national Topical Meeting. – Atlanta, USA: American Nuclear Society, 1994. – Vol. 3. – P. 1640–1644.
9. Flue gas cleaning for incinerators [Text] // Filtration & Separation. – 1996. – Vol. 33, No. 3. – P. 178. doi:10.1016/s0015-1882(96)90781-8
10. Operating experience with filter bags in flue gas cleaning on refuse incinerators // Filtration & Separation. – 1995. – Vol. 32, No. 1. – P. 27–30. doi:10.1016/s0015-1882(97)84007-4

ИЗМЕРЕНИЯ ВЫБРОСОВ ЗОЛЫ УСТАНОВКИ ПО СЖИГАНИЮ РАДИОАКТИВНО ЗАГРЯЗНЕННОЙ ДРЕВЕСИНЫ

Исследована эффективность пылегазоочистного оборудования, установленного в г. Чернобыль (Украина) на инсинераторы радиоактивно загрязненной древесины КВм(а)-2,0. Данная установка включает в себя грубую и тонкую очистку (группа циклонов типа ЦП-15 и группа рукавных фильтров). В результате проведенных экспериментальных исследований подтверждена эффективность работы пылегазоочистного оборудования и достигнуты требования по выбросам инсинераторной установки за концентрацией золы до 4 мг/м^3.

Ключевые слова: выбросы загрязняющих веществ, экологические измерения, инсинератор радиоактивно загрязненной древесины, пылегазоочистное оборудование.

Ivasenko Vitaliy, *PhD, Assistant, Department of Scientific Analytical and Environmental Devices and Systems, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: ivasenko-vitaliy@ukr.net, ORCID: http://orcid.org/0000-0001-8318-7437*

Shvayko Volodymyr, *Department of Scientific Analytical and Environmental Devices and Systems, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: lis.shv.vs@gmail.com, ORCID: http://orcid.org/0000-0002-5048-8601*

Kulik Nadiya, *Department of Scientific Analytical and Environmental Devices and Systems, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: kulik.nadinka1996@gmail.com, ORCID: https://orcid.org/0000-0002-8686-2327*

Havryliuk Vladyslav, *Department of Scientific Analytical and Environmental Devices and Systems, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: h.vladyslav87@gmail.com, ORCID: http://orcid.org/0000-0001-9046-7381*

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Vasiutynska K., Arsirii O., Ivanov O.

DEVELOPMENT OF THE METHOD FOR ASSESSING THE ACTION ZONES OF HAZARDS IN AN EMERGENCY AT A CITY FILLING STATION USING GEOINFORMATION TECHNOLOGY

Проведено аналіз розвитку аварійної ситуації на автозаправній станції (АЗС), розташованої в житловому районі великого міста. Розроблено метод оцінювання зон дії факторів ураження із застосуванням географічної інформаційної технології. Метод включає етапи вибору сценарію розвитку надзвичайної ситуації, обробки первинних даних, розрахунку величин та радіусів зон складових параметрів аварійної ситуації, а також візуалізації зон руйнувань в Quantum GIS для мінімізації ризиків об'єктів «турботи».

Ключові слова: *потенційно небезпечний об'єкт, автозаправна станція, ударна хвиля, геоінформаційна технологія, техногенний ризик.*

1. Introduction

The scientific and technological revolution (STR) during the XX–XXI centuries. caused a rapid development of the industry, the emergence of new industries, which has led to a redistribution of labor resources and the intensification of urbanization throughout the world. The general growth of the population led to the concentration of technogenic objects, including potentially dangerous ones, in metropolitan cities.

The process of forming security systems has become much more complicated through two important circumstances that simultaneously led to the expansion of the zones of the population's defeat:

1) increase in the number and density of population, to enhance its mobility, as well as the increase in the size of urban areas leads to a constant decrease in the distance from the potentially dangerous objects (PDO) in residential development zone;

2) toxic explosion fier hazardous are substances accumulated in the PDOs in such quantities that the consequences of accidents at these sites can be compared with the effects of severe natural disasters (earthquakes, tsunamis or hurricanes).

Maintaining the state of man's technogenic security on the priorities of a person's safe life, a healthy and safe environment is one of the most important tasks of the state. An important element of technological safety of the process is a procedure for assessing emergency risks in PDO, which is enshrined in the Law of Ukraine «On the major hazard», the Cabinet of Ministers of Ukraine «On the identification of and declaring the security of

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heightened danger». These documents are the basis for making informed management decisions.

Due to the increase in the number of cars in Ukraine, primarily in large cities, the number of filling stations has increased, the number of which is about 7000 and is constantly increasing. Significant turnover of petroleum products at filling stations, are highle flammable liquids (HFL), cause increased attention to these objects as sources of high explosive danger. Normative acts regulating the design and construction of filling stations with the provision of fire and explosion standards quickly become obsolete and do not keep pace with the oil products market, is developing dynamically. Particularly disturbing is the tendency to place new filling stations within the urban development, in historical centers of cities with outstanding architectural monuments, and also near places of mass gathering (playgrounds, garden and park areas, pedestrian areas with a significant flow of people). Another negative fact was the aggravation of competition between the filling station networks, which save on technogenic safety measures, use low-quality gasoline, reduce security engineer positions and use unqualified personnel.

So, the filling station is a source of dangers that are inherent in all enterprises with high risks of fires and explosions. Business interests require the placement of such potentially hazardous facilities in densely populated areas of the urban environment. This greatly complicates the consequences of possible emergencies in the operation of stations and increases the level of danger to the public. Zoning of the location of the filling station on the basis of the consequences of the effects of the damaging factors of a possible accident is an actual and timely task of ensuring the environmental safety of the city. The definition of the boundary of danger zones with specific objects, public and residential buildings, etc., is a necessary step in the development of systems for diversification and risk management.

2. The object of research and its technological audit

The object of research is a filling station of the traditional type [1], which is located in a densely populated residential area of Odessa, Ukraine. The filling station provides vehicles with motor fuel and oil. The filling station consists of an operator, underground tanks with fuel, emergency tank, a reservoir for collecting atmospheric precipitation and technological hatches, fuel dispensers.

On the territory of the filling station in the office building there is a store, an express cafe and a toilet. The filling station also includes a car wash and a maintenance station (MS). The schematic diagram of the filling station is shown in Fig. 1.

