STATISTICAL MODELS FOR FORECASTING EMERGENCY SITUATIONS OF MAN-CAUSED CHARACTER

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Abstract

The aim of the study is to develop predictive and analytical solutions for technogenic threats for urban areas, the mathematical basis of which is Bayesian classifiers. The result of the work is a formalized description of models for predicting the consequences of a heat supply shutdown; consequences of a power outage; consequences of oil and oil products spills; the consequences of the discharge of liquid technological waste into the hydrosphere; the consequences of the release of hazardous chemicals into the environment.

Keywords: predictive and analytical solutions; Bayes method; man-made emergencies; shutdown of heat supply; power outage; spill of oil and oil products; discharge of liquid technological waste into the hydrosphere; release of hazardous chemicals into the environment.

I. Introduction

The subject of the work is technogenic threats to urban areas with the aim of their formalized description using Bayesian classifiers. The main part of the work contains five sections: a model for predicting the consequences of a heat supply shutdown; a model for predicting the consequences of a power outage; a model for predicting the consequences of an oil spill and oil products; a model for predicting the consequences of the discharge of liquid technological waste into the hydrosphere; model for predicting the consequences of the release of hazardous chemicals into the environment.

II. Methods

The main input data for the formation of the basic training set of the model for predicting the consequences of a heat supply shutdown are the following data: characteristics of heat supply systems and consumers; failure characteristics of heat supply systems; characteristics of reduced (emergency) heat supply to consumers; parameters of the meteorological situation [1].

The main calculated dependencies for determining the reliability indicators of heat supply to a consumer connected to the heat network of the heat supply system are presented in [2].

In the short-term forecasting model, probabilistic assessment using a Bayesian classifier is subject to hypotheses that estimate the deviation of the predicted time until the restoration of heat supply as a result of the failure of the heat network section from its calculated value.

In the medium-term forecasting model, the hypotheses given in Table 1 are subject to probabilistic assessment using a Bayesian classifier.

Table 1: *List of hypotheses of the medium-range forecasting model*

Hypothesis number	Content of the hypothesis
1.	During the heating period, there were (will be recorded) cases of a decrease in the air temperature in consumer buildings below the limit value
2.	During the heating period, cases of interruptions in the supply of the estimated amount of heat and a decrease in air temperature in the buildings of consumers of the first category below the standard values were recorded (will be recorded)
3.	During the heating period, cases of exceeding the time for eliminating accidents in the TS system by more than 54 hours were recorded (will be recorded) for consumers of the second category

Based on the results of the probabilistic assessment, the level of threat is determined for each consumer (by the worst value).

Statistical model for predicting the consequences of a power outage

The initial data of the model for predicting the consequences of a power outage are: characteristics of electrical energy consumers located on the territory of a municipal district; characterization of massive damage to power grid facilities [3].

In case of accidents on power grids, it is important to timely identify consumers, the consequences of stopping the transmission of electrical energy to which, due to damage to the power grid facilities of grid organizations or equipment of power generation facilities, cause the greatest damage to the life of the population.

To this end, for each de-energized consumer of electrical energy, an index of the priority of restoration of power supply is determined, which takes into account the following factors: classifying the consumer of electrical energy as consumers whose limitation of the mode of consumption of electrical energy may lead to economic, environmental or social consequences; the degree of participation of the consumer of electric energy in ensuring the life of the population; the number of people in the buildings of the consumer of electrical energy; the estimated time at which the consumer can function when the main power supply is turned off if he has an independent power source - an autonomous backup power source; the time of the year and the day of the week in which the consumers of electrical energy were de-energized [4].

The power supply restoration priority index of the j-th transformer substation is determined according to Table 2.

Table 2: *Criteria for determining the index of priority of restoration of electricity supply to consumers*

Index value	Power restoration priority	Index criteria
1	Максимальный	$F_j \leq 50$, in the absence of de-energized consumers with a relative importance coefficient equal to 1
2	Average	$50{,}01 < F_j \leq 80$, in the absence of de-energized consumers with a coefficient of relative importance equal to 1; $F_j \leq 50$, in the presence of de-energized consumers with a coefficient of relative importance equal to 1
3	Minimum	$80{,}01 < F_j \leq 100$, in the absence of de-energized consumers with a coefficient of relative importance equal to 1; $50{,}01 < F_j \leq 100$, in the presence of de-energized consumers with a coefficient of relative importance equal to 1

Statistical Model for Predicting the Consequences of an Oil and Oil Product Spill

In the general case, the process of developing a statistical model for predicting the consequences of an oil and oil spill includes: collecting initial information and forming a basic training set; selection of a Bayesian classifier, preparation of methods for analyzing and interpreting the results of statistical processing.

