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ANALYSIS OF RISKS TO THE ENVIRONMENTAL SAFETY OF WATER TREATMENT

The paper provides the algorithm for effective recognizing the dangerous factors in water treatment complex systems functioning, caused by possible emergencies and catastrophes or terrorism threats. Environmental safety risks include the emissions of pollutants that lead to the formation of toxic compounds. An important aspect is the impact on the stability of engineering and technical facilities, which can result in accidents and disasters. Anthropogenic factors, earthquakes, and fires cause hazardous changes in the natural environment, disrupting the engineering and geotechnical stability of the foundations of critical infrastructure objects and creating preconditions for emergency situations. The emissions of pollutants from technogenic processes have affected the safety of the environment, air, surface water, and groundwater, and the presence of untreated sewage in rivers has exacerbated environmental risks, as highlighted. Modern environmental monitoring and information processing systems are largely based on artificial intelligence systems in order to guarantee maximum environmental safety. One of the main problems of such systems is identification, which can be solved by using associations and analogies for an appropriate risk assessment process. The search for associations should be done with the help of heuristics. The application of the mentioned heuristics enables a rapid assessment of the scale and degree of terrorism threats to wastewater treatment processes and other complex technical systems. This approach facilitates the early identification of potential issues and ensures effective recognition of situations arising in real conditions due to changes in external factors, recognition system configurations, object behavior parameters, and system objectives. Heuristics are the most effective and flexible tools for formalizing relationships between associations and relationships. The heuristics for minimizing the impact of terrorist threats in water treatment that should be considered when making decisions under unclear and incomplete information are presented.

Key words: *risk, water treatment, heuristics, associations, analogies.*

Introduction. The environmental safety risks include the emissions of pollutants, which lead to the formation of toxic dangerous substances. The significant is the impact on sustainability of engineering technical objects and possible emergencies and catastrophes on these objects. As a result of anthropogenic or earthquakes, fires and demolitions of constructions and buildings the dangerous changes in the natural environment are observed. Thus the engineering-geotechnical stability of the foundation of critical infrastructure objects is disturbed and the emergencies take place [1].

The mechanical impact on the environment (as a result of mining, the movement of heavy machinery and equipment, the constructions, etc.), effects disturb of the soil structure, which leads to its erosion [2–3]. As a result of equipment breakdowns and accidents, chemical soil pollution occurs, which causes secondary chemical reactions in the environment, capable not only of polluting the soil, but also of destroying the useful microflora that restores the soil and forms humus. The salt and water balance of nutrients absorbed by plants is also disturbed, while the latter die, which also contributes to a decrease in soil fertility and soil erosion.

The most dangerous thing in technogenic disasters for the environment is the ingress of harmful substances into the geological environment, soil and groundwater namely. Usually, a significant excess of the content of carcinogenic substances is recorded, which threatens the health of residents of settlements located near the epicenter. It is necessary to check the water in the wells, because there is a possibility that dirt will get into the groundwater. In such accidents, an excess of benzopropylene content is detected. Sulfuric and sulfurous anhydrides, carbon monoxide, and nitrogen oxide get into the air together with flue gases. Pollutants settle on the soil, surface water, migrate into the ground water, natural reservoirs. That can lead to the impoverishment of species biodiversity in the rivers and ground ecosystems.

This negative trends for the environment is exacerbated by already existing environmental problems, such as inefficient functioning of the treatment equipment. The main pollutants, present in rivers, are heavy metals, groups of pharmaceutical substances, substances containing phosphates, organic substances, agricultural pesticides. In particular, herbicides, insecticides, and fungicides were found in the water. Also, pharmaceuticals were found in the water – such as even ordinary Ibuprofen, traces of antidepressants, antiviral agents etc. [4].

Untreated industrial and communal discharges get into the rivers heavy metal ions, oil and petroleum products from metallurgical and chemical enterprises. The pulp and paper industry, sugar and food productions pollutes rivers with organic substances. This causes a decrease in the concentration of oxygen in the water, which is why fish and vegetation die.

For the timely detection, response and prevention of the consequences of intervention in the geological environment, it is advisable not only to use a traditional system of environmental pollution monitoring, but also to involve artificial intelligence. Modern automated environmental information processing systems should include the artificial intelligence (AI) systems able to analyze changes at the environment state and to react to achieve specific aims. However, one of the main problems of AI systems is the problem of recognition [5–6]. This problem affects many aspects of the functioning of AI systems:

– choosing the optimal information processing technology;

– choosing a target that is located against the background of various types of obstacles (including active, artificial);

– choosing a behavior strategy under conditions of fluctuating environmental conditions; changes in the reaction to certain actions of the researched object; changes in one’s condition, etc.;

– recognition of the behavior model of the researched object;

– recognition of the distribution, configuration and degree of threat (toxicity) of the state of the surrounding environment after a natural or man-made accident (catastrophe);

– recognition (estimation) of the parameters of the researched object;

– assessment of recognition risks under conditions of obstacles (natural and artificial) and virtual reconfigurations of the AI system.