One of the most problematic places and a specific feature of the filling station is the placement of technological equipment in open areas in the middle of the «sleeping» area of the city. In this arrangement, the combustible and toxic fumes released by the air are dispersed and their concentrations are further reduced to a safe level. Explosions and fires on outdoor installations are possible in emergency situations associated with the formation of explosive concentrations of petroleum vapor in air [2].

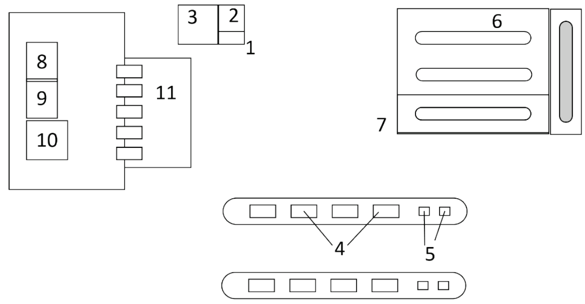

Fig. 1. Schematic diagram of a traditional filling station: 1 – building of the operator; 2 – toilet; 3 – shop and express cafe; 4 – fuel dispensers; 5 – columns for refueling with oil; 6 – underground tanks with fuel; 7 – platform for a tanker; 8 – service station; 9 – washing; 10 – local treatment facilities for cleaning oily wastewater; 11 – platform for fuel drainage with technological hatches and wells of storm sewage; 12 – emergency tank

Emergency situations at the filling station may occur when:

- overfilling of tanks when draining oil products from road tankers;
- disconnection of connecting pipelines between the tank and the tanker;
- overfilling of fuel tanks of cars;
- damage to the fuel dispenser;
- corrosive wear of pipelines and tanks.

The potential danger of the filling station is also conditioned by technological equipment, which has fulfilled its normative service life. The increased fire hazard is inherent in both tanker trucks and cars that can simultaneously be refueled, depends on the number of fueling and oil filling stations (4 for oil, 8 for fuel).

The presence of a large amount of diesel fuel and gasoline in the capacitive equipment of the filling station creates the danger of a fire in the event of fuel leakage and sources of ignition. When a fuel leak in a technological well creates the danger of formation of explosive concentrations of the fuel-air mixture (FAM), which, in the presence of an initiation source, can cause the explosion of this mixture in technological wells and create conditions for further development of the accident in underground storage facilities.

Thus, the causes of fires and explosions at filling stations can be: open fire, sparks, static electricity discharges, lightning discharges, autoignition, spontaneous combustion and pyrophoric deposits. The initial event of the accident at the filling station is a leak of fire and explosive product.

3. The aim and objectives of research

The aim of research is development of a method for assessing the zones of action of damaging factors with the use of geoinformation technology on the basis of an analysis of scenarios for the development of an emergency situation at a filling station (gas station).

To achieve this aim, the following tasks are defined:

1. To analyze the fire hazard factors at the filling stations and possible scenarios for the development of the emergency in the event of an emergency at the site, and in accordance with the selected scenario, to carry out the processing of the primary data necessary for further calculations.

2. According to the chosen scenario of the emergency development on the basis of processed primary data to calculate the affected areas of the dangerous factor arising from the development of the accident.

3. To substantiate the structural components of the geo-information system, which will be used to apply the corresponding zones of damage to the urban development map with a dangerous factor.

4. To carry out a classification of «care» objects that have fallen into the appropriate zone of injury by a dangerous factor.

4. Research of existing solutions of the problem

A characteristic feature of all technical systems is the risk of loss of static reliability, as a result of which there may be emercencies with significant material losses. Already from the end of the 70s of the 20th century, the world has a policy of «acceptable» technology risk, which is the basis of technogenic environmental safety and is aimed at solving environmental problems related to human economic activity and the functioning of the technosphere.

In recent years, significant research has been carried out in the field of methodology for determining technogenic risks for the PDOs. Thus, in [3], the main algorithms for determining the industrial risk of an industrial facility are presented with a comparison of the methods of index and simulation modeling. The methods of constructing «Trees of failures» are studied using the example of water heaters of TPPs plants that allow them to be used for process equipment even in the normal operation mode. The use of environmental risk indices was extended by the authors [4] to assess the ecological security of territorial entities by establishing correlations between the object sources of hazards and the ecosystems of the territories.

In recent years, a significant number of geographic information systems (GIS) have been created for the visualization of crisis situations and scenarios for their development. The embodiment of the GIS-oriented system approach to the reflection and analysis of the pollution state of urbanized territories in the construction of thematic maps is discussed in [5]. The results of using modern GIS-technologies for creating cartographic models of zones of atmospheric, acoustic and soil contamination of territories with the purpose of determining their ecological quality in the example of Khmelnitsky, Ukraine, are also given there.

The study of the problem of formation of hazards and risks in the operation of filling stations, gas stations, oil and gas networks and other enterprises of the oil and gas complex is conducted both in Ukraine and around the world. The analysis shows that the overwhelming majority of studies link the danger of the operation of a filling station with the effects of toxic constituents of fuel on all components of the environment [6–8].

The author of the work [6] based on the assessment of the effects of pollutants on air, groundwater and soil has developed systems for monitoring and managing the quality of the environment. The used method of estimating the ratio of the content of aliphatic and aromatic hydrocarbons in the air of the city and in the zone of influence of filling stations allows to allocate in the city's territory danger bands for the population, schools, hospitals, and other public facilities. Features of gasoline as a liquid fuel contribute to the leakage of highly volatile organic compounds (VOCs). Their distribution in the airspace in the area of the filling station is devoted to work [7]. The conducted studies also determine the atmospheric conditions of ignition of gasoline components formed as a result of the leak of clouds, taking into account the lower and higher fire-resistant boundaries of each compound.

In [8] the emission of pollutants into the air as a source of secondary pollution of groundwater and soil, aren't only considered but also offers measures for managing the quality of the environment. The control of the environmental consequences of the operation of filling stations is proposed for the state of São Paulo, Brazil.

Toxic components of fuel have adverse consequences for human health. The authors [9] investigated the physical, chemical, biological and physiological risk factors in the working environment of workers at the filling station. High risk values were identified, industrial accidents covered 94.1 % of filling station employees, and 74.2 % of the total number of personnel affected by contact with the eyes.

