Modern approaches to analysis of emergency risks in the Irkutsk Region

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Abstract. The paper presents a retrospective analysis of the risks inherent in man-made and natural emergencies in the territory of the Irkutsk Region and assesses their level based on the modern risk analysis methodology. In the work, we used methods of statistical analysis. The processing and synthesis of statistical data was carried out as a whole for the Irkutsk Region and the Russian Federation for the period 2009-2019. A quantitative assessment of the risk of emergencies in the Irkutsk Region for the period 2009-2019 was carried out based on the number of emergencies and the number of injured in emergencies. We calculated the average statistical indicators of the recurrence of man-made and natural hazards, as well as the average indicators of collective risk, based on which the territory of the Irkutsk Region was assigned to the high-risk zone for emergencies of any origin. A comparison of the individual risks of death in emergencies and fires with the national indicators allowed them to be considered acceptable relative to the national level, while the individual risk of death in emergencies and fires exceeded the standard levels by about 4 times.

1. Introduction
The development and intensification of industrial production in modern conditions inevitably leads to an increase in the number of accidents and the magnitude of the consequences associated with the uncontrolled release of toxic or explosive substances into the atmosphere. On the other hand, anthropogenic human activity changes the world around, which leads to global natural changes and also contributes to an increase in natural disasters. Social and material losses from catastrophic natural and man-made phenomena are constantly growing. A number of researchers [1-5] attribute this not so much to the growing hazards of natural disasters, but to the increasing vulnerability of society. On the one hand, man develops territories subject to natural hazards, on the other hand, he creates more and more objects with the ability to increase natural risk. Also, when studying hazardous natural phenomena at the present stage, it is necessary to take into account the sharp changes in the planetary climate, which in recent years have led to the activation of many natural hazards. A common characteristic feature of hazardous natural and man-made threats at the present stage is their synergistic nature, expressed in the fact that one disaster can cause a whole chain of others, sometimes even more catastrophic processes. In this regard, there is a need to use evidence-based approaches to ensure the safety of people [6-9].

An integral part of safety management is risk assessment, which involves obtaining quantitative assessments of the potential hazard of industrial facilities and quantitative assessments of the probability of occurrence and impact on people and other objects of nature. The accumulated foreign
and domestic experience in solving the problems of ensuring public safety indicates that the methodology for assessing and managing risk is the most reliable analytical tool. It allows ranking sources and factors of hazard by degree of importance, identifying priorities for risk management and areas of effective activity to minimize the level of risk [10,11]. This paper presents a retrospective analysis of the risks inherent in man-made and natural emergencies in the territory of the Irkutsk Region and assesses their level based on the modern risk analysis methodology.

2. Methods

In the work, we used methods of statistical analysis. The processing and synthesis of statistical data was carried out as a whole for the Irkutsk Region and the Russian Federation for the period 2009-2019 based on the data of the State Reports “On the State of the Protection of the Population and Territories of the Russian Federation from Natural and Man-made Emergencies” in the relevant years; we also used data from the Federal State Statistics Service for the Russian Federation and the Irkutsk Region and information from the official website of the Main Directorate of the EMERCOM of Russia in the Irkutsk Region.

3. Results and discussion

The main goal of emergency risk assessment is to determine the quantitative indicators of emergency risk at the facility/in the territory under study to organize the risk management process. A comprehensive assessment of the risk of a territory includes two components - an assessment of the frequency of occurrence of a natural emergency and the probability of its impact on human and material resources and, on the other hand, an assessment of the man-made risk caused by industrial accidents, also from the point of view of the probability of a man-made accident and the severity of the consequences of its impact on vulnerable resources.

The constant risks of emergencies determine the need for a thorough retrospective analysis or the use of other risk analysis methodologies based on simulation modeling, which allows studying scenarios of the occurrence and development of natural disasters and integrate them into the processes of risk assessment and processing [12-15].

In 2015, at the Sendai World Conference [16], Russia, along with other states participating in this conference, reaffirmed its firm intention to ensure that issues of disaster risk reduction and building resilience to disasters are addressed as a matter of priority. In order to better protect people, communities and countries, as well as their source of subsistence, health, cultural heritage, socio-economic assets and ecosystems, it is extremely important to forecast disaster risk, to carry out planning in preparation for disasters and to reduce disaster (emergency) risk, which is a condition of strengthening their resilience [17-19].

In this study, we carried out a quantitative assessment of the risk of emergencies in the Irkutsk Region for the period 2009-2019 based on the number of emergencies and the number of injured in emergencies in the territory of the Irkutsk Region. The data are presented in Figures 1 and 2 and partially in Table 1.

