Method of Using Hazard Criteria for Identifying Hazardous Situations

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Abstract. The paper presents criteria for hazard and threat identification based on the systematization of the parameters of the comprehensive area safety monitoring. The numerical values of the intervals of functional safety of regional social-natural-technogenic systems have been obtained based the requirements of regulatory and guidance documents, and expert assessments. A method of using criteria has been proposed for identifying hazardous situations which consists in the comprehensive analytical processing of monitoring data.

Keywords: comprehensive monitoring, operational environment, hazard criteria

Introduction

To fulfill the tasks of ensuring the safe functioning of regional S-N-T systems requires the establishment of allowable range of parameters controlled by various systems for monitoring natural and anthropogenic processes [1]. A large list of possible risks characteristic of the territory of Siberia, and their mutual influence which enhances negative effects of the risk manifestation, justify the need for collecting, consolidating and comprehensive processing of data from the entire range of active observations [2, 3]. The development of a unified approach for identifying hazards and threats allows creating integrated information and analytical systems allowing one to solve immediate and strategic tasks of the area safety management [4].

Unlike integral risk assessments, which are annually performed, the area safety management authorities are permanently solving the problems of hazard identification [5]. Here, virtually the same information resources of comprehensive monitoring are used, and methods of analytical data processing are similar to those used in solving the problems of information support for preventive measures for risk reduction.

The functionality of most monitoring systems is reduced to on-line visualization of controlled parameters and analytical processing of observation archives [6]. The identification of hazards and threats, as a rule, is carried out in manual mode by selecting the maximum (or minimum) values for the period under consideration. Further decision-making is performed, which involves additional information resources, and systems of situational and analytical modeling. The use of a large number of highly specialized systems in decision-making significantly reduces the management effectiveness. Fragmented software implementation of the tasks of safe development of territories leads to the duplication of information, while the difference in the regulations of updating causes contradictions, whose resolution would reduce the efficiency and reliability of management decisions, to result in excessive expenses for ensuring security.

In order to build a universal approach for identifying hazards and threats, criteria have been developed for the threshold values of parameters for the available types of monitoring the S-N-T systems. A method of using the criteria is proposed for early detection of precursors of dangerous situations and for timely notification of emergency rescue units, population, and authorities.

Systematization of the monitoring parameters

For the systematization of the monitoring parameters *PR* we introduce the notions of «*comprehensive monitoring*» and «*current situation*» as well as notations of their components [7]. *Comprehensive monitoring* is a system of monitoring and control regularly performed according to a certain procedure for estimating the state of the environment and technosphere objects representing hazards O_1, analysis of the occurring processes and timely identification of the environment changes as well as collection of data on the characteristics and current state of the protected objects O_2 and management objects O_3 for further comprehensive processing [8]. *Current situation ST* is a collection of factors, conditions and circumstances in which certain activities are prepared and performed to ensure the safety of objects and areas described by the values of components of information resources *S* of multiple types for certain types of situations *H* [9].

The main types of ST are meteorological, hydrological, seismic, radiation, forest fire, sanitary and epidemiological conditions. The consolidation of the parameters of different types of monitoring allows one to take into account the mutual effect of ST. For example, adverse weather conditions increase the scale of hazards for almost all types of dangerous situations while the phytopathological environmental factors determine the risk of natural fires.

The primary source of the control parametric data O_1 is instrumental monitoring. Nowadays devices allow measuring the values of physical parameters, such as temperature, pressure, velocity, substance concentration, radiation power, size change, etc., and transmit data for processing at arbitrarily small intervals. Instrument monitoring also includes alarms transmitting signals about a dangerous event based on internal processing of measurement results. The information resources of monitoring include the results of instrumental measurements with various levels of processing (error correction, aggregation, etc.). However, for direct monitoring of the equipment functioning at the object level, devices are the only method of immediate identification of hazards and threats.

