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RISK ZONES FROM THE FILLING STATIONS MODELLING WITH APPLICATION OF GEOINFORMATION TECHNOLOGY

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ABSTRACT

In this paper the questions of technogenic safety of the city Odesa with a population of over 1 million are considered on the example of the analysis of an emergency situation that may arise at filling stations (FS) of the city. The fire safety of the FSs network becomes very important in the context of urban buildings and traffic flows compaction, a significant increase in the number of cars, as well as in the construction of new potentially hazardous objects (PHO) within the urban territory. To solve the problem of analysis of the risk zones of FSs, a conceptual digital model of a FS was created, a numerical simulation of the scenario of an unfavourable situation development at the FS was carried out according to the approved state methodology (an explosion of a vapour-air fuel mixture with a shock wave formation), as well as the obtained zones were visualized on a map of the city of Odessa using the geographic information system QGIS. The digital model of the FS was created taking into account the requirements for the presentation of attributive and spatial data of the relevant GIS. The components of the developed conceptual model are: universal digital identifier, spatial data in the form of type and coordinates of the object, attributive data, which consist of static and dynamic features, as well as numerical models of emergency situation development. During the visualizing of the obtained calculated data by means of GIS, OSM Place Search, QuickOSM and Multi Ring Buffer plugins were used, as well as data from the OpenStreetMap server. The presented results of modelling and visualization indicate that, when the most unfavourable development scenarios are realized, the nature of accidents at FS can go beyond the local scale and move to the borders of the residential zone, as well as to nearby industrial buildings and FSs, which in turn can cause unfavourable situations on them by the domino effect. In addition, the results of the analysis of the obtained heterogeneous modelling and visualization data to determine technogenic risk indicates the possibility of applying the studied principles to other PHOs and also allows to present the data in a visual and accessible form for decision-makers.

Keywords: Geographic information systems GIS; data visualization; risk; filling stations; geospatial data

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INTRODUCTION. PROBLEM STATEMENT

One of the important tasks nowadays is to ensure an acceptable level of safety of human life, which includes many aspects, including technogenic and environmental safety. This aspect is gaining significant importance in large cities with dense urban development with a population of over 1 million people. The number of these cities in the world is constantly growing due to the achievements of the scientific and technological revolution, as well as a high level of urbanization. Large crowds of people on relatively small areas of the surface cause the competent authorities to pay more attention to the task of ensuring their safety.

One of the aspects of the city's security is its technogenic safety, namely ensuring the normal work of enterprises that are potentially hazardous objects. Particularly, according to [1] in 2020, 116 emergency situations (ES) were recorded in Ukraine, of which 47 were technogenic, and the sum of material damage from ESs amounted to UAH 9,916,677,000. The level of natural and technogenic ESs risks and the level of losses from them remain practically unchanged and quite high for most regions of Ukraine, which is confirmed by the record sum of damages caused by ESs in 2020.

According to the law [2], a potentially hazardous object should be understood as an object on which dangerous substances, biological preparations, as well as other objects that under certain circumstances may create the real threat of an accident can be used or manufactured, processed, stored or transported. Within the city, such objects may be filling stations, oil depots, warehouses of chemicals and other hazardous substances, industrial refrigeration plants, pipelines etc. This paper focuses on filling stations due to the growth of their network through the increase in the number of cars in large cities; an appearance of a tendency to place filling stations within dense urban development, in historic centres of cities, as well as near crowded places (playgrounds, pedestrian areas with a significant flow of people, as well as garden and park areas). We also consider it rational to study the compliance of the FSs network location with the norms of fire safety and impact on nearby buildings.

Risk zones from the FSs modelling and visualization is carried out using today's spread geographic information systems and technologies. The use of GIS allows the visualization of various origins geospatial data and illustrates the process of situation monitoring and decision-making. Particularly, the use of geographic information systems for monitoring agricultural lands, the state of green areas, creating thematic maps, studying the impact of technogenic objects on the environment, earthquakes and other natural ESs etc. was quite successful. However, the task of technogenic risk assessment and visualization in a simple form for decision-makers still remains relevant, considering complexity, heterogeneity and uncertainty of data for their graphical representation, including for FSs. Intelligent analysis of weakly structured, heterogeneous data with the help of information technology in order to increase the speed of decision support processes by officials still remains an urgent task [3-4]. The authors think it is expedient to model the ES development at the filling station (the paper considers the occurrence of a shock wave due to the explosion of fuel-air mixture (FAM) due to evaporation of petroleum products) using tools of geographic information system to visualize its dynamics, which will allow to study the impact a probable ES at a PHO on the environment and objects of "care" of society (people, enterprises and organizations etc.) and assess the probable risks. Therefore, the development of a digital model of a filling station as a typical PHO becomes relevant, followed by numerical modelling of ES development scenarios on it and visualization of the results of quantitative assessment using a geographic information system.

LITERATURE OVERVIEW

In [5], the authors developed and implemented a tool for urban regional risk assessment, based on GIS geoprocessing. Geoprocessing workflow models were built for severity calculation, vulnerability evaluation and risk mapping respectively. These models were integrated into an automatic GIS tool and applied in a typical urban district of north China. The successfully obtained risk map can be used as a tool for decision-making in emergency management and urban planning.