In addition to emergency situations, man-made fires are hazardous man-made incidents, often leading to death and serious material damage. In official statistics, it is customary to take emergencies and fires into account separately, although when determining the acceptability of the individual risk level, one considers a generalized indicator calculated taking into account fatalities both in case of emergency and fire.

For zoning of territories according to risk levels, it was proposed [10] to use integrated indicators that will allow assessing the probability of natural and man-made hazards, as well as the possible extent of social and material damage, that is, assessing the risk of emergencies precisely from the point of view of combining the probability of an event and the severity of its consequences. This integrated indicator consists of the potential territorial risk characterizing the frequency (repeatability) of the implementation of the damaging factors at the considered point in space, and the collective risk indicator characterizing the level of damage.
Figure 1. Dynamics of the number of emergencies in the Irkutsk Region in the period 2009-2019.

Both of these indicators were calculated on the basis of a synthesis of statistical data for the Irkutsk Region. Table 1 shows the average repeatability of natural and man-made emergencies (F, 1/year) in the region and the average number of people injured in these emergencies over the year (H, people); the indicators were calculated for the period 2009-2019. When calculating the number of injured, we took into account the total number of injured as well as people whose health and property were damaged. The determination of the degree of acceptability of the emergency risk level consisted in comparing the obtained values of the average frequency of emergencies of each type for the year and the average number of injured in emergencies for the year with standards of acceptable risk. The assignment of the considered territory to the emergency risk zone was performed on the basis of the matrix presented in Table 2.

Table 1. Average statistical indicators for calculating complex risk.

| Total years | Emergencies of all kinds | Man-made emergencies | Natural emergencies | Biological and social emergencies |
|-------------|--------------------------|----------------------|---------------------|----------------------------------|
|             | F, 1/year                | H, people            | F, 1/year           | H, people                        |
| 11          | 6.09                     | 607.0                | 4.45                | 28.9                             |
|             |                          |                      | 1.45                | 560                              |
|             |                          |                      | 0.18                | 18.09                            |
The calculations show that, in general, in terms of emergencies of any origin, the Irkutsk Region should be classified as a zone with high risk of emergencies. Thus, the average repeatability for the considered 11 years is more than 6 cases per year with an average number of injured of more than 10 people. It should be noted here that the average number of injured in the Irkutsk Region is significantly higher than 10 people. It will be 121 people, if we do not take into account 2019, and 607 people, if we take into account the catastrophic flood of 2019. Although, in our opinion, the figure of 121 injured per year over an average of 10 years will be more correct, since catastrophic floods, such as that in 2019, are much less common than in the frequency of occurrence once every 10 years and, thus, we should use statistics over a longer period of time (for example, 20-30 years) to account for such rare emergencies.

### Table 2. Matrix assigning territories to emergency risk zones.

| Average frequency of emergencies per year, 1/year | Collective risk (average number of injured per year), people |
|-------------------------------------------------|----------------------------------------------------------|
|                                                 | Degree 1 (up to 10 people) | Degree 2 (up to 50 people) | Degree 3 (up to 500 people) | Degree 4 (over 500 people) |
| 1 and more                                      | *                           | **                           | ***                          | ****                         |
| Less than 1 to 0.3                              |                             |                               |                             |                             |
| Less than 0.3 to 0.1                            |                             |                               |                             |                             |
| Less than 0.1 to 0.03                           |                             |                               |                             |                             |
| Less than 0.03 to 0.01                          |                             |                               |                             |                             |
| Less than 0.01                                  |                             |                               |                             |                             |

Designations:
- high risk zone
- elevated risk zone
- acceptable risk zone
* - emergencies of any origin
** - man-made emergencies
*** - natural emergencies
**** - biological and social emergencies

When considering emergencies of various kinds, the Irkutsk Region should also be classified both as a high risk zone for natural and man-made emergencies (repeatability - 1.45 and 4.45 1/year, respectively, and collective risk - 560 people and 28.9 people, respectively, with 560 people taking into account the data of 2019) and to an elevated risk zone for biological and social emergencies (repeatability - 0.18 1/year and collective risk - 18.09 people).

Another officially recognized indicator characterizing the level of hazard in the territory is the individual risk of death in emergencies.

The calculated values of individual risk from emergencies and fires in the Irkutsk Region according to retrospective data for 2009-2018 are given in Table 3 along with the corresponding values as a whole for Russia. For the calculation we used the data of the Federal State Statistics Service on the population of the Russian Federation and the Irkutsk Region as of January 1 of the corresponding year.