The most important source of information on the conditions of large areas is the data of remote sensing of the Earth [10]. In addition to the parameters listed above, spacecraft control a wide range of electromagnetic radiation, albedo, and spatial surface characteristics [11]. Depending on the spatial resolution of the received channels, and the periodicity of shooting, earth remote sensing systems are used to provide information support for management and control in almost all types of dangerous situations [12]. Unlike ground monitoring, in order to be used for the hazard and threat identifying, satellite imagery data require complex processing with the use of highly specialized software [13].

Criteria for identifying hazards and threats

The solution for the hazard identification problem is based on real-time analytical processing of data streams of comprehensive real-time monitoring of the environment and objects of the technosphere. The identification of hazards and threats consists in comparing the observed or calculated parameters with the criteria unique for the type of situations *H*.

The main document used as the basis for the development of the criteria for hazards and threats identification is the Order of the Ministry of Emergencies of Russia No. 329 dated July 8, 2004 “Concerning the Implementation of the List of Criteria for Information on Emergency Situations”. In addition, use was also made of departmental methods and regulatory acts of Roshydromet, Ministry of Natural Resources of the Russian Federation, Ministry of Transport of the Russian Federation, Ministry of Energy of the Russian Federation and others.

General criteria are used for all points of observation of seismic, and radiation conditions while unique ones are used for the hydrological situation (data of critical water levels), functioning of techno-sphere objects, etc. Group criteria of the meteorological situation are applied for various climate zones - areas located in temperate latitudes, Arctic zone, and highlands.

Hazard criteria are reviewed at different time intervals: limits for the discharges of hydropower plants are set monthly, depending on the hydro and meteorological conditions; critical water levels - once every five years. Longer periods of action are characteristic for the criteria of radiation hazard which depend on lengthy medical research as well as for the criteria for identifying technogenic acci-dents. Since some types of situations H are of seasonal character, their control is performed in certain months of the annual cycle. For natural emergencies which depend on air temperature, there are daily intervals of hazard control. For example, rising water levels and fires in the forest are most likely to occur during the day between 1 to 5 pm. It is appropriate that the seasonal and daily intervals for other types of situations are based on the analytical processing of catalogs of emergency situations.

The values of the threat criteria in the absence of specific data in literature or results of field observations were determined by expertise as a fraction of the dangerous value. Most hazard criteria rep-resent the maximum or minimum possible value of the monitored parameter, and the threat criteria represent a percentage of the critical value. In addition, the criteria can represent the sum of the values for a certain period, difference of consecutive measurements, as well as the number of objects having certain properties, or changed properties during the period. For technogenic objects, hazard and threat criteria may be in the middle of the operation intervals (for example, the rotation velocity of the hydroengines of a power station).

Decision making on emergency response to hazards and threats has a multi-level character. The real-time monitoring of the state of the environment is carried out at the regional level. The monitoring of technosphere objects is performed by duty dispatch services at the object level, the information is presented to higher-level management bodies in a summarized form. This is due not only to the large amount of control information concerning units and modules of industrial facilities and infrastructure of the areas, but also to the need for special knowledge to interpret signals as signs of a non-routine or emergency situation.

Thus, in most cases, hazard criteria are necessary but not sufficient conditions for a hazardous event to occur. After double-checking the signal using other sources of information and depending on the type of situation H, a decision is made on the response of operative services or their transfer into high-alert regime. The full cycle of management information support using identification criteria consists in the successive solution of the following tasks:

– identification of hazards or threats in terms of the current or forecasted state of any situation ST at the observation point PO, with notification (informing) of response services and population for a particular area;

– identification of risk indicators exceeding the allowable values with the fulfillment of the tasks of planning preventive measures for the territory with an increased level of emergency risk [14].

Table 1 shows the hazard criteria for the parametric monitoring of different types of hazards.

Table 1. Criteria of hazards and threats.