The aim of the research is the development of the decision-making approach for recognizing situations that arise in real circumstances in geological environment during the functioning of objects under the conditions of unexpected harsh changes.

Results and discussion. One of an effective means of recognition is the use of analogies, but there is an opinion that hidden biases (on the background of insufficient, limited information) may create a kind of implicit associative bias, which affects on an unconscious level of the making of a wrong decision [7–10]. This opinion is quite valid, but mainly concerns linguistic and philosophical problems – in AI systems, it is necessary to provide a number of measures that are designed to minimize this virtual threat. The use of “hard” algorithms and neural networks to increase the “viability” of intelligent systems and reliability recognition does not exclude the influence of implicit associative biases: a flexible approach is needed, based on a wider use of the theory and methods of fuzzy sets and the methodology of expert systems.

In order to successfully solve the above-mentioned problems, it is worth turning to the idea of association, that is, to the search for a connection between those new, not yet understood concepts, phenomena, information, individual events that are observed, and those facts, phenomena, objects that are already known, but reflected in the mind of the analyst (and in the base of facts or knowledge of the AI system) and fixed as belonging to a completely different sphere that has, it would seem, no relation to what is being observed. Such a connection, if discovered, allows to analyze new information by analogy, that is, to identify the similarity of objects, phenomena, processes, patterns of behavior, etc. and thus to learn something new, unknown by comparing it with the known, but in a completely different field of knowledge [11].

The main problems associated with the use of analogies are the possible randomness of the selected characteristics of the comparison by analogy, the formality of forecasting by analogy without taking into account specifics, the unjustified predictability of consequences, the historical uniqueness of just one problem, etc. [12]. In order to increase the probability of formal analogy conclusions, requirements for analogies are accepted, such as an increase in quantitative and qualitative features, the non-identity of the analyzed objects, the presence of differences between them, as well as a clear connection between the features of the object and the selected feature – associations.

The search of associations should take place with the help of heuristics, as the most effective and flexible tool for formalizing connections and relationships between certain connections.

As a rule, heuristics can be formulated as follows:

IF {certain unknown event, phenomenon, object, etc. cause a certain association *ASSOC* with known phenomena, events, objects, the description of which, their parameters, behavior patterns, characteristic features, etc. are in the banks of knowledge (*BK*), facts (*BF*) or data (*DB*)}, *THEN* {it is necessary to use the information stored in these banks to simulate by analogy the behavior of these unknown objects (processes) by influencing them with a virtual set of adequate input signals and at the same time to simulate the behavior of a known object (process) under the influence of similar (adequate) virtual signals with a comparison of the results} *AND* {make a decision based on the results of the comparisons regarding the correspondence of the association and the chosen analogy} *AND* {start the procedure for specifying the parameters of the recognized object} *ELSE* {return to the search for another adequate analogies} [13].

To implement the procedure of searching of association of a given unknown phenomenon or an object, a set of virtual (possible) objects (models), that cause association under existing conditions, is used at the same time, of which it is not known in advance. If there is data on the reaction of analog objects under the influence of certain exciting signals at the moment of predicting the behavior of the object that causes association, that is, the values at a certain point (according to each of the models), the actual value of the adequate parameters is determined at this point. This is done at a number of points along the direction of action of the corresponding (virtual) exciting signals. After the reactions are determined at all predetermined points, the real spectrum distribution is compared with the model distribution (for each of the models separately) and a metric is calculated that characterizes the degree of difference between the real and model spectrum distributions for each of the models. The metric corresponding to the smallest value characterizes the optimal model for this case. After that, this optimal model as an associative link can be used and decisions based on the simulation data can be made, and other models can be not used. However, it is necessary to monitor the abrupt changes in the parameters of the environment, as well as the behavior of the researched object. In case of such changes, it is necessary to use all the models again and find the best one (as shown above), etc. The approach is, of course, rather artificial, but it helps each time to find and to use the best of the set of models and, thus making it easier to provide and display the situation, which helps to solve the recognition problem.