Researchers have used GIS as a decision-making tool in designing a network of new filling stations in [6]. They used the method of multi-criteria analysis to analyse the criteria for the location of the filling station site. The collected data were analysed using descriptive statistics (frequency distribution, histograms, pie charts and percentage ratios), which allowed to create a map of the distribution of filling stations in the area using GIS, which facilitates the task of management decisions.

The concept of three-dimensional risk management (3DRM) on the example of a hydrogen gas station is presented in [7]. The 3DRM structure includes a detailed site-specific 3D model, a fluid dynamics calculation tool for simulating accident scenarios, a frequency analysis and risk quantification methodology, and visualization techniques. It is proposed to expand the analysis to include personnel risk for a given population density and set of risk factors.

The work of researchers is devoted to the risk research methodologies for the terminal where the fuel is stored, using the methods of HAZOP (HAZard and OPerability analysis) and the fault tree analysis FTA [8]. Quantitative risk assessment shows that the most dangerous event is a fuel spill, and the human factor plays an important role in all possible accidents, which leads to the need for training of plant personnel.

With the help of the TOXI+Risk software package, modelling of emergency situations related to the depressurization of a tanker at a gas station in Svirsk was performed in [9]. The reasons of the emergency situation were analysed, and the "fault tree" and the "event tree" were compiled on the basis of the logical-probabilistic approach. The events of the oil spill fire, as well as the explosion of the fuel-air mixture were simulated and situational accident plans and risk fields for a specific gas station were developed with the help of a software package. The developed fields of potential risks indicate that in the event of an accident, the zones of damage factors spread only on the territory of the gas station [9].

The study [10] is devoted to the creation of an evacuation plan for accidents involving the release of hazardous chemicals using risk analysis methods based on GIS tools. In such accidents, evacuation plans should be selective enough to take into account the concentration of nearby buildings and the time to reach maximum concentrations of unsafe chemicals. The proposed simulation modules integrated into GIS were used to assess the situation of chlorine leakage from an industrial plant near the city of Ulsan.

The authors of [11] dealt with practical issues of forest fire management using a platform based on GIS. This platform uses real-time data from tracking devices and fire means cameras (cars, planes etc.), automatic weather stations and weather maps to cover the real situation. The system also provides a geographical representation of the probability of ignition and daily identifies high-risk areas in different regions based on a pilot high-performance computing application running on Windows HPC Server.

In the article [12] the authors considered in detail the use of heat maps as a method of visualization using GIS. The results of the work are a general set of recommendations for setting heat maps, data presentation in specific cases. The heat maps were used to study data on road accidents in Olomouc, Czech Republic.

The article [13] is devoted to the general issue of the role of geographic information systems and technologies in decision-making processes in the management of corporate facilities with territorially distributed resources. Web-services providing GIS were considered, their possibilities and spheres of use were described.

To the problems of creation of applied geoinformation systems for the decision of various problems on the basis of existing universal GIS and problems of increase of efficiency of decision support in applied GIS at the expense of creation of corresponding methods, models and information technologies is devoted the work [14].

Consideration of the use of GIS in air quality management tasks is given in [15]. 4 classes of tasks regarded to air quality management systems are considered, and also possibilities of GIS which can be used for the decision of these tasks are analysed. The structure of the DSS-GIS decision support system in air quality management tasks is considered, as well as the data flows in these information systems. An analysis of examples of information systems for air quality management from various sources was also presented.

In [16], information technology and the concept of a web service and a mobile application were proposed to assess the complex environmental risk from time and space distributed risk factors. The main difference between the proposed information technologies from existing analogues is the methods of processing data on hazards from open web resources and the ability to assess environmental risk comprehensively.

In [17] the integration possibilities of specialized GIS of ecological monitoring of the city of Kyiv, its structural model in connection with GPS-modelling of electronic maps were considered. Methods of formation of spatial databases of natural-technogenic territories of the city and practice of their application are investigated. A series of maps of the natural-technogenic environment of the city of Kyiv was created using the capabilities of various applications (MapInfo, Surfer, Illustrator etc.).

THE AIM AND OBJECTIVES OF THE RESEARCH

The aim of the study is to model the selected scenario of emergency situation development at a potentially hazardous object (as which the filling station was chosen by the authors), followed by visualization of technogenic risk zones by means of geographic information system.

To achieve this aim it is proposed to solve the following tasks:

1) a creation of a digital model of FS, taking into account for further use in GIS;

2) a numerical modelling conducting to obtain the size of risk zones in the more common scenario of ES development at FS, namely the outbreak and explosion of FAM due to spill of petroleum products from the tank with the formation of a shock wave;

3) a visualization of obtained risk areas with the use of GIS software to assess the state of PHO technogenic safety.

The object of the study is the determination of the risk zones in the event of an ES at the FS.

The subject of the research are models, methods and geoinformation technologies of modelling and visualization of risk zones in the event of an ES at the FS.