A comparative analysis of the risks of emergencies in the Irkutsk Region and Russia as a whole showed that the average individual risk of death in emergencies in the Irkutsk Region, as well as the individual fire risk in the region, was higher than the national risk for all the years considered. There is an approach according to which the risk is to be considered relatively acceptable if the corresponding value of the average individual risk differs by no more than a third from the average individual risk in the country. Also, from this point of view, the risk will be relatively unacceptable if the corresponding value of the average individual risk is more than a third higher than the value of the individual risk in the country.
Table 3. Dynamics of the average values of the individual risk of death in emergencies in the Irkutsk Region and the Russian Federation in the period 2009-2018.

| Year | Average value of the individual risk from emergencies, 1/year | Average value of the individual risk from fires, 1/year | Average value of the individual risk from a combination of factors, 1/year | Average value of the individual risk from emergencies, 1/year | Average value of the individual risk from fires, 1/year |
|------|---------------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------|--------------------------------------------------------|
|      | Irkutsk Region                                                | Russian Federation                                     |                                                                       |                                                               |                                                        |
| 2009 | 5.100·10^{-6}                                                 | 1.253·10^{-4}                                          | 1.304·10^{-4}                                                         | 5.170·10^{-6}                                                 | 9.748·10^{-5}                                           |
| 2010 | 2.400·10^{-6}                                                 | 1.272·10^{-4}                                          | 1.296·10^{-4}                                                         | 4.780·10^{-6}                                                 | 9.088·10^{-5}                                           |
| 2011 | 2.883·10^{-6}                                                 | 1.260·10^{-4}                                          | 1.289·10^{-4}                                                         | 5.590·10^{-6}                                                 | 8.410·10^{-5}                                           |
| 2012 | 4.950·10^{-6}                                                 | 1.077·10^{-4}                                          | 1.127·10^{-4}                                                         | 5.700·10^{-6}                                                 | 8.040·10^{-5}                                           |
| 2013 | 1.073·10^{-5}                                                 | 9.950·10^{-5}                                          | 1.102·10^{-4}                                                         | 4.400·10^{-6}                                                 | 7.370·10^{-5}                                           |
| 2014 | 2.068·10^{-6}                                                 | 9.759·10^{-5}                                          | 9.666·10^{-5}                                                         | 3.876·10^{-6}                                                 | 6.928·10^{-5}                                           |
| 2015 | 6.211·10^{-6}                                                 | 8.779·10^{-5}                                          | 9.400·10^{-5}                                                         | 4.902·10^{-6}                                                 | 6.230·10^{-5}                                           |
| 2016 | 3.810·10^{-5}                                                 | 7.164·10^{-5}                                          | 1.097·10^{-4}                                                         | 5.408·10^{-6}                                                 | 5.793·10^{-5}                                           |
| 2017 | 3.716·10^{-6}                                                 | 7.640·10^{-5}                                          | 8.012·10^{-5}                                                         | 3.790·10^{-6}                                                 | 5.330·10^{-5}                                           |
| 2018 | 3.328·10^{-6}                                                 | 8.402·10^{-5}                                          | 8.735·10^{-5}                                                         | 5.685·10^{-6}                                                 | 5.225·10^{-5}                                           |

Our analysis of the individual risk levels showed that with this approach in the Irkutsk Region in all the years considered, except for 2016, the level of the individual risk of death in emergencies and from fires was acceptable relative to the national level. Yellow in Table 3 shows a relatively acceptable level, and red (2016) indicates a relatively unacceptable level of risk.

A comparison of the obtained risk values with the standard value of the allowable risk for the Irkutsk Region shows that the average value of the individual risk of death in the Irkutsk Region in terms of the totality of factors (emergencies and fires) in 2017-2018 exceeded by 3.9-4.3 times the allowable risk established for the territory of the Irkutsk region. But this does not allow us to classify the individual risk level as unacceptable, because the same document indicates that the risk is to be considered unacceptable if it is 10 times higher than the established acceptable risk.

4. Conclusion

Thus, based on the assessments made, the territory of the Irkutsk Region is classified as a zone with high risk of emergencies of any origin. The individual risk of death in emergencies and fires exceeds the standard values by about 4 times. This state of affairs requires careful consideration and justification of each step in the planning and implementation of measures to reduce the risk of emergencies from everyone involved. In conclusion one can say the words from the manifesto [20]: “Understand the genuine developments in safety science and incorporate these findings in your professional practice”.

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