In [10, 11], the risks to the health of the service staff of filling stations were estimated based on the toxicological parameters of the half and 95 % mortality. It is shown that cleaning the aerosol sources reduces health risks, but does not affect the overall risk of cancer and the risk of a decrease in life expectancy due to cancer. In [11], Monte Carlo method simulates health risks in comparison with the overall risk probability. This made it possible to determine the risk of adverse health effects from exposure to toxic aromatic compounds in a service station environment to within 3 % of the total population, which is acceptable. The weighty results of the risk analysis of the security of complex objects are presented in [12]. The authors rightly emphasize the subjectivity of the existing measurement of the safety of oil and gas enterprises. An integrated system was developed in which the most important risk factors, including the reliability of static and dynamic equipment, control problems, are determined based on the failure tree. In order to implement a practical security strategy for a complex technological system, an integrated assessment is applied.

In Ukraine, the issue of ensuring environmental safety of transportation, pumping and storage facilities for oil and oil products has not been adequately studied. The methodology of modeling emergencies at oil and gas transportation facilities has been studied in [13, 14], which gives some examples of the use of GIS technologies for determining risk zones in accidents on trunk pipelines. The authors of [2, 15] described qualitatively the consequences of accidents at the filling station, the problems of ensuring their fire and explosion hazard, concluded that a detailed assessment of the degree of risk from these technogenic objects is necessary.

It is possible to state a wide range of pending issues of minimizing the risks of technological processes for storing oil products and fuel materials in such PDOs as filling stations (gas stations) within urban agglomerations.

5. Methods of research

The methods of risk analysis, the method of visualization and geoinformation modeling were used in the work.

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The analysis of events that can lead to an accident (a breach of the tightness of the technological system) allows them to be divided into 2 main groups: the events of the first group and the events of the second group.

Events of the first group are events that can lead to a violation of the normal technological regime of the filling station, for example:

- painful narcotic state of the employee of the filling station;
- wear of materials, parts of equipment, fasteners, gaskets, stuffing boxes, etc.;
- failure of means of protection against static electricity and secondary manifestations of lightning;
- malfunction of the breathing valve.

Events of the second group are emergency situations of violation of the normal technological regime of the filling station or the condition of the equipment, lead to the fact that the integrity of the technological system can be violated, for example:

- overfilling of tanks, vehicles;
- operation of an unpressurized fuel dispenser pump;
- inclusion in the work of unsealed sections of the pipeline;
- work with the instrument, which sparks, and so on.

Emergency situations can have several stages of development and if certain conditions are combined then they may be suspended, go to the next stage or go to a higher level:

- level «A» – an accident, the development of which does not exceed the limits of the technological block in question;
- level «B» – an accident, the development of which extends beyond the considered technological block, but is limited by the territory of the filling station;
- level «C» – an accident, the development of which goes beyond the limits limited by the territory of the filling station.

Localization of a number of accidents is possible only at the first stages of development. If it is not possible to localize the accident, a chain development takes place – the depressurization of the main equipment and the release of other products, etc., which leads to the domino effect, which is especially dangerous for large quantities of explosive substances at the filling station [15].

As the object of modeling, a specific filling station is selected within a large city, which is chosen as the filling station, which is located in the Odessa (Ukraine) on the Gastello street. The main types of work performed at the filling station: the reception of petroleum products (gasoline A-80, A-93, diesel fuel) storage of petroleum products; refueling of cars. Let's assume that the PDO structure includes a reservoir capacity of 40 m^3 (according to [16], the capacity is the highest possible for a city with a population of more than 200 thousand) and 1 tank capacity of 15 m^3. Characteristics of the PDO location: east of the filling station at a distance of 40 m there is a motorway; west of the filling station at a distance of 20 m there is a car wash, and at a distance of 40 m – a garage cooperative. To the south of the filling station at a distance of 53 m there is a catering establishment – a cafe-bar. To the north of the filling station at a distance of 55 m is a multi-storey house. To the east of the filling station along the motorway at a distance of 70 m there is a gas distribution station. As an emergency, let's consider the local destruction of the reservoir with a subsequent ignition of the leak, which can lead to the emergence of a shock wave.

A shock wave is a section of strong compression of air heated to several million degrees, which propagates at supersonic speed (335 m/s) in all directions from the center of the explosion [17].

The amount of oil products that can spill onto a free surface is assumed by the following assumptions [18]:

- when calculating the values of explosion risk criteria, as calculated, one should choose the most unfavorable version of the accident or the period of normal operation of the apparatus, in which the greatest number of substances and materials, the most dangerous consequences of the explosion, participate in the explosion;
- the entire contents of the device enters the surrounding space (40 and 15 m^3, respectively);
- evaporation occurs from the surface of the spilled liquid. The area of evaporation during a spill on a horizontal surface is determined on the basis of the calculation that 1 liter of mixtures and solutions containing 70 % or less by weight of solvents is dispensed on an area of 0.1 m^2 and other liquids by 0.15 m^2 (1 l by 0.15 m^2);
- duration of the fluid evaporation is assumed equal to 3600 s.

Let's accept meteodata for Odessa, Ukraine, for the month of July (the most unfavorable period): $t = 29$ °C; wind speed 3,0 m/s [19].

6. Researhc results

6.1. Calculation of the sizes of shock wave damage zones during the explosion of a container with petroleum products at a filling station. The calculations are carried out according to the methodology defined in the normative document [18]. The mass of liquid vapor, kg, received in the surrounding space in the presence of several sources of evaporation (surface of spilled liquid, open containers, etc.) is determined by the formula:

$$m = m_l + m_{\text{const}} + m_{oh}, \tag{1}$$

where m_l – the mass of liquid evaporated from the surface of the spill, kg; m_{const} – mass of liquid evaporated from the surfaces of open containers, kg; m_{oh} – mass of liquid evaporated into the surrounding space in case of its overheating, kg.

In this case, each of the components (m_l, m_{const}) in the formula (1) is determined by the equation:

$$m = W \cdot F_e \cdot \tau, \tag{2}$$

where W – evaporation intensity, kg/(c·m^2); F_e – evaporation area, m^2; τ – duration of the intake of HFL vapors into the external environment, s.

The evaporation intensity is determined from reference and experimental data. For HFL, it is not heated above the ambient temperature, in the absence of data it is possible to calculate according to the formula:

$$W = 10^{-6} \cdot \sqrt{M} \cdot P_S, \tag{3}$$

where M – molar mass, g/mol; P_S – saturated vapor pressure at the design liquid temperature, which is calculated from reference data, kPa, or by the formula:

$$P_S = 0.133 \cdot 10^{A - \frac{B}{C+t}}, \quad (4)$$

where A, B, C – Antoine constants (reference data); t – the design liquid temperature, °C.

Proceeding from the considered variant of the accident, the mass, m, kg, combustible gases and (or) vapors that enter the atmosphere from the technological apparatus are determined.