MAIN PART.
DIGITAL MODEL OF THE FILLING STATION

A filling station is a complex of buildings, structures, technical equipment intended for receiving, storing motor fuel and refuelling vehicles. A filling complex also includes premises for servicing drivers and passengers (retail), vehicles (service centres, car washes), as well as retail trade in spare parts, lubricants etc.

During the developing a digital model of a FS it is necessary to take into account the following components for further modelling and visualization of risk zones by GIS:

1) an attributive component of the digital model of the FS must contain a set of data for further numerical modelling of the ES development at the FS according to the methods approved by law;

2) a spatial component of the digital model of the FS must be presented in accordance with the requirements of the relevant GIS;

3) a dynamic component of the digital model of the FS should take into account the features of the scenario of ES development on the basis of attributive and spatial information, as well as the

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selected model of ES development on the basis of appropriate calculation methods.

On the other hand, for further use in QGIS in the digital model of the FS, it is necessary to provide three components that create a complete digital description of the spatial object:

1) the universal digital identifier of the object ID, which is an universal numerical sequence assigned to each object;

2) the spatial data, which include the type of object (polygon, point, segment etc.) and the corresponding coordinate reference of the object;

3) the attributive data, i.e. the set of characteristics and properties of the object with their values (non-spatial data or non-positional part of this data).

The interconnection scheme of components of the developed conceptual digital model of the FS is shown in Fig. 1.

The following are offered as attributive characteristics of the studied object (their list is not exhaustive and can be increased according to the needs of modelling):

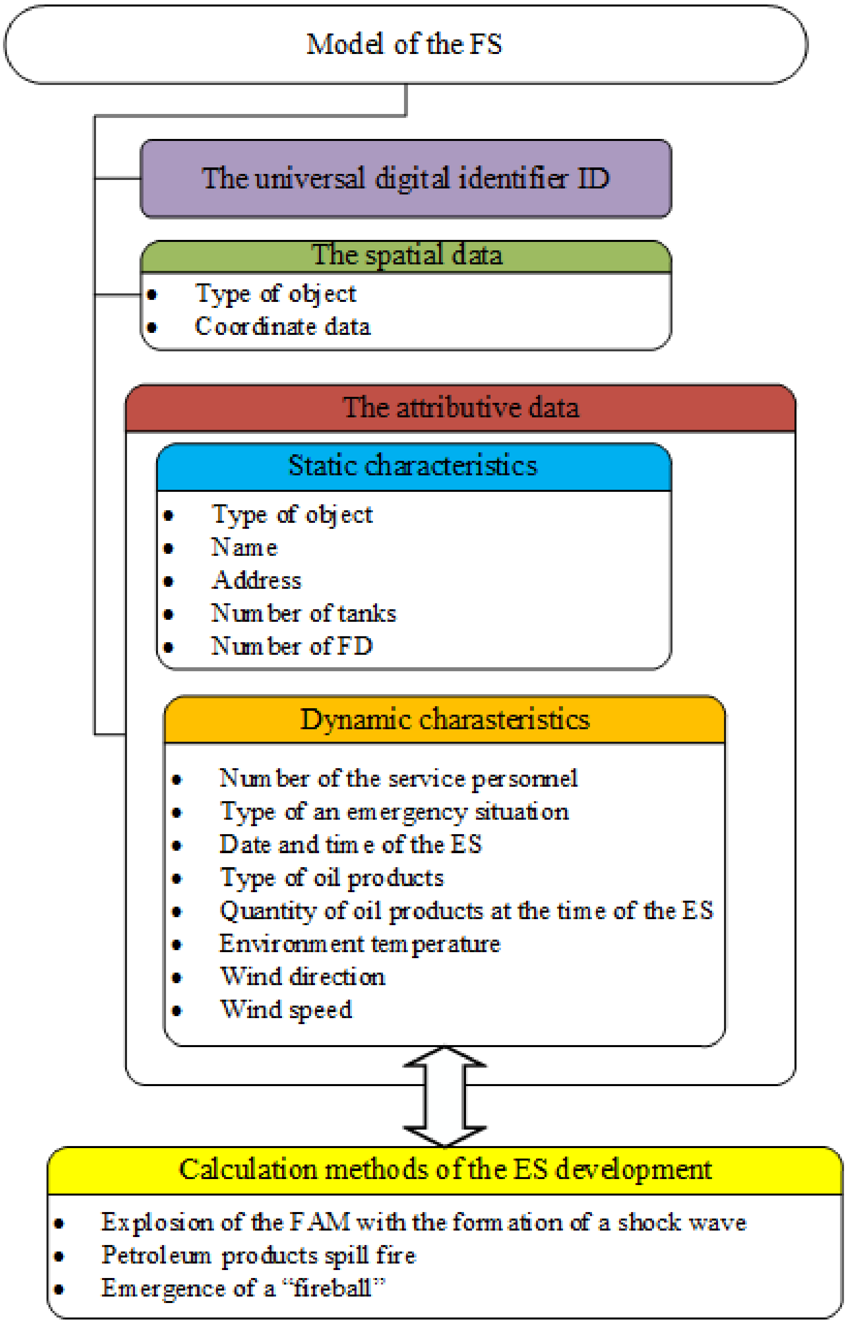

Fig. 1. **Diagram of interconnection of components of conceptual digital model of the FS**
Source: **compiled by the author**

– type of object (filling station);

– name (name of the owner);

– address (legal address);

– the number of tanks indicating their type (ground, underground);

– number of fuel dispensers (FD);

– number of the service personnel, people;

– type of an emergency situation (scenario of unfavourable event selected for modelling);

– date and time of the ES;

– type of oil products (indicating in which of the tanks they are stored);

– quantity of oil products (indicating their quantity at the time of the ES in specific tanks);

– environment temperature, °C;

– wind direction;

– wind speed, m/s.