The distance between the distribution of the actually determined values y_i and the distribution of the values y_i^m (the Euclidean metric d_E, which correspond to the m-th model) is calculated by the expression:

$$d_E = \left(\frac{1}{n-1} \sum_{i=1}^{n} (y_i - y_i^m)^2 \right)^{1/2}. \quad (1)$$

The selection of the optimal model M_{opt} corresponds to the condition:

$$M_{opt} = M(U_{j=1}^{m}(\min d_E^i)), \quad (2)$$

where n – number of points at which the parameters of the corresponding models y_i^m and the real object y_i are determined, m – number of the model (association).

As the simplest example, the problem of detecting a virtual terrorist act in the mine wastewater treatment and drainage system can be considered. Under conditions of extraordinary circumstances (floods, earthquakes and other natural disasters, as well as man-made disasters, and, in the case of war – terrorist acts), the situation changes dramatically: water indicators deviate significantly from statistical averages, which requires an adequate response from regulatory bodies and, in some cases, switching to another wastewater treatment technologies, changing modes of operation, possible serious changes in the treated wastewater drainage system, etc. In other words, the model of wastewater treatment and drainage is changing.

In the case of natural and man-made cataclysms, the very fact of the disaster is a signal for a change in the paradigm of wastewater treatment and treated water drainage (of course, such virtual situations are predicted and modeled). But in the case of terrorist acts, the matter is much more complicated, since simulating the latter is quite difficult, although, in principle, it is possible. It is impossible to predict a terrorist act, neither in terms of the place of its planning and organizing, nor in terms of the direction of actions, nor in terms of the means of carrying out the action. If it is about the use of toxic substances by terrorists, then most of them have no color, smell, or taste, and their content in water is not very easy to detect in real time, even with complex and expensive analyzers. But these substances have one thing in common – they are transported in a concentrated form and have an acidic or alkaline base, that is, they significantly affect the *pH* of water, in addition, they are usually sensitive to the chlorine, which is present in the mine wastewaters [14]. This gives reason to believe that if continuous monitoring of these parameters is organized, then it is quite possible to receive a signal about a terrorist attack in a timely manner and take precautionary measures regarding notification of consumers and emergency services, as well as regarding the minimization of possible consequences for the environmental safety.

It is worth citing, as an example, heuristics for assessing the situation and decision making for the risk minimization that actually occurred:

$$\textbf{\textit{IF}}\ (Cl2 \approx 0)\ \textbf{\textit{AND}}\ (|\Delta \mathrm{Cl}_2| > (|\Delta \mathrm{Cl}_2|\mathrm{max})$$
$$\textbf{\textit{AND}}\ (WS = 0)$$
$$\textbf{\textit{AND}}\ (DC = 1)\ \textbf{\textit{AND}}\ (SC = 1)\ \textbf{\textit{AND}}\ (LE = 1),$$
$$\textbf{\textit{THEN}}\ (DIAGN)\ \textbf{\textit{ELSE}}\ (TER),$$
$$\textbf{\textit{IF}}\ (|\Delta pH| > |\Delta pH|\mathrm{max})\ \textbf{\textit{AND}}\ (\mathrm{Cl}_2 > 0)$$
$$\textbf{\textit{AND}}\ (WS = 0)$$
$$\textbf{\textit{AND}}\ (LE = 1)\ \textbf{\textit{AND}}\ (RPA = 0),\ \textbf{\textit{THEN}}\ (DIAGN)$$
$$\textbf{\textit{ELSE}}\ (TER), \qquad (3)$$

where Cl_2 – residual chlorine content in wastewater; $|\Delta \mathrm{Cl}_2|$ – absolute value of the increase in residual chlorine during the current monitoring cycle; $|\Delta \mathrm{Cl}_2|\mathrm{max}$ – the maximum possible absolute increase in the content of residual chlorine in water (according to long-term statistics); *WS* = 0 – confirmation that there have been no water spills caused by downpours, earthquakes, floods, or tornadoes in the previous few days; *DC* = 1 – confirmation of the fact of normal operation of the wastewater treatment unit; *SC* = 1 – ascertaining the fact that the sealing of the treatment tanks was not broken and there was no spillage of chemical treatment reagents; *LE* = 1 – localization of the place with abnormal indicators is established; *DIAGN* – need for urgent diagnostics of all controlled objects; *TER* – terrorist act; $|\Delta pH|$ – absolute value of the increment of the *pH* indicator; $|\Delta pH|\mathrm{max}$ – the maximum possible absolute value of the increment of the *pH* indicator in water (according to long-term statistics); *RPA* = 0 – no reports of possible accidents associated with the release of significant acidic or alkaline masses into the drainage area.