The amount of excess pressure ΔP, kPa, which develops in the case of combustion of gas-vapor-air mixtures, is determined by the formula:

$$\Delta P = P_0 \cdot \left(\frac{0.8 \cdot m_r^{0.33}}{r} + \frac{3 \cdot m_r^{0.66}}{r^2} + \frac{5 \cdot m_r}{r^3} \right), \quad (5)$$

where P_0 – atmospheric pressure, kPa (allowed to be equal to 101 kPa); r – distance from the geometric center of the gas-vapor clouds, m; m_r – reduced mass of gas or steam, kg, is calculated by the formula:

$$m_r = \left(\frac{Q_c}{Q_0} \cdot m \cdot Z \right), \quad (6)$$

where Q_c – the specific heat of combustion of gas or steam, J/kg; Z – coefficient of participation of combustible gases and vapors in combustion, which can be taken equal to 0.1; Q_0 – a constant equal to $4.52 \cdot 10^6$ J/kg; m – mass of combustible gases and (or) vapors, received as a result of an accident in the surrounding space, kg.

Based on the above data, the HFL amount that was released into the atmosphere, as well as the area of the spill to which these petroleum products fall, is calculated. The calculation is carried out for 3 types of fuel, respectively, for a tank (40 m^3) and a tank (15 m^3) (Table 1).

The intensity of evaporation and the amount of vapor of the liquid are also calculated and participates in the explosion. Since the standards use data for A-72 gasoline, they are no longer used for refueling modern vehicles, and the proximity of the composition and properties with gasoline A-80, let's accept the A-72 gasoline parameters for the A-80.

The magnitude of the excess pressure within a radius of 30 m from the source of the accident is determined to be 68.591 kPa for gasoline A-80, 67.796 kPa for gasoline AI-93 and 5.466 kPa for diesel fuel (for tanks with a capacity of 40 m^3). When the tanks are destroyed, these values are respectively 38.551 kPa; 38.148 kPa and 3.740 kPa. As it is possible to see, diesel is the most safe in the explosion.

6.2. The use of geoinformation technologies for determining the level of PDO technogenic safety within an urban area. To visualize the affected areas by hazardous factors, as a result of an emergency at a filling station within the city territory, methods of geoinformation modeling are applied. GIS-technologies have certain advantages – visibility and accessibility of information, which allow to adequately assess the situation and quickly make appropriate management decisions to minimize the consequences of accidents. Let's note that the limits of the application of the GIS method depend on the accuracy of the calculation models used to determine scenarios for development of emergency situations. Let's also note an important feature of the GIS – a multilayered thematic map, allows to combine different indicators within a single map to obtain in-depth information. For example, impose isolines of risk values (individual, collective, public) on the population density map.

Therefore, let's consider it expedient to create an integrated GIS that allows to operate in all PDO areas with a certain areas, choosing and calculating for them any scenario for the development of emergencies or accidents, depending on the specific situation. The architecture of the complex GIS is proposed, which is presented in Fig. 2.

The whole set of information that is entered into the unit for preparing primary data and necessary for predicting the consequences of accidents and disasters can be divided into three groups:

– immanent PDO characteristics, which include, among other things, the properties of potent poisonous substances;
– characteristics of the object location;
– climatic characteristics.

Table 1

The results of calculations of shock wave damage zones from the destruction of tanks (40 m^3) and cisterns (15 m^3) containing flammable substances

Parameter	Gasoline A-80		Gasoline АИ-93		Diesel fuel	
	Tank	Cistern	Tank	Cistern	Tank	Cistern
FAM combustion with a shock wave formation						
HFL mass, which got to the environment m, kg	28880.0	10830.0	30100.0	11287.5	34160.0	12810.0
HFL spill area, m^2	6000	2250	6000	2250	6000	2250
HFL saturated vapor pressure P_s, kPa	3.9714	3.9714	3.9304	3.9304	0.0156	0.0156
HFL evaporation intensity W, kg/s·m^2	$3.915 \cdot 10^{-5}$	$3.915 \cdot 10^{-5}$	$3.895 \cdot 10^{-5}$	$3.895 \cdot 10^{-5}$	$2.219 \cdot 10^{-7}$	$2.219 \cdot 10^{-7}$
Mass of liquid vapor m_l, participates in the explosion, k, kg	845.73	317.15	841.28	315.48	4.79	1.80
Specific combustion heat of HFL vapor, Q_c, kJ/kg	44239	42239	43641	43641	43419	43419
Reduced mass of liquid vapor m_r, kg	827.75	310.41	812.26	304.60	4.60	1.73
The value of the excess pressure ΔP, kPa (radius 30 m)	68.591	38.551	67.796	38.148	5.466	3.740
Radius of the destruction zone r, m:						
full (100 kPa)	24.65	17.81	24.50	17.70	4.41	3.18
strong (50 kPa)	35.70	25.80	35.48	25.64	6.40	4.62
medium (30 kPa)	48.31	34.93	48.01	34.71	8.67	6.27
weak (10 kPa)	102.94	74.45	102.30	73.99	18.53	13.40

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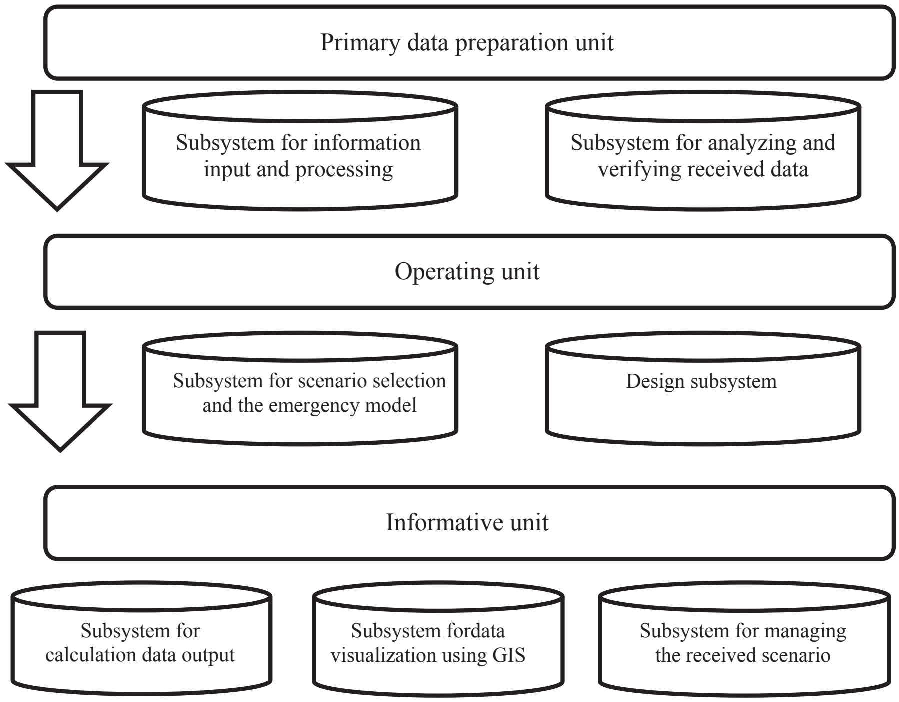