On the other hand, it is a set of attributive data used in the numerical simulation of adverse situations at the FSs and therefore the number of characteristics depends on the approved calculation method, which is used to simulate ES. We propose to divide these data into static (little or unchanged in relatively long time intervals) and dynamic characteristics (parameters for which a specific value is currently important for the simulation of the ES). The static and dynamic characteristics are divided in Fig. 1.

In the future, we use dynamic characteristics to conduct numerical modelling of the development of an unfavourable situation.

NUMERICAL SIMULATION OF THE ES DEVELOPMENT

The main technological stages at the FSs are [18]:

– stage of acceptance of oil products from fuel tankers into underground or aboveground tanks;

– stage of storage of oil products in tanks;

– stage of refuelling of motor vehicles through the FDs with oil products from underground or ground tanks.

Emergency situations at FSs can occur [19]:

– when tanks overflow during the discharge of petroleum products from tankers;

– disconnection of connecting pipelines between the tank and the tanker;

– overfilling of fuel tanks of cars;

– damage to the FDs;

– corrosion wear of pipelines and tanks.

The causes of fires and explosions at FSs can be: open flames, sparks, static discharges, lightning discharges, spontaneous combustion and pyrophoric deposits. The initial event of the accident at the FS is a spill of flammable product.

The presence of a large amount of diesel fuel and gasoline in the tank equipment of the FSs creates a risk of fire in the event of a fuel spill and the presence of an ignition source. When fuel spills into technological wells there is a danger of formation of explosive concentrations of fuel-air mixture, which in the presence of a source of explosion initiation can cause the explosion of this mixture in technological wells and create conditions for further development of the accident in underground storages [19].

The main impact factors in an explosion are:

– shock wave;

– fragments of destroyed equipment, collapse of buildings and structures.

The shock wave is a region of strong compression of air, heated to several million degrees, spreading at supersonic speeds (335 m/s) in all directions from the centre of the explosion [20].

The shock wave causes damage as a result of excessive pressure, high-speed air thrust; it instantly covers a person from all sides.

Depending on the excess pressure and high-speed air thrust, various injuries occur to humans and animals, which according to the lesion severity are divided into light (excessive pressure 20-40 kPa), medium (40-60 kPa), severe (60-100 kPa) and very severe (>100 kPa) injuries.

In order to determine the nature of the destruction and to establish the scope of rescue and other emergency works depending on the excessive pressure in the front of the shock wave, the lesion focus is conventionally divided into four zones:

– zone of complete destructions (value of excess pressure >100 kPa);

– zone of strong destructions (50-30 kPa);

– zone of average destructions (30-10 kPa);

– zone of weak destructions (20-7 kPa).

Damages to buildings occur at an excessive pressure of 3-5 kPa (according to [20]).

We have chosen a FSs network in Odessa as objects of modelling. The approved normative methodology used for modelling is the Methods for calculating the values of the criteria for explosion and fire hazard of outdoor plants (paragraph 10 [21]). As a calculation option, you should choose the most unfavourable version of the accident or the period of normal operation of the devices, in which the explosion and/or fire involves the largest number of substances and/or materials, which are most dangerous to the consequences of such an explosion and/or fire, contained in one device (plant).

The amount of substances that have entered the environment and may form explosive gas and vapour mixtures is determined under the following conditions (paragraph 10.1.1.2 [21]):

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– all contents of the device get to the environment (further under the device we will consider tanks with oil products);

– there is a simultaneous spill of substances from the pipelines that supply the device in direct and reverse flows, during the period of time required to block the pipelines;

– evaporation occurs from the surface of the spilled liquid; the evaporation area in the case of spillage on a horizontal surface is determined (in the absence of reference or experimental data), based on the calculation that 1 litre of flammable liquids is spilled on an area of 0.15 m^2;

– the duration of the liquid evaporation is taken to be equal to the time of its complete evaporation, but not more than 3600 s.

The value of the calculated excess pressure ΔP in kilopascals, which develops in the case of ignition of gas and steam-air mixtures, is determined by the equation:

$$\Delta P = P_0 \cdot \left(0{,}8 m_{rd}^{0{,}33} / r + 3 m_{rd}^{0{,}66} / r^2 + 5 m_{rd} / r^3\right), \quad (1)$$

where: P_0 – the atmospheric pressure, kPa (allowed to be taken as equal to 101.3 kPa);

r – the distance from the geometric centre of the outdoor plant to the boundary of the calculation zone, m.

