On the Approach to Substantiating Decisions on The Elimination of the Effects of Domestic Gas Explosions

Rybakov A.[1], Shmyrev V.[2], Ponomarev A.[3], Koverkina E.[4]

[1]Doctor of Technical Sciences, Associate Professor, Professor of the Department of Technospheric Security and Ecology of the Russian State Social University (RUSSIA)
[2] Ph. D., Associate professor, Head of Department at Faculty of Technospheric Security and Ecology, Russian State Social University (RUSSIA)
[3] Assistant professor at Faculty of Technospheric Security and Ecology, Russian State Social University (RUSSIA)
[4] Senior Lecturer at Faculty of Technospheric Security and Ecology, Russian State Social University (RUSSIA)

anatoll_rubakov@mail.ru, shmyrevvi@rgsu.net, ponomarevaja@rgsu.net, koverkinaev@rgsu.net

Abstract

The article proposes a method of calculating the attracted forces and assets, structural units that are part of a unified state system of prevention and liquidation of emergency situations, to eliminate the consequences of emergency situations associated with the explosions of household gas at residential facilities. The technique was implemented in the form of an interactive system for predicting the state of residential facilities in conditions of domestic gas explosions and developing proposals for the formation of a rational composition of the grouping of forces and means to eliminate the consequences of explosions.

Keywords: explosions, forces and means, household gas, information and control systems.

1. INTRODUCTION

Currently, the accident statistics on domestic gas explosions in Russia is disappointing [1], as evidenced by both data from previous years and the latest events of November-December 2017.

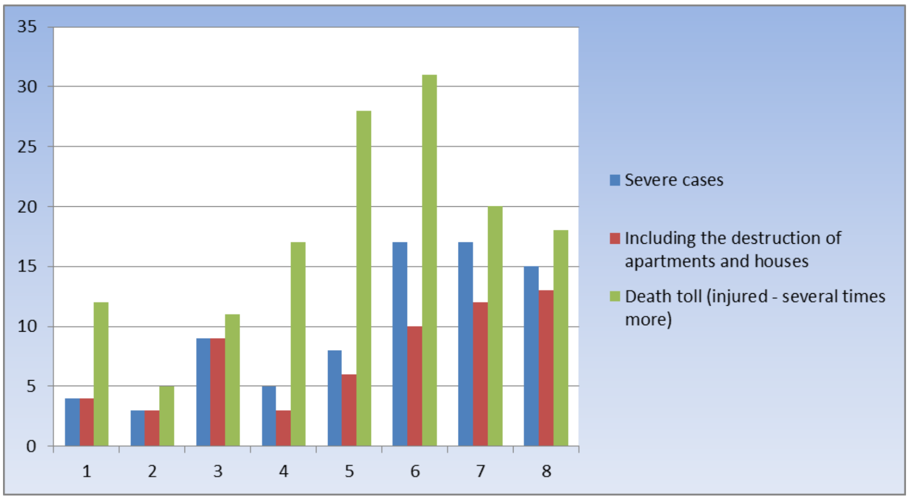

Fig. 1. Statistical data on domestic gas explosions in residential buildings

The explosions of domestic gas lead to large amounts of casualties, material losses. The Ministry of Civil Defence, Emergencies and Disaster Relief faces the task of preventing such explosions and eliminating their consequences (minimizing the loss of human life and economic losses). The fulfilment of these tasks is possible only if all factors affecting the circumstances of the emergency that led to the explosion are considered and if the rescue tasks and other urgent work are properly organized to eliminate the consequences of the explosion.

Proper organization and conduct of rescue tasks and other urgent work are possible only with the proper organization of the management system of the forces and assets involved in eliminating the consequences of the explosion. To assist decision-making, automated information management systems (hereafter, AIMS), based on the geo-information systems already developed, have been introduced in order to enhance the ability of management systems to prevent and eliminate emergency situations, to develop optimal solutions at all levels of management, and also increasing the readiness of communication and warning systems, forces and means to act in emergency situations [2]. Unfortunately, many software products created (operating in AIMS), often unrelated to each other, do not simplify the work of the heads of government bodies, but also make it difficult. All this may ultimately lead to the irrational use of attracted forces and means to mitigate the consequences of an emergency [3], or to the disruption of the implementation of the tasks set in a timely manner.

2. METHOD

Therefore, there is a need to develop proposals for the formation of a rational composition of the grouping of forces and means to eliminate the consequences of the explosions. At the same time, for the qualitative solution of the task of forming a group it must work through the following questions:

- to simulate the situation that develops as a result of the explosion of household gas at the residential development object;

- to calculate the required amount of forces and means necessary to eliminate the consequences of a domestic gas explosion;

- to form a rational grouping of forces and means required to eliminate the consequences of the explosion of household gas;

- to develop proposals for laying the optimal route for the input of forces and assets to the work sites.