Fig. 2. Diagram of the architecture of the complex geoinformation system for assessing the technogenic safety of a potentially dangerous object

The other part of GIS information (for example, the location of settlements with respect to the considered object) is used at the stage of hazard level analysis, because the magnitude of damage in an accident depends on the mutual arrangement of the risk recipients and the accident site.

It should be noted that all PDOs that are registered in the PDO State Register and are monitored by the State Emergency Service of Ukraine (SES) should be placed on the map, which reduces the time required to search for the facility. The inherent PDO characteristics are taken from the relevant data of the SES bodies, enterprise managers, and other departmental bodies. The climatic characteristics of the atmosphere at the time of the scenario are taken from the data of the Ukrainian Hydrometeorological Center.

After the primary data is entered into the system, a possible scenario of development is selected from the ones proposed by the operating unit. The scenarios that are proposed are considered in accordance with the instructions approved by the departmental authorities and the methods for calculating them. Obviously, a complex GIS can include already processed and algorithmized options that are presently available. For other scenarios, algorithmization and processing on a computer must be carried out with the writing of the corresponding program. The calculated subsystem is a program written on the basis of the algorithm for calculating the model, which in turn has the basis of the approved calculation technique. Obviously, after selecting the scenario for the development of the event, a certain amount of additional information needed for the calculation may be required.

The informative unit provides output of calculated data on the user's request in abbreviated or expanded table forms. Also in this block the user has the opportunity to work with electronic cards, after which specific information (zones of defeat, etc.) has already been reflected after specifying a specific PDO and calculating the scenario.

Developed GoogleMaps are the basis. According to the GIS architecture (Fig. 2), the thematic map will depict PDOs, the zone of action of the damaging factors (shock wave), and an display board. The display board displays general information – a zone of high, medium, low risk; a description of possible threats to a person in each zone, as well as possible destruction of buildings and property. The use of cloud technologies in GIS is provided for the purpose of speeding up the calculations, and also with a view to maximally prompt updating of information.

As a GIS for modeling technogenic risks zones, the Quantum GIS geoinformation system version 2.18.2 is used. It is a high-tech model of visualization with an open information code, it is distributed on the terms of the GNU General Public License. QGIS is the project of the Open Source Geospatial Foundation (OSGeo) [20].

Data on the size of the zones using GIS QGIS 2.18.2 are plotted on the map in order to identify objects that are affected (Fig. 3).

6.3. Classification of «care» objects falling into the shock wave damage zone. If it is possible to initiate and develop an emergency situation at the PDO, it is necessary to classify the «care» objects, which fall into high, medium and low risk zones, in order to make weighted management decisions.

By definition [21], the «care» object is recipients, in which the negative impact of accidents creates a danger to the life of the population and the environment and affects the interests of the public. The main «care» object is a person. It is necessary to determine the threat to a person, for which purpose to allocate residences, enterprises and organizations falling into the zone of destruction. How other «care» objects should be considered:

– socially significant objects;
– elements of the ecosystem;
– property of legal entities and individuals.

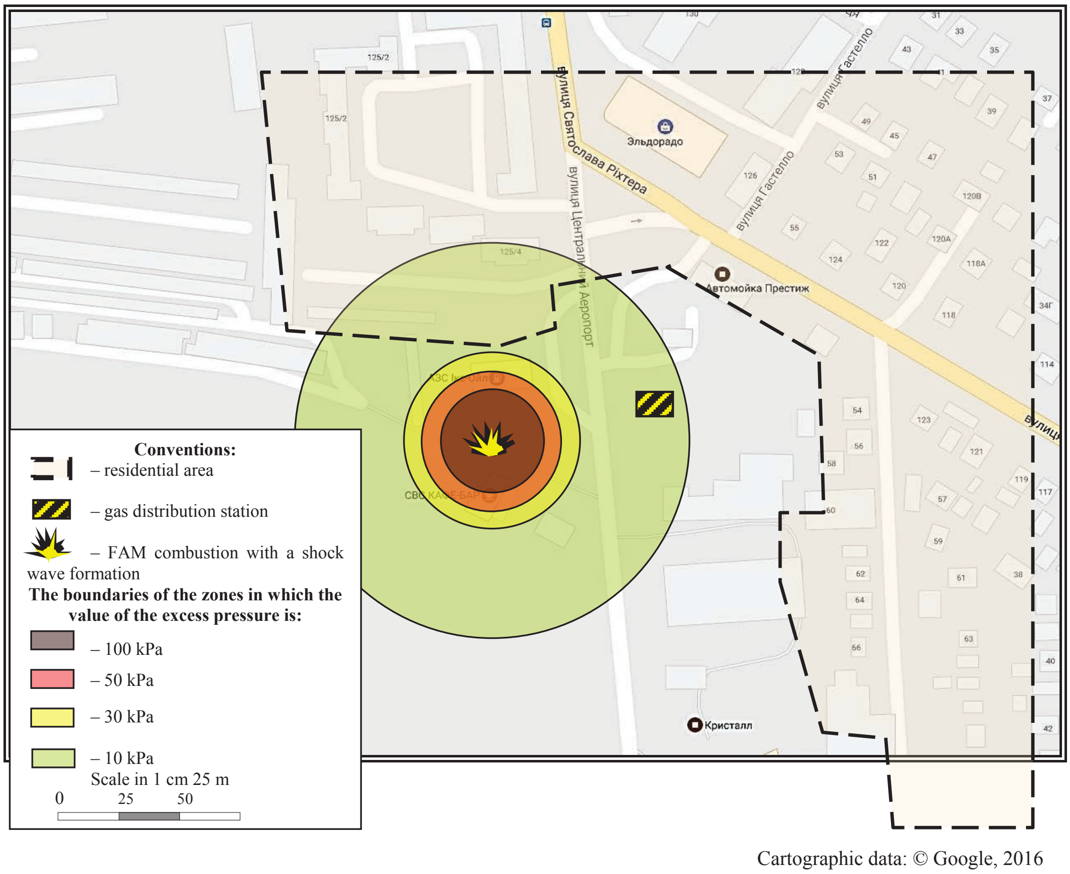

Fig. 3. Visualization of shock wave damage zones at a filling station on the map of Odessa, Ukraine, using Quantum GIS

As socially important objects should be considered:
– places of a large crowd of people (stadiums, cinemas, hospitals, etc.);
– nature protection facilities (reserves, parks, etc.);
– recreation areas (recreational areas);
objects of culture (museums, palaces, monuments of architecture, etc.);
– life support facilities (water treatment stations, power supply facilities, utilities, transport arteries, etc.);
– location of local government, state administration and other bodies of life management.