The reduced mass of combustible gases (CG) and/or vapours of flammable (FL) and combustible liquids (CL) m_{rd} in kilograms is calculated by the equation:

$$m_{rd} = \left(Q_{ht} / Q_0\right) \cdot m \cdot Z \quad , \qquad (2)$$

where: Q_{ht} – the heating value of CG and/or vapours of FL and CL, J·kg^{-1};

Z – the coefficient of participation of CG and/or vapours of FL and CL in combustion, which is allowed to take 0.1;

Q_0 – a constant equal to 4.52·10^6 J·kg^{-1};

m – the mass of CG and/or vapours of FL and CL, which entered the environment as a result of the calculated accident, kg.

The mass of vapours of liquid m, kg, entering the environment, is determined by the equation:

$$m = W \cdot F_e \cdot \tau_e \quad , \qquad (3)$$

where: W – the evaporation intensity, kg·s^{-1}·m^{-2};

F_e – the evaporation area, m^2;

τ_e – duration of FL and CL evaporation to the environment, s.

The evaporation intensity W is determined from reference or experimental data. For FL that are not heated above environment temperature, in the absence of such data, it is allowed to calculate W by the equation:

$$W = 10^{-6} \cdot \sqrt{M} \cdot P_V \quad , \qquad (4)$$

where: M – the molar mass, kg·kmol^{-1};

P_V – the vapour pressure, kPa, at the calculated temperature of the liquid, determined by reference data or by the equation:

$$P_V = 10^{\left(A - \frac{B}{C_a + t_{lq}}\right)} \quad , \qquad (5)$$

where: A, B, C_a – Antoine constants (reference data) are determined when the vapour pressure is measured in kPa;

t_{lq} – liquid temperature, °C.

Calculations according to equations (1)-(5) are carried out according to the approved methodology (paragraph 10.1 [21]). The values of molar mass, Antoine constants and heating value of CG and/or vapours of FL and CL are determined in accordance with the Table 2 of Annex 1 in [22].

Meteorological data are accepted according to the data for the city of Odessa for the month of July (the most unfavourable period): t = 29°C, wind speed 0 m/s according to the data [23].

For modelling, we selected the quantities of oil products in tanks in the amounts of 15 and 40 m^3 (the most possible tank capacity in the central densely built districts of cities with a population of 250 thousand people and more in accordance with the Table 10.9 of the standard [24]).

The results of numerical simulation are shown in the Table 1.

Fig. 2 shows a graph of the dependence of the excess pressure value in the shock wave front as a function of the distance from the explosion epicentre for both types of fuel for tank capacities of 15 and 40 m^3. As can be seen from the results of the numerical simulation, the safest type of fuel is diesel fuel, the most dangerous – gasoline.

If the shock wave during its spread encounters obstacles in its path, it interacts with the obstacle. This is manifested in shock wave reflection from the obstacle or flow around it, but due to the complex physics of the process and the absence of approved calculation methods in [21-22] this issue was not considered in this study.

RISK ZONES VISUALIZATION USING GIS TOOLS

To visualize the consequences of accidents at filling stations, which were obtained during numerical simulation, we used a free GIS called *QGIS* [25]. We obtained the spatial location of the FSs from open sources, in our case such a source is *OpenStreetMap* [26] – a non-profit web-map project to create a detailed free map of the world by the community of Internet users.

Table 1. **Results of risk zones numerical simulation from the impact of the shock wave during the destruction of tanks containing FL and CL at FSs**

Calculating parameter	Gasoline АИ-93 (summer)		Diesel fuel "S"	
FL and CL amount in a tank, m^3	40	15	40	15
Mass of FL and CL, which entered the environment *m*, kg	29376	11016	32880	12330
Evaporation area of FL and CL F_e, m^2	6000	2250	6000	2250
Vapour pressure of FL and CL P_V, kPa	29,5515	29,5515	0,1169	0,1169
Evaporation intensity of FL and CL *W*, kg/s·m^2	$2{,}928\cdot10^{-4}$	$2{,}928\cdot10^{-4}$	$1{,}668\cdot10^{-6}$	$1{,}668\cdot10^{-6}$
Mass of liquid vapours, involved in the explosion $m_{vapours}$, kg	6325,42	2372,03	36,04	13,51
Heating value of FL and CL vapours Q_{ht}, kJ/kg	43641	43641	43419	43419
Reduced mass of liquid vapours m_{rd}, kg	6107,25	2290,22	34,62	12,98
Excess pressure value ΔP, kPa (radius 50 m)	91,847	50,159	6,622	4,489
Radius of destructions zone *r*, m:				
complete (100 kPa)	47,88	34,59	8,62	6,23
strong (50 kPa)	69,3	50,09	12,5	9,03
average (30 kPa)	93,75	67,78	16,94	12,24
weak (10 kPa)	199,64	144,4	36,16	26,15