The main initial data describing the characteristics of an oil and oil product spill (hereinafter referred to as ROP) are: input data characterizing the main parameters of the ROP; input data characterizing the storage tanks for oil and oil products (hereinafter referred to as NN); input data characterizing the meteorological situation; input data characterizing the properties of NN; input data characterizing the site of a possible RUI [5].

The main predictive parameters of the RNN are: the predicted area of the RNN in time corresponding to the forecast step; the predicted mass of the spilled HH after a time corresponding to the step of the forecast; forecasting water pollution, fire, explosion.

The output data of the model for medium-term forecasting are the results of a probabilistic assessment of the possibility of RNR from the storage tanks of HH during the forecasting period (10 days).

The output data of the model for short-term forecasting are [6]:

a) data implemented using the Bayesian classifier: the deviation of the actual value of the mass of the spilled HH onto the site as a result of RNN from its calculated value during the day every 3 hours; deviation of the actual value of the area of the contaminated territory as a result of RNR from its calculated value during the day every 3 hours; probabilistic assessment of the emergence of man-made threats as a result of RNN; probabilistic assessment of pollution of a water body as a result of ROP;

b) initial data used at each step of forecasting.

Statistical model for predicting the consequences of the discharge of liquid technological waste into the hydrosphere

The main input data for the formation of the basic training set of the model for predicting the consequences of the discharge of liquid technological waste into the hydrosphere are the following groups of parameters: parameters of systems (posts) for monitoring discharges of liquid technological waste (hereinafter referred to as LTW) located in close proximity to the sources of discharges of liquid technological waste from industrial facilities; parameters of systems (posts) for monitoring discharges of liquid waste; characteristics of sources of liquid waste disposal; characteristics of sections of a water body (hereinafter - VO); characteristics of the hydrological situation [7].

In this model, hypotheses are subject to probabilistic assessment using a Bayesian classifier: for predicting the concentrations of substances that make up the LTO; to predict the decline in chemical oxygen demand (hereinafter - COD) and biochemical oxygen demand (hereinafter - BOD) [8].

To predict the decline in COD and BOD, the hypotheses indicated in Table 3 are applied.

Table 3*: List of hypotheses of the model for predicting the decline in COD and BOD*

Number hypotheses	Content of the hypothesis
1.	At the observed values of the concentration of the substance that is part of the LTO, as a result of its discharge into the WW, the COD indicator dropped (drops) below 6.0 mg/dm^3
2.	At the observed values of the concentration of the substance that is part of the LTO, as a result of its discharge into the WA, the BOD indicator dropped (drops) below 2.1 mg /dm^3
Note - The content of each hypothesis in the past tense is used at the training stage of the	

SAM-SO, and the content of the hypothesis in the future tense is used when predicting the corresponding events on new values of the observed parameters.

The output data of the model are: a probabilistic assessment of the predicted concentrations of various types of LTL in a given period of time at systems (posts) for monitoring discharges during the spread of the LTL discharge; probabilistic assessment of the decrease in COD and BOD indicators as a result of the discharge of liquid waste; assessment of the level of water pollution based on the overall water quality index SCWQI.

Statistical model for predicting the consequences of the release of hazardous chemicals into the environment

The main input data for the formation of the basic training set of the model for predicting the consequences of the release of hazardous chemicals into the environment are the following groups of parameters: parameters of systems (posts) for monitoring emissions of hazardous substances located along the perimeter of industrial facilities that have sources of hazardous chemical emissions; parameters of systems (posts) for monitoring emissions of OHV; characteristics of the meteorological situation; characteristics of sources and parameters of OHV emissions [1].

In this model, the following parameters are subject to probabilistic assessment using a Bayesian classifier: the release rate and concentration of OHV at the location of the system (post) for monitoring OHV emissions [9].

The output data of the model are: probabilistic assessment of the predicted concentrations of various types of OHV in a given period of time at systems (posts) for monitoring emissions during the propagation of the OHV release; assessment of air pollution levels based on the SCAQI general air quality index.

III. Results

Thus, this article discusses predictive and analytical solutions for technogenic threats for urbanized areas, the mathematical basis of which is Bayesian classifiers. The result of the work is a formalized description of statistical models for predicting the consequences of a heat supply shutdown; consequences of a power outage; consequences of oil and oil products spills; the consequences of the discharge of liquid technological waste into the hydrosphere; the consequences of the release of hazardous chemicals into the environment.

IV. Discussion

The discussion of the verbal and mathematical foundations of predictive modeling of technogenic emergencies is quite active in the scientific literature [10 - 12].

The scientific novelty of the developed models lies in a single scientific approach to their creation, namely, the use of a statistical processing method based on Bayes' theorem.

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