As elements of the ecosystem, where possible the negative impact of accidents, should be considered: flora and fauna; atmosphere; water environment (rivers, water bodies, sea water) land, including groundwater; other objects of influence.

As property of legal entities and individuals can be considered:
– residential and farm buildings;
– vehicles;
– garden and garden areas;
– buildings, structures and equipment of enterprises;
– property of industrial enterprises, organizations and institutions;
– arable land, livestock and other agricultural objects;
– raw materials and products of production, including crops and crops;
– other movable and immovable property.

In addition, it is necessary to identify other «care» objects falling into the zone of dangerous impact of the accident. Depending on the excess pressure and high-speed air pressure, various injuries occur in humans and animals, which are divided into lungs, medium, severe and very serious injuries according to the complexity of the lesion (Table 2).

Table 2

Characteristics of damage to people and animals, depending on the magnitude of the excess pressure in the front of the shock wave*

The value of excess pressure, kPa	Damage	Damage characteristic
20–40	Light injuries	Dislocation, temporary damage to hearing, concussion
40–60	Average injuries	Contusion, damage to the hearing organs, dislocations of the limbs, bleeding from the nose and ears, ruptured eardrums
60–100	Serious injuries	Heavy contusions, fractures of the limbs (often open), severe bleeding from the nose and ears
>100	Very serious injuries	Fractures of bones, ruptures of internal organs (liver, spleen, kidneys, lungs and others), open fractures of limbs, concussions, fractures of the spine

Note: * is compiled on the basis of data [18].

In order to determine the nature of the damage and determine the amount of rescue and other urgent work, depending on the excess pressure in the front of the shock wave, the lesion is conventionally divided into four zones (Table 3).

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Table 3

Characteristics of the destruction of objects, buildings, depending on the magnitude of the excess pressure in the front of the shock wave*

The value of excess pressure, kPa	Destruction degree	Destruction characteristic
>100	Zone of complete destruction zone	Destruction or severe deformation of all load-bearing structures and structural elements, the formation of solid debris. Underground (basement) parts of structures are much less destroyed. Residential and industrial buildings are completely destroyed. Up to 90 % of underground communal-energy networks remain
50–30	Strong destruction zone	The destruction of multi-storey buildings occurs at an overpressure of 25–30 kPa, low-rise buildings – 25–35 kPa, structures of production type – 30–50 kPa. Most of the load-bearing structures are deformed. Some walls and floors of the lower floors may remain partially. blockages are formed
30–10	Medium damage zone	Most load-bearing structures are preserved, only partially deformed. The main part of the walls with possible cracks in the outer walls and dips in certain places is retained, but minor and part of the supporting structures can be completely destroyed. Arise at an excess pressure of 10–20 kPa for multi-storey buildings, 15–25 kPa – low-rise, 20–30 kPa – production facilities. On the communal-energy network, separate supports of overhead power lines are deformed and destroyed, process pipelines are damaged
20–7	Weak damage zone	The destruction of windows, doors, light partitions, the appearance of cracks, mainly in the walls of the upper floors. Basements and lower floors are preserved. Minor damage and damage to the utility network
5–3	Damage	Violation of the weakest elements of buildings: cornices, partitions, doors, windows, etc. Glazing destruction by 90 % at an overpressure of 5–10 kPa

Note: * is based on the data of [21].

The calculation of the size of hazardous areas in which full (overpressure greater than 100 kPa), strong (100–50 kPa), medium (50–30 kPa) and weak destruction (10 kPa) of objects and buildings are possible, and corresponding injuries occur people (Table 2).

As can be seen from the visualization results (Fig. 3), part of the residential development (in particular, 2 multi-storey houses), the gas distribution station, the public catering establishment get into the medium destruction zone (pressure from 30 to 10 kPa). At the same time, most of the load-bearing structures are partially deformed in apartment houses, cracks appear in the outer walls and ditches in certain places, while minor and some supporting structures can be completely destroyed. The technological pipelines are damaged on the utility network, which can cause a domino effect at the gas distribution station. People who fall into this zone may experience minor injuries (concussion, dislocation of limbs, temporary hearing loss).

It is also worth noting that almost completely from the shock wave, not only the filling station can be affected, but also there is a car wash nearby (20 m), and the garage cooperative experiences strong disruptions. Also, a significant part of the freeway falls under the impact zone of the shock wave, which can cause significant human casualties, when a large number of cars gather at the peak hour near the intersection.

In general, the number of human victims can increase not only at the expense of the personnel of the filling station, but also the personnel of the car wash, residents of buildings, random passers-by on the street.

7. SWOT analysis of research results

Strengths. Thus, the proposed integrated GIS as a result will have the following useful properties:

1) systemic – a combination of the PDO as an object of impact with the subjects of the consequences of emergency situations and recipients of impacts in a system of interrelated elements;

2) integrity – a possibility of the system in the framework of the proposed method to consider not only one development scenario, but their totality, as well as options for their branching and overlapping;

3) visibility (informativeness) – an ability to make weighted, adequate management decisions;

4) efficiency;

5) cross-platform – a possibility of using this GIS on various computing devices due to the use of cloud technologies;

6) openness – ensures publicity and free access of all interested parties.

Using the method of modeling the development of an emergency situation at filling stations within the city of a million people raises the efficiency of the information presentation, allows to adequately predict the development of the environmental situation in the risk management system. This also has a positive effect on the work of the SES bodies in providing technogenic security of the city.