***Source*: compiled by the author**

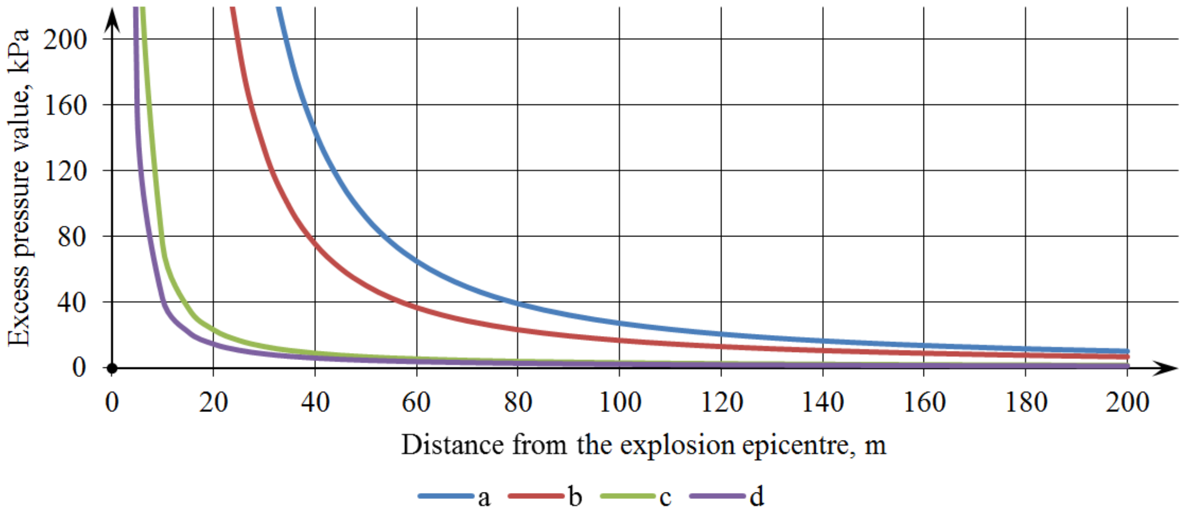

Fig. 2. **The graph of change of excess pressure value of a shock wave depending on distance from the explosion epicentre:**
a, b – for gasoline tanks with a capacity of 40 and 15 m^3 respectively; c, d – for diesel fuel tanks with a capacity of 40 and 15 m^3 respectively
***Source:* compiled by the author**

Additional *OSM Place Search* and *QuickOSM* plugins were used to obtain the geospatial component of the data [27].

OSM Place Search helps in finding the right place (in the study the city of Odessa). An example of the dialog box of this plugin is shown in Fig. 3a. After finding the geographical object of research, we use the *QuickOSM* plugin to obtain the spatial location of the filling station network in the city of Odessa.

Using the dialog box, we generate a request to the server to obtain the necessary data. The *amenity* key is used to describe useful and important objects for visitors and residents of the city. These facilities include, for example, schools, banks, telephones, pharmacies, prisons, toilets and so on. In our case we specify filling station (*fuel*). In the field *in* we indicate the location of research objects (city of Odessa). An example of a corresponding query, which is implemented in the form of a script, is shown in Fig. 3b. The network of filling stations is plotted on city maps in the form of polygons or as a point object, the type of object visualization (points,

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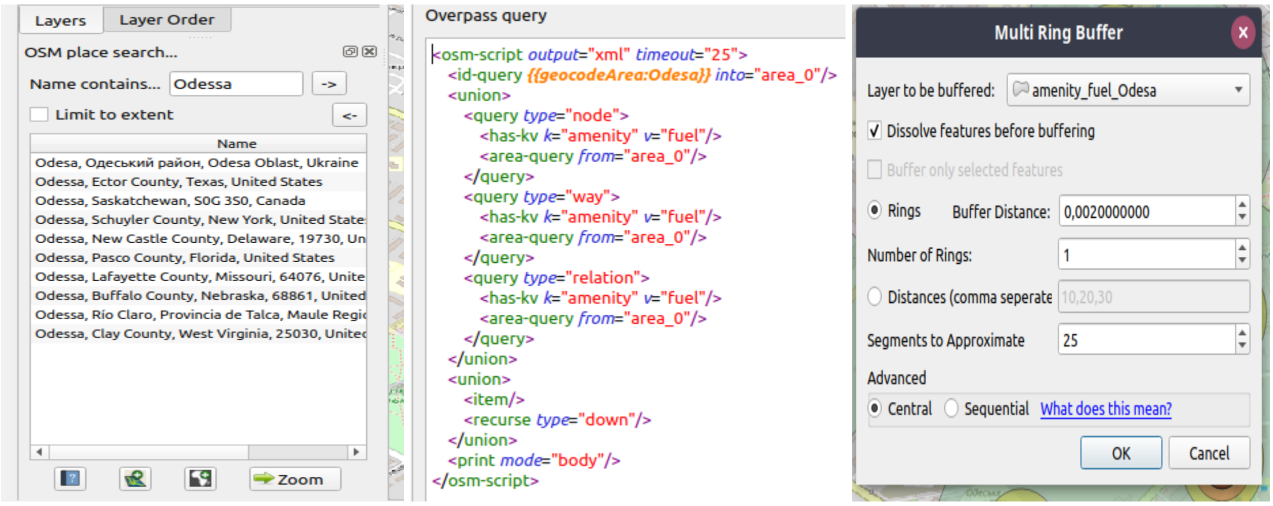
nodes, lines, polygons etc.) is specified in the extension to the query.