<table>
<tr><th>Parameter, PR</th><th colspan="2">Threat criteria, KR_2</th><th colspan="2">Hazard criteria , KR_1</th><th>Comment</th></tr>
<tr><td colspan="6">TECHNOGENIC HAZARDS</td></tr>
<tr><td colspan="6">Radiation situation</td></tr>
<tr><td>MED (Md, mSv)</td><td colspan="2">$Md > 0,6$</td><td colspan="2">$Md > 1,2$</td><td>One-time value</td></tr>
<tr><td colspan="6">Collapse of buildings and constructions</td></tr>
<tr><td>Snow level on large-span buildings (LS, cm)</td><td colspan="2">$LS > 20$</td><td colspan="2">$LS > 30$</td><td>Can change depending on a particular object</td></tr>
<tr><td colspan="6">Accidents in housing and utility sector</td></tr>
<tr><td>Hot water pressure in the heat supply chamber (PW, atm)</td><td colspan="2">$PW < 6$</td><td colspan="2">$PW < 4$</td><td>Direct feed</td></tr>
<tr><td>Hot water temperature in the heat supply chamber (TW, °C)</td><td colspan="2">$TW < 90$</td><td colspan="2">$TW < 70$</td><td>Direct feed</td></tr>
<tr><td colspan="6">NATURAL HAZARDS</td></tr>
<tr><td colspan="6">Weather hazards</td></tr>
<tr><td rowspan="2">Temperature (t, °C)</td><td colspan="2">$30 \leq t < 35$ or $-40 < t \leq -35$</td><td colspan="2">crossing 0</td><td rowspan="3">Can vary depending on the climate zone</td></tr>
<tr><td colspan="2">$t \geq 35$</td><td colspan="2">$t \leq -40$</td></tr>
<tr><td>Wind velocity (SW, m/s)</td><td colspan="2">$15 \leq SW < 25$</td><td colspan="2">$SW \geq 25$</td></tr>
<tr><td>Precipitation (Pre, mm)</td><td>$Pre \geq 30$ per 1 h.</td><td colspan="2">$Pre \geq 50$ per 12 h.</td><td>$Pre \geq 120$ per 42 h.</td><td>For solid and liquid precipitation</td></tr>
<tr><td>Wet snow diameter (DS, mm)</td><td colspan="2">$DS > 20$</td><td colspan="2">$DS > 30$</td><td></td></tr>
<tr><td>Fire hazard class, CFD</td><td colspan="2">$CFD = 3$</td><td colspan="2">$CFD \geq 4$</td><td>Estimated based on air temperature and humidity, duration of the period without precipitation</td></tr>
<tr><td>Snow level in the avalanche-prone area (LS, cm)</td><td colspan="2">$LS > 30$</td><td colspan="2">$LS > 50$</td><td>Can vary depending on the slope and exposure</td></tr>
</table>

Parameter, PR	Threat criteria, KR_2	Hazard criteria , KR_1	Comment
Long drought (DD, days)	$DD > 7$	$DD > 14$	Can vary depending on the climate zone
Hydrological hazards			
Water level in rivers (RL, cm)	$RL \geq$ Starting level of flood $Kh_1 \times 0,8$		Unique criteria Kh_i for each point of observation PO
	$RL \geq$ Starting level of flood Kh_1		
Daily variation of the water level (dRL, m)	$dRL > 100$		
BIOLOGICAL AND SOCIAL HAZARDS			
Mass diseases			
Concentration of the contaminating substance, Cp	$Cp \geq maxD$	$Cp \geq maxD_{24}$	$maxD$ – maximum one-time concentration; $maxD_{24}$ – maximum day exposure concentration
	$C \geq maxD \times Nc$ or $C \geq maxD_{24} \times Nc$		$Nc \in [3; 10]$ depending on the control parameter

Table 1 is regularly supplemented with new data of hazard monitoring O_1. For example, to reveal hot spots in forest areas based on the remote sensing data in the infrared range, use is made of the criterion of extreme temperatures of +60°…+80° depending on the fire hazard class, type of the receiver, and characteristics of the area. [14].