Unlike the analogues described above, a method has been developed that allows to visualize a specific area of the city, which is covered by negative factors of the consequences of the accident. This allows to identify the «care» objects falling into the corresponding risk zones, to classify them according to the levels of damage and to organize appropriate measures to minimize risks in the city's environmental safety management system.

Weaknesses. If the proposed method is used to assess the impact of an accident on an urban filling station, it becomes necessary to develop computational methods for a combination of different scenarios, even those that have not been previously considered. This approach will require the development of additional calculation algorithms, new software products, possibly remote sensing data and modern geoinformation technologies. Therefore, the final product can be more difficult for the staff in the conditions of its practical application, which, on the contrary, will lead to an increase in the processing time of information.

Opportunities. Due to the presence of highly toxic substances at the filling station facilities, the development of various scenarios for both humans and the environment can be catastrophic. Using the same cloud technology allows to simultaneously use the resources of many computers, which will allow in the shortest possible time to provide a reliable forecast of the specific situation and the magnitude of its consequences. Branching of the event tree and taking into account combined scenarios requires the use of intelligent visualization [22].

In order to develop a more informative geoinformation model in the future, it is possible to add layers of data on the state of natural components of the territory of the PDO location. Therefore, it is advisable to involve the results of assessments of the risks of flooding of soils, landslides, karst and increase in the level of groundwater occurrence. Among the technogenic factors, it is necessary to take into account the background condition of atmospheric pollution, groundwater, soil on the basis of monitoring data, as well as data on the traffic intensity of vehicles in the city. The use of such complex information and the creation of appropriate databases will make it possible to assess the level of natural and technogenic safety of the areas where the PDO is located (the filling station in a particular case) in the city in real time.

Threats. The proposed method requires the coverage of specific technological parameters of filling stations, which, above all, carry out commercial activities. The implementation of the method may contradict the business interests of the owners, and require additional financial investments for organizing the security of the events. But the security of the city as a whole urban ecological system, the safety of every inhabitant must be the absolute prerogative in the management systems of any activity.

8. Conclusions

1. The primary data necessary for the analysis of explosive-fire hazard factors and possible scenarios for the development of emergency situations at filling stations are processed. The initial event of the accident at the filling station is the leakage of fire and explosion hazard products (gasoline, diesel, motor oil). Open fire, sparks, static discharges, lightning discharges, spontaneous combustion, spontaneous combustion and pyrophoric deposits can lead to fires and explosions.

2. The selected scenario of the development of the emergency on the basis of processed primary data determines the size of the destruction area that arise as a result of the development of the accident. Shock wave damage zones are calculated in which full (overpressure greater than 100 kPa), strong (100–50 kPa), medium (50–30 kPa) and weak (less than 10 kPa) destruction of objects and buildings are possible, and corresponding injuries occur in people.

3. The proposed architecture of an integrated GIS, which includes the steps of selecting an emergency scenario, processing primary data, calculating the values and radii of the zones of the component parameters of the emergency situation, and visualizing the destruction zones. GIS is used to apply three famage zones by a shock wave factor to a map of urban development and further analysis of scenarios for the development of an accident at a filling station.

4. The «care» objects that fall into the corresponding risk zones, including 2 multi-storey houses, a gas distribution station, a cafe-bar, a garage cooperative, a significant part of the motorway are identified. Classification of «care» objects that fall into high, medium and low risk zones, depending on the excess pressure in the front of the shock wave, is carried out. Diversification of risks is the basis for determining the nature of destruction and establishing the scope of rescue operations and other measures to minimize the consequences of accidents.

References

1. Jelnovach, A. N. Analiz ekologicheskih vozdeistvii i riskov pri ekspluatatsii avtozapravochnyh stantsii [Text] / A. N. Jelnovach, N. V. Prokopenko // Vestnik HNADU. – 2014. – Vol. 67. – P. 78–88.
2. Radchenko, Yu. S. Otsenka posledstvii avarii na avtozapravochnyh stantsiiah [Text] / Yu. S. Radchenko // Trudy BGTU. Ser. 4, Himiia, tehnologiia organicheskih veshchestv i biotehnologiia. – 2008. – Vol. 4. – P. 125–129.
3. Boyko, T. Calculation and analysis of predictable technological risk value of industrial objects in stationary operating conditions [Text] / T. Boyko, P. Vavulin // Eastern-European Journal of Enterprise Technologies. – 2014. – Vol. 5, No. 10 (71). – P. 42–46. doi:10.15587/1729-4061.2014.27981
4. Boyko, T. Using the assessment method of environmental risk of a project in strategic territorial planning [Text] / T. Boyko, I. Dzhygyrey, A. Abramova // Eastern-European Journal of Enterprise Technologies. – 2017. – Vol. 3, No. 10 (87). – P. 10–17. doi:10.15587/1729-4061.2017.101848
5. Popov, V. M. Informatsiina tekhnolohiia pidvyshchennia tekhnohennoi bezpeky rehionu [Text] / V. M. Popov, I. A. Chub, M. V. Novozhylova // Systemy obrobky informatsii. – 2015. – Vol. 12 (137). – P. 181–184.
6. Morales Terres, I. M. Assessing the impact of petrol stations on their immediate surroundings [Text] / I. M. Morales Terres, M. D. Minarro, E. G. Ferradas, A. B. Caracena, J. B. Rico // Journal of Environmental Management. – 2010. – Vol. 91, No. 12. – P. 2754–2762. doi:10.1016/j.jenvman.2010.08.009
7. Kountouriotis, A. Numerical investigation of VOC levels in the area of petrol stations [Text] / A. Kountouriotis, P. G. Aleiferis, A. G. Charalambides // Science of The Total Environment. – 2014. – Vol. 470–471. – P. 1205–1224. doi:10.1016/j.scitotenv.2013.10.064
8. De Sousa, T. B. Environmental Impacts Management of a Brazilian Gas station: A Case Study [Text] / T. B. De Sousa // Global Journal of Researches in Engineering: G Industrial Engineering. – 2015. – Vol. 15, No. 3, Version 1.0. – P. 22–32. – Available at: \www/URL: https://globaljournals.org/GJRE_Volume15/4-Environmental-Impacts-Management.pdf
9. Cezar-Vaz, M. R. Risk Perception and Occupational Accidents: A Study of Gas Station Workers in Southern Brazil [Text] / M. R. Cezar-Vaz, L. P. Rocha, C. A. Bonow, M. R. S. da Silva, J. C. Vaz, L. S. Cardoso // International Journal of Environmental Research and Public Health. – 2012. – Vol. 9, No. 12. – P. 2362–2377. doi:10.3390/ijerph9072362
10. Edokpolo, B. Health Risk Assessment of Ambient Air Concentrations of Benzene, Toluene and Xylene (BTX) in Service Station Environments [Text] / B. Edokpolo, Q. Yu, D. Connell // International Journal of Environmental Research and Public Health. – 2014. – Vol. 11, No. 6. – P. 6354–6374. doi:10.3390/ijerph110606354
11. Edokpolo, B. Health risk characterization for exposure to benzene in service stations and petroleum refineries environments using human adverse response data [Text] / B. Edokpolo, Q. J. Yu, D. Connell // Toxicology Reports. – 2015. – Vol. 2. – P. 917–927. doi:10.1016/j.toxrep.2015.06.004
12. Zhang, L. An integrated framework of safety performance evaluation for oil and gas production plants: Application to a petroleum transportation station [Text] / L. Zhang, J. Kang, J. Zhang, J. Gao // Journal of Loss Prevention in the Process Industries. – 2016. – Vol. 43. – P. 292–301. doi:10.1016/j.jlp.2016.05.029
13. Verchenov, O. D. Modeliuvannia tekhnohennoho ryzyku dlia nebezpechnykh vyrobnychykh obiektiv hazotransportnykh pidpryiemstv z vykorystanniam HIS tekhnolohii [Text] / O. D. Verchenov, A. A. Verlan, S. V. Volkodav, A. H. Mikhailenko, A. S. Markov, A. V. Yanchuk // Vcheni zapysky Tavriiskoho natsionalnoho universytetu imeni V. I. Vernadskoho. Seriia: Heohrafiia. – 2012. – Vol. 25, No. 1 (64). – P. 14–27.
14. Struchkova, G. P. Ispol'zovanie GIS dlia otsenki riska bezopasnosti truboprovodov [Text] / G. P. Struchkova, T. A. Kapitonova, L. E. Tarskaia, P. V. Efremov // Fundamental'nye issledovaniia. – 2014. – No. 5–5. – P. 994–999.