After plotting the network of filling stations on the city map using the *Multi Ring Buffer* plugin settings (see Fig. 3c), we visualize the shock wave action zones in the event of a combustion and explosion of FAM due to oil spill from filling station tanks (Fig. 4). When visualizing the action zones, the results of numerical simulation are used, examples of which according to the calculated parameters are shown in Table 1.



a b c

Fig. 3. **Results of *QGIS* plugins settings for visualization of the filling station network as potentially hazardous objects:**
a – *OSM Place Search* plugin dialog box; b – *OpenStreetMap* server request script text;
c – *Multi Ring Buffer* plugin dialog box
***Source:* compiled by the author**

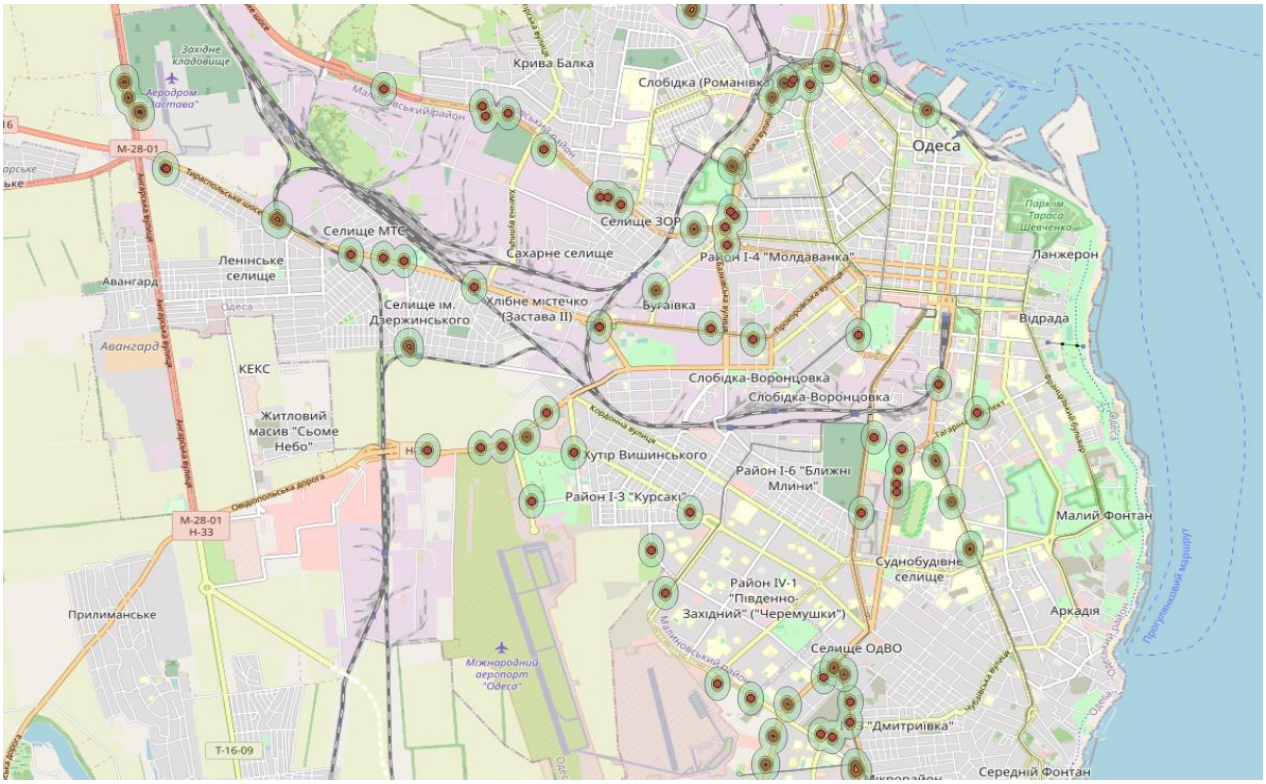


Fig. 4. **Results of visualization of risk zones from filling stations for the city of Odessa using the geographic information system *QGIS* in case of emergency situations**
***Source:* compiled by the author**

Fig. 5. **Visualization of risk zones from gasoline tanks of filling stations with maximum capacity (40 m³) in one of the residential districts of the city of Odessa**
Source: **compiled by the author**

The analysis of visual simulation results shows that during the realization of the most unfavourable scenario, namely for gasoline tanks with a capacity of 40 m³, it is clear that unfortunately not all filling stations meet the norms of fire distances to the objects of "care" of society (people, enterprises, organizations etc.), residential areas etc. It should also be noted that some of the filling stations are located on highways with a significant flow of cars, which only increases the number of potential victims during the rush hours. In addition, it is shown that some filling stations are very close to each other (particularly as it is becoming increasingly popular to place natural gas stations near traditional filling stations), that in the event of ES at one of them may cause an unfavourable situation at another by cascade effect "dominoes", namely the destruction of nearby tanks and technological equipment and the escalation of the emergency situation. This is well illustrated in Fig. 5 on the example of one of the residential districts of the city of Odessa. The study also conducted modelling and visualization of risk zones from FSs tanks with minimal capacity of petroleum products (15 m³). In this case, the nature of accidents is in most cases local (at the filling station), but still possible impact on neighbouring objects, as well as a small scale of damage to surrounding buildings and people.

