risk taking into account working conditions in the workplace (based on measurements during the special assessment of working conditions and production control) and health status of workers [19, 20]. The method takes into account cases of occupational diseases and injuries at the workplace.

The scoring method for assessing occupational risk is based on assessing the degree of compliance of working conditions with standard values in the form of a system with special scores. The scores have the following meaning: the higher the score, the greater the discrepancy between the state of working conditions for this factor and the current standards and the greater its hazardous and harmful effect on the organism. The calculated values of the occupational risk level for each workplace must be compared with the maximum allowable risk for a given workplace. This comparison is necessary for ranking risks that require early intervention and adjustment [21]. Deviation of the actual occupational risk level from the maximum allowable level does not allow for a probabilistic risk assessment, but there is a scale for converting the deviation of the actual occupational risk level from the maximum allowable level into qualitative risk indicators [22].

The main idea of the Fine-Kinney method is to assess individual risks as a product of three components - the impact, probability and consequences of the event. In each case, it is determined how a particular violation of labor protection requirements can lead to occupational injury or occupational disease. All stages of work are to be considered: from the preparation process to the stages of implementation and completion [23]. Based on the production assessment, risks are formed into an
ordered system in the form of a matrix that takes into account all risk components [24].

Applying a set of methods will make it possible to assess occupational risks from different perspectives, taking into account many factors, which will allow taking into account all possible aspects in each workplace. The object of the study was RUSAL Bratsk Aluminum Smelter OJSC, the largest of the smelters belonging to RUSAL, which produces about 30% of all Russian aluminum.

3. Results and discussion

The information base for calculating occupational risks was the materials of the special assessment of working conditions. In addition, we carried out an analysis of production control materials, local regulations, job descriptions and generalized results of medical examinations, and conducted discussions with workers and their questioning.

According to the results of the special assessment of working conditions in 2015 and 2019, it was revealed that the number of workplaces with optimal and acceptable working conditions at RUSAL Bratsk OJSC amounted to only 21.9%. The remaining workplaces were classified as harmful (3rd class of different degree of harmfulness). The significant spread in the number of workplaces in a particular class, apparently, should be explained by the incomplete identification of all production factors affecting workers, the underestimation of the exposure duration, and measurement errors [25]. An objective assessment of working conditions is of particular importance, since the classes and degree of harmfulness determine the benefits and compensations provided for work in harmful and hazardous conditions [26]. Trade union organizations are currently called upon to pay special, paramount attention to the quality of the special assessment of working conditions and to objectively assess the state of workplaces [27].

In relation to our study, for the main workers ensuring the implementation of the technological process, the assessment of risks was performed using the previously discussed methods. The results were compared on the basis of the general risk profile of each of the methods, and are presented in the form of a complex (Fig. 3).

![Figure 3](image-url)  

- Very high level of risk;  
- High level of risk;  
- Medium level of risk;  
- Low level of risk

**Figure 3.** Results of a comparative assessment of occupational risks at RUSAL Bratsk OJSC.

Based on the results of the assessment, it was found that the overall occupational risk level for RUSAL Bratsk OJSC as a whole corresponded to the “medium” and “high” values of these methods, which is considered unacceptable, and the workers of this enterprise are highly likely to get occupational
pathology before reaching retirement age. To reduce the risk, it is necessary, in particular, to implement additional or modernize existing labor protection measures:

- modernization of technological processes and equipment; carrying out technical inspections of the condition of equipment (machines, mechanisms, tools), checking its compliance with safety requirements;
- conducting various training events;
- conducting preventive and compulsory medical examinations;
- monitoring the state of health of workers.

Assessment of occupational risk will allow developing an integrated program for the prevention of occupational diseases of workers and determining the most effective measures.

4. Conclusion

The considered methods for assessing occupational risk will allow for an integrated assessment of working conditions in workplaces, providing the most reliable data on the probability of negative changes in the state of human health. It is proposed to use the results of risk calculations for each workplace in the development of preventive measures to improve working conditions and the safety of workers. When developing recommendations on managing labor protection risk in workplaces, a risk management strategy is needed that will reduce the risk by developing measures to reduce the impact of harmful substances in the air of the workplace, adverse microclimate and noise.

5. References

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