ISSN 2226-3780

15. Mykhailiuk, O. P. Problemy zabezpechennia pozhezhovybukhobezpeky avtozapravnykh stantsii [Text] / O. P. Mykhailiuk, S. Ya. Kravtsiv // Problemy pozharnoi bezopasnosti. – 2012. – Vol. 32. – P. 149–154.
16. DBN 360-92** Mistobuduvannia. Planuvannia i zabudova miskykh i silskykh poselen [Text]: Order of the State Committee for Construction of April 17, 1992 No. 44. – Introduced: 2017-07-01. – Kyiv: Minrehionbud Ukrainy, 2002. – 6 p.
17. Stebliuk, M. I. Tsyvilna oborona [Text]: Handbook / M. I. Stebliuk. – Kyiv: Znannia, 2006. – 487 p.
18. NAPB B.03.002-2007. Normy vyznachennia katehorii prymishchen, budynkiv ta zovnishnikh ustanovok za vybukhopozhezhnoiu ta pozhezhnoiu nebezpekoiu [Electronic resource]: Order of the Ministry of Ukraine on Emergencies and Affairs of Population Protection from the Consequences of the Chernobyl Disaster from December 3, 2007, No. 833. – Kyiv, 2007. – Available at: \www/URL: https://dnaop.com/html/32980/doc-НАПБ_Б.03.002-2007
19. DSTU-N B V.1.1-27:2010. Budivelna klimatolohiia. Zakhyst vid nebezpechnykh heolohichnykh protsesiv, shkidlyvykh ekspluatatsiinykh vplyviv, vid pozhezhi [Text]. – Introduced: 2011-11-01. – Kyiv: Ukrarkhbudinform, 2011. – 123 p.
20. QGIS – providna vilna nastilna HIS [Electronic resource]. – Available at: \www/URL: http://www.qgis.org/uk/site/about/index.html
21. Pro zatverdzhennia Metodyky vyznachennia ryzykiv ta yikh pryiniatnykh rivniv dlia deklaruvannia bezpeky obiektiv pidvyshchenoi nebezpeky [Electronic resource]: Order of the Ministry of Labor and Social Policy of Ukraine from December 4, 2002 No. 637 // Informatsionnyi portal Ukrainy. – 2017. – Available at: \www/URL: http://ua-info.biz/legal/basene/ua-cmelgt/index.htm
22. Arsirii, O. Developing of hydro-aerodynamic systems' elements based on intellectual visualization [Text] / O. Arsirii // Eastern-European Journal of Enterprise Technologies. – 2013. – Vol. 3, No. 8 (63). – P. 4–8. – Available at: \www/URL: http://journals.uran.ua/eejet/article/view/14826/12628

РАЗРАБОТКА МЕТОДА ОЦЕНИВАНИЯ ЗОН ДЕЙСТВИЯ ОПАСНЫХ ФАКТОРОВ АВАРИИ НА ГОРОДСКОЙ АВТОЗАПРАВОЧНОЙ СТАНЦИИ С ИСПОЛЬЗОВАНИЕМ ГЕОИНФОРМАЦИОННОЙ ТЕХНОЛОГИИ

Проведен анализ развития аварийной ситуации на автозаправочной станции (АЗС), расположенной в жилом районе большого города. Разработан метод оценки зон действия поражающих факторов с применением геоинформационной технологии. Метод включает этапы выбора сценария развития чрезвычайной ситуации, обработки первичных данных, расчета величин и радиусов зон составляющих параметров аварийной ситуации, а также визуализации зон разрушений в Quantum GIS для минимизации рисков объектов «заботы».

Ключевые слова: потенциально опасный объект, автозаправочная станция, ударная волна, геоинформационная технология, техногенный риск.

Vasiutynska Kateryna, *PhD, Associate Professor, Department of Applied Ecology and Hydrogasdynamics, Odessa National Polytechnic University, Ukraine, e-mail: ekaterina.vasutinskaya@gmail.com, ORCID: https://orcid.org/0000-0001-9800-1033*

Arsirii Olena, *Doctor of Technical Sciences, Professor, Head of the Department of Information Systems, Odessa National Polytechnic University, Ukraine, e-mail: e.arsiriy@gmail.com, ORCID: https://orcid.org/0000-0001-8130-9613*

Ivanov Oleksii, *Postgraduate Student, Department of Information Systems, Odessa National Polytechnic University, Ukraine, e-mail: lesha.ivanoff@gmail.com, ORCID: https://orcid.org/0000-0002-8620-974X*