CONCLUSIONS

In this paper, the authors modelled risk zones in the implementation of an emergency situation at a filling station (the scenario of an explosion of FAM with the formation of a shock wave was chosen), and also visualized them on a map of Odessa using geographic information system *QGIS*.

Analysis of recent studies and publications has shown that geographic information technologies are widely used to solve a wide range of issues, but, in our opinion, insufficient to identify risk zones from potentially hazardous objects, one of which is the filling station. Despite the well-developed apparatus for quantitative and qualitative assessment of emergency risk at filling stations, qualitative analysis of fire causes [18-19], visualization of risk zones in a visual form for decision makers by means of open GISs remains an actual issue. Despite the well-developed apparatus and capacity of commercial products (including TOXI+Risk in [9]), the possibility of their use for training and work is limited by the high cost of software and difficult access to them, so means of open geographicinformation technologies can be a good alternative.

The results of modelling and visualization showed that the use of geographic information technologies is possible for other types of potentially

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hazardous objects (not only for filling stations) under the conditions of using approved normative methods for numerical modelling of risk zones from PHOs. The analysis of the obtained images shows that in the implementation of the most unfavourable events at the filling station the scale of accidents can go beyond the local (filling station territory) and spread to nearby enterprises and organizations, as well as residential area and possible crowds. This allows to use this method both to check the compliance of FSs networks with existing fire safety regulations and while designing new stations in densely built areas and crowds, and therefore can serve as a tool of analysis in the design of urban development. The obtained research data can be used by a wide range of specialists, civil safety and environmental inspection entities, insurance organizations in the calculation of insurance benefits, research organizations, training and so on.

In the future, it is proposed to use the experience to model risk zones from other adverse situations (particularly for filling stations spill fire and the emergence of a "fireball") for the most complete analysis of technogenic safety of a potentially hazardous object. It should also be noted that in order to improve the simulation results it is necessary to reflect on the risk maps not only the areas of danger, but also the objects of "care" of society (including people, enterprises and organizations etc.) to analyse the specific impact on each object. It is proposed to use both the analysis of cadastral maps (to determine the buildings, their type etc.) and geopositioning data to plot the objects of "care" on the situational map. It is worth noting then the use of cluster analysis methods to correlate risk areas and objects of "care", which in particular were used by researchers [28-29] in solving actual problems.

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МОДЕЛЮВАННЯ ЗОН РИЗИКУ ВІД АВТОЗАПРАВНИХ СТАНЦІЙ ІЗ ЗАСТОСУВАННЯМ ГЕОІНФОРМАЦІЙНИХ ТЕХНОЛОГІЙ

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АНОТАЦІЯ

У роботі розглядаються питання техногенної безпеки міста-мільйонера України Одеси на прикладі аналізу надзвичайної ситуації, що може виникнути на автозаправних станціях (АЗС) міста. Пожежна безпека мережі АЗС стає дуже актуальною в умовах ущільнення міської забудови та транспортних потоків, значного збільшення кількості автомобілів, а також при проектуванні нових потенційно небезпечних об'єктів (ПНО) у межах міської забудови. Для вирішення задачі аналізу зон ризику від АЗС була створена концептуальна цифрова модель АЗС, проведено чисельне моделювання сценарію розвитку несприятливої ситуації на АЗС за затвердженою державною методикою (вибух паро-повітряної суміші палива із утворенням ударної хвилі), а також за допомогою геоінформаційної системи QGIS отримані зони були візуалізовані на карті міста Одеси. Цифрову модель АЗС створено з урахуванням вимог до представлення атрибутивних та просторових даних відповідної ГІС. Складовими розробленої концептуальної моделі є: універсальний цифровий ідентифікатор, просторові дані у вигляді типу та координат об'єкта, атрибутивні дані, які складаються із статичних та динамічних ознак, а також чисельні моделі розвитку надзвичайної ситуації. При візуалізації засобами ГІС отриманих розрахункових даних використовувались плагіни OSM Place Search, QuickOSM, Multi Ring Buffer, а також дані відкритого серверу OpenStreetMap. Представлені результати моделювання і візуалізації свідчать про те, що при реалізації найбільш несприятливих сценаріїв розвитку характер аварій на АЗС може вийти за рамки локального і перейти на межі селітебної зони, а також на близькорозташовані промислові об'єкти та АЗС, що може у свою чергу викликати несприятливі ситуації на них за ефектом "доміно". Крім того результати аналізу отриманих неоднорідних даних моделювання та візуалізації для визначення техногенного ризику свідчить про можливість застосування досліджених принципів і для інших ПНО, а також дозволяє представляти дані у наочній і доступній формі для осіб, що приймають рішення.

Ключові слова: геоінформаційні системи ГІС; візуалізація даних; ризик; АЗС; геопросторові дані

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