Along with the maximum values of the PR parameters, hazard and threat criteria have been developed within the monitoring systems of events. For technogenic hazards this is the alarm actuation, for example, ERA-GLONASS, Gonets, Cospas-Sarsat, fire alarm, etc. The threat criterion is the time, which passes after the failure of the system. For example, decisions concerning the emergency evacuation of the population are made based on the duration of the heat supply system failure in combination with the accident scale and external temperature. The manifestation of natural hazards (drizzling rain, glazed frost, ice jams, dry thunderstorms, etc.) is difficult for numerical estimation. However, the arising threats increase the probability of emergency situations of other types: road accidents, floods, natural fires.

Widely spread systems of video monitoring can also be the sources of information about hazards and threats. The positive sides of their use are their relatively low cost and applicability for almost all the types of situations H. The limiting factors are the necessity of using complex software for recognizing hazardous situations and identification of the precursors of an emergency.

Using the criteria of hazards and threats

The software implementation of automatic indication of emergency and unfavorable parameters of the situation is based on the “semaphore principle” [15]. The detection of threats is done by verifying the correspondence of the monitoring data to the established threshold values or revealing their discrepancy. The data are evaluated by comparing the current values of the parameters being controlled with the criteria given in Table 1. Filtration is done to determine the levels of the conditions of the objects under control. Depending on its results, the parameters under control have the following colors:

- «green» - the conditions correspond to the norm, the values of the parameters under control are within the allowable limits;
- «threat» – the identification of a threat when the parameters approach the critical values, or dramatic changes are detected, or else a prolonged deviation is observed from the average standard values;

▪ «red» – the identification of a hazard, increased risk of a situation connected with damages or interruption of the activities in the area. In this case, the parameters are equal or exceed the critical values.

The grey color of the indicator shows the absence of the current data for the estimation and the necessity to verify the source of information and channel of data transmission.

The application of the three-color gradation has been shown to be optimum for prompt decision making by the authorities of the Emergency Ministry of Russia using the earlier developed response scenarios. The scenarios describe the consequences and actions in a dangerous situation, depending on its type, and scale; and they are adjusted to a particular area and arising conditions.

The algorithm of using the criteria for the hazard and threat identification is presented in Figure 1. The process includes three cycles: taking into account the types of situations *ST*, observation points *PO* and measured parameters *PR*. The content of the monitoring information depends on the type of the information source. The data package of the instrumental monitoring can be represented by the vector of the parameters *PR*. The data from the observation systems and web-portals integrate the information from all the observation points *PO* (matrix $PO \times PR$).

Most situation types *ST* depend on the weather conditions and forecast, thus, in analyzing the situations meteorological parameters are to be taken into account. The range of the allowable values for the situations with the unfavorable values of the meteorological parameters decreases. Some of the parameters *PR* require preliminary calculation, for example, the precipitation sum *Pre* for the period or the fire hazard class in the forests *CFD*. In the process of comparison of the current *PR* with the criteria of hazards and threats *Kr* the array *Signal* is filled. In the cases of varying values of the elements of the array *Signal[st, po, pr]* the tasks of prompt response t_{21} and t_{22} are solved according to the earlier developed scenarios of actions.