Usually, risk forecasting takes place on the basis of statistical data on the possible causes of man-made and ecological disasters, as well as various models of functioning, behavior, trees of the development of events, based on various initial data and criteria. However, representative statistical data can be obtained only if there is information on a significant number of cases with clearly defined conditions of the circumstances of the occurrence of disasters. In the case of unique disasters, there are no statistics at all, which makes risk forecasting a rather difficult problem, since even failure statistics are based on considerations about average operating conditions, average external and internal factors, etc. [15]. It is not for nothing that the well-known expert in economics, political scientist S. N. Parkinson claims (and not without reason) that if a catastrophe can happen, then its realization is inevitable, regardless of any small probability of this event [16]. Indeed, let's turn to the facts. The probability of a severe radiation accident at nuclear facilities six months before the accident at the Chernobyl Nuclear Power Plant (Ukraine) was estimated as one per million reactor-hours, which, taking into account the number of nuclear units operating in the world at that time and the total operating time, corresponded to the average probability of one accident per 100 years [17]. However, during the 50 years of the "atomic era", there were large-scale accidents at the factories for the production of nuclear explosives Windscale (Great Britain), the Plutonium production for atomic bombs "Mayak" (USSR), at the Three Mile Island NPP (USA) and at the Chernobyl nuclear power plant. That is, «statistics» provided data that were eight times smaller than the actual result! The fact is that statistics is based on the prerequisites of the «statistical average level» of the state of technical and software tools, personnel training, external conditions, etc.

In fact, before assessing the possibility of realizing a particular disaster, it is worth turning to the *SWOT* analysis procedure, that is, an analysis that separates and takes into account factors and phenomena of four categories: strengths and weaknesses risks, as well as opportunities and threats associated with their implementation [18–19].

Conclusions. The use of the mentioned heuristics makes it possible to quickly assess the scale and degree of risk of terrorism threats for the process of wastewater treatment or the functioning of other complex technical systems and identify (recognize) problems at the initial stages of their development.

The above-mentioned approach allows recognizing effectively situations that arise in real circumstances during the functioning of objects of various nature under the conditions of changes in external factors, the configuration of recognition systems, changes in the parameters of the behavior of objects under investigation, changes in goals that systems should achieve.

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Дичко А. О., Єремєєв І. С., Ремез Н. С., Барабаш О. В., Мінаєва Ю. Ю. **АНАЛІЗ РИЗИКІВ ЕКОЛОГІЧНОЇ БЕЗПЕКИ ВОДООЧИЩЕННЯ**

У роботі запропоновано алгоритм ефективного розпізнавання небезпечних факторів у функціонуванні водоочисних комплексних систем, спричинених можливими надзвичайними ситуаціями та катастрофами або загрозами тероризму. Викиди забруднюючих речовин від техногенних процесів вплинули на безпеку навколишнього середовища, повітря, поверхневих і підземних вод, а наявність неочищених стічних вод у річках посилює екологічні ризики. Ризики екологічної безпеки включають викиди забруднюючих речовин, що спричиняють утворення токсичних сполук. Важливим аспектом є вплив на стійкість інженерно-технічних об'єктів, що може призводити до аварій та катастроф. Антропогенні фактори, землетруси та пожежі викликають небезпечні зміни в природному *середовищі, порушуючи інженерно-геотехнічну стійкість основи об'єктів критичної інфраструктури та створюють передумови для аварійних ситуацій. Сучасні системи екологічного моніторингу та обробки інформації значною мірою базуються на системах штучного інтелекту, щоб гарантувати максимальну екологічну безпеку. Однією з головних проблем таких систем є ідентифікація, яку можна вирішити шляхом використання асоціацій і аналогій для відповідного процесу оцінки ризику. Пошук асоціацій повинен здійснюватися за допомогою евристики. Застосування евристичних методів дозволяє оперативно оцінювати масштаби та ступінь ризику загроз для очищення стічних вод та функціонування складних технічних систем. Такий підхід забезпечує ефективне розпізнавання проблем на ранніх етапах їх розвитку та адаптацію до змін зовнішніх факторів, параметрів систем і цілей їх функціонування. Евристики є найбільш ефективними і гнучкими інструментами для формалізації зв'язків між асоціаціями і відносинами. Наведено евристики мінімізації впливу терористичних загроз на очищення води, які слід враховувати при прийнятті рішень в умовах нечіткої та неповної інформації.*

Ключові слова: *ризик, водопідготовка, евристика, асоціації, аналогії.*