Modeling of the situation resulting from the explosion of domestic gas at the residential development object is carried out on the basis of the scenario where the type of object, the year of its construction, the number of rooms in the apartment where the explosion occurs, the time of day, the floor on which the apartment is located, the nature of the residential gas in the apartment.

1 $$\Delta P = \frac{M_g \cdot H_T \cdot P_0 \cdot Z}{V_{CB} \cdot \mathrm{P}_B \cdot C_p \cdot T_0} \cdot \frac{1}{K_H}$$ **2** (1)

where Mg is the mass of household gas in the mixture;

Z is the participation rate of household gas in combustion (= 0.5);

HT is the heat of combustion (= 41.51 MJ / kg);

P0 is the initial pressure (= 101 kPa);

VCB is the volume of rooms where the formation of gas-air mixture;

T0 is an absolute temperature, initial, (= 293 K);

Cp is the heat capacity of air (= 1010 J / kg · K);

ρB is the air density (= 1.225 kg / m3);

KN is the coefficient of considering the leakage of the room (= 3).

The calculation of the degree of destruction of residential objects is carried out based on the methodology described in [4], based on the calculated values of excess pressure (Table 1).

3. CALCULATION

The calculation of the required amount of forces and means necessary to eliminate a domestic gas explosion is carried out based on the methods described in [5]. The obtained data on the required number of forces and means can be used by the heads of structural subdivisions that manage the Unified state system of emergency prevention and response when making decisions on emergency response. However, this information is often not enough to make an informed decision to attract those or other structural units relating to the Unified state system of emergency prevention and response forces.

Table 1. Values of excess pressure with the appropriate degrees of destruction of residential objects

№	Degree of damage	Values of overpressure, kPa
1	Complete destruction of buildings	100
2	50% destruction of buildings	53
3	Average damage to buildings	28
4	Moderate damage to buildings (damage to internal partitions, frames, doors, etc.)	12

For the formation of a rational grouping of forces and means required to eliminate the consequences of a domestic gas explosion, it is necessary to consider the possibility of attracting the widest range of forces required. The solution of this task will be to determine the optimal plan for the formation of a grouping of forces of the Unified state system of emergency prevention and response in such a way that the work on the aftermath of the explosion of household gas will be carried out in full and with minimal time, involving as few specialists as possible. At the same time, the mathematical problem of linear programming of a special type (transport problem) is solved for each type of special equipment, gear and each type of specialists (Fig. 2 and 3) (determined by the methodical instructions [5]).

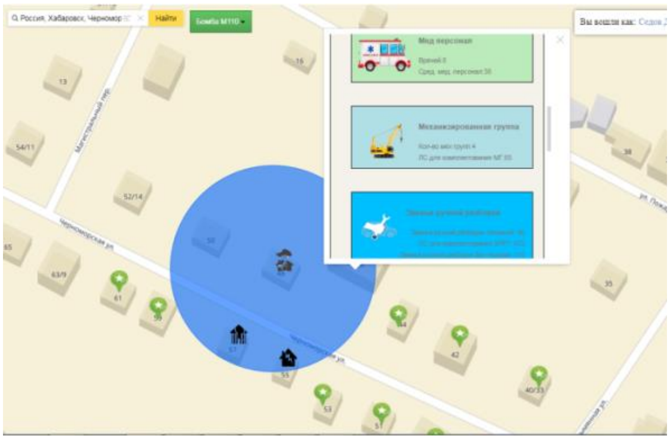

Fig. 2. An example of calculating the required amount of forces and assets in an interactive system

When solving the transportation problem, the time of arrival of the structural units (taking into account the sequence of their entry into the work area) can be taken into account; the effectiveness of the emergency and rescue equipment used, the readiness of the personnel of the units, other factors, etc.

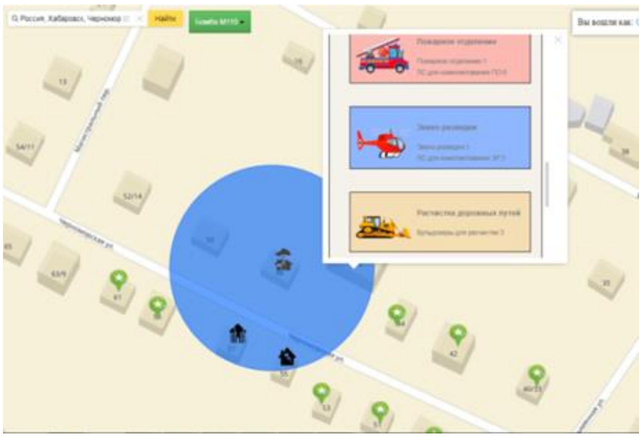

Fig. 3. An example of calculating the required amount of forces and assets in an interactive system

A general view of the matrix required to solve the transportation problem can be represented as follows:

Table 2. The matrix for solving the transport problem for the i-th specialist

	Work area				
	Area 1	**Area 2**	**…**	**Area n**	**Total manpower**
Object 1	t_{11}	t_{12}	…	t_{1n}	x_1
Object 2	t_{21}	t_{22}	…	t_{2n}	x_2
…	…	…	…	…	…
Object m	t_{m1}	t_{m2}	…	t_{mn}	x_m
The need to solve problems	y_1	y_2	…	y_n	$\Sigma y / \Sigma x$

Where

n – the number of sites on which the work is carried out;

m – the number of units from which forces and means are attracted;

y_n – the required amount of forces and means at the work sites;

x_m – the number of forces and means in the units where the attraction to work comes from;

t_{mn} – the time of delivery of forces and equipment from each object to the appropriate area.

The information displayed in the cells of the table will be the time of arrival at the site of work. Filling the cells is carried out considering the separation of forces and equipment and the need to provide for a reserve.

The basis for drawing up the initial plan (Table 2) in the software environment, which is an interactive system for predicting the state of residential buildings in conditions of domestic gas explosions and developing proposals for the formation of a rational composition of the grouping of forces and means for eliminating the consequences of explosions, will be served every day the change of the day-to-day management body - the regional center for civil defense, emergency situations and disaster management and the authority, with information about the forces of the unified state system of warning and emergency response (hereinafter RSChS) for each structural unit that is part of the RSChS forces.

It should be noted that the use of the transportation task for the formation of a rational grouping of forces and means has already been undertaken [6].

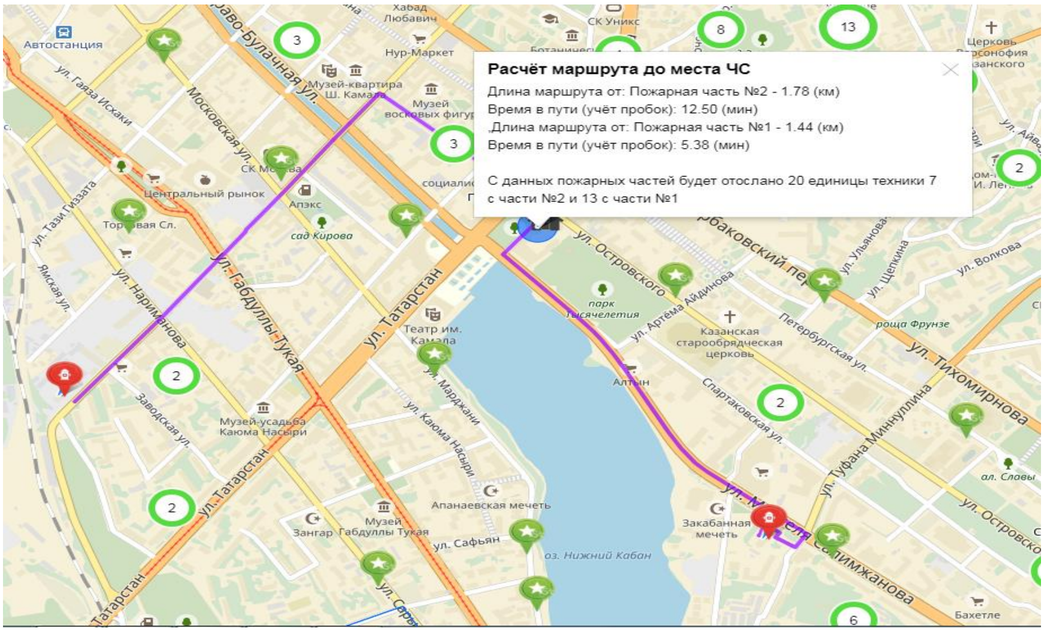

Fig. 4. An example of the working environment of an interactive system with a solved transportation problem

In addition, the platform of the interactive system (based on the geographic information system) allows the mapping of the entry routes of the structural units involved in the formation of the grouping of forces and means depending on the situation on the transport network (Fig. 4).

Thus, having solved the transportation problem for all the necessary specialists for eliminating the consequences of the strike, we will determine the required amount of forces and means from each organization that is part of the subsystem of the emergency response system.

4. CONCLUSION

The paper presents an interactive system based on the proposed approach and designed to ensure the functioning of the AIMS of the RSChS, which allows, based on an assessment of the situation resulting from an emergency, to calculate the required amount of forces and means for carrying out the work to eliminate the consequences of an explosion. One of the directions of formation of a rational composition of the group involved in its liquidation is shown.

The novelty of the proposed interactive system is in the application of algorithms used to solve the transportation problem to form a rational grouping of forces and means designed to eliminate the consequences of an explosion. This will allow the selection of structural units from where it is planned to attract forces and means to eliminate the consequences of the explosion, taking into account the workload of the transportation network, the effectiveness of the rescue equipment used, the readiness of the personnel of the units, etc.

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