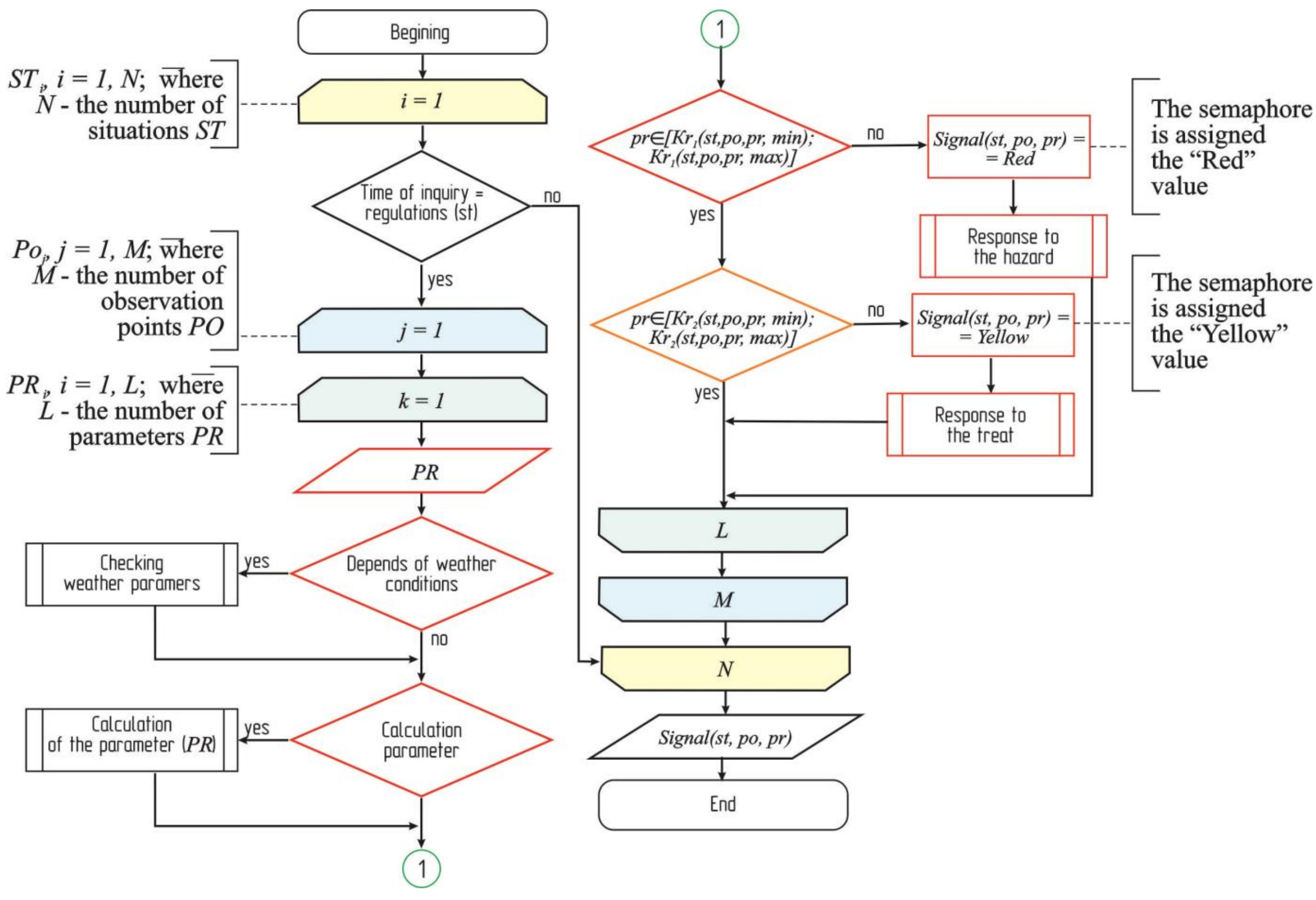

Figure 1. Algorithm for hazard and threat.

Automatic indication of hazards and threats for the situation as a whole has been developed with the help of the operation of aggregation. The situation is assigned a level of hazard corresponding to the worst of the levels from multiple analytical indicators. Notification of hazards and threats occurs at the level of the whole area and the function of the refinement of the analytical model OLAP allows one to check the observation point and parameter whose values exceed the allowable level. The given function is implemented in the system ESPLA-M included into the automated working place of an operator at the Regional Monitoring Center of the Krasnoyarsk Region [16].

Conclusions

Criteria for the hazard and threat identification have been developed based on systematizing the parameters of comprehensive monitoring of the area safety. The numeric values of the intervals, which correspond to the safe functioning of the regional social- natural-technogenic systems have been developed taking into account the regulations and guidance documents and expert estimates. A method of using the criteria for the identification of hazardous situations has been developed consisting in comprehensive analytical processing of the monitoring data.

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