Modelling of explosion consequences using geo-informational technologies based on service-oriented architecture

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Abstract. The paper examines mathematical models describing spatial data used for calculation of possible damage areas. Software implementation of the models is based on set-theoretic description, relation algebra, topological relations, geo-informational technologies. These models allow describing facilities (buildings, structures, equipment, pipelines) on the territory of linear operation and dispatcher stations (LODS) and oil pumping stations (OPS) in the form of theme-based generality.

1. Introduction
The relevance of the work is linked to regular updating of equipment and revamping of oil pumping and linear operation and dispatcher stations (including their tank farm) which necessitates updating the significant scope of documentation containing data on possible accidents and emergencies at these facilities which are submitted to public supervisory and regulatory authorities by operating company [1].

Therefore, company professionals are required to perform prompt, efficient, the high-scientific level update of the relevant sections of documentation, pursuant to existent regulations and approved procedures, which are submitted to regional and municipal authorities, including the main directorate of the Ministry of civil defense, emergency management and natural disaster response of the Russian Federation in the constituent entity, counter-terrorism committee in the constituent entity, the Federal security service, the Ministry of home affairs. This type of documentation includes fire safety declaration, industrial safety declaration, safety passport of the hazardous industrial facility, emergency response plans, and other documents. The above-listed documents may contain sections describing the geographic location of the hazardous industrial facility, damage areas at the implementation of the most hazardous and probable scenarios of emergencies, the list of buildings, facilities, structures, equipment, the distance from explosion epicenter, and other spatial and semantic properties [2,5,13].

The most convenient tools to make spatial calculations and prepare cartographic materials are software products employing geo-informational technologies.

The following high-level target can be implemented within the framework of this research - increasing the efficiency of managers and professionals of oil and gas companies by reducing time and
human resources involved in preparing various documentation that contains data on the areas of
damage and impact at OPS and LODS by means of the automatization of designing areas of damage
while modelling explosions at stations utilizing geo-informational technologies based on service-
oriented architecture [4,7,9].
To achieve the target set, the following tasks need to be solved:
• To collect and analyze literature data, legislative acts, statutes and regulations, documentation
developed at companies operating the hazardous industrial facilities (potentially hazardous
facilities);
• To analyze the methods and the procedures of calculating oil and oil vapors explosions and
fires both in tank and in tank farm dykes as well as OPS rooms;
• To analyze factors that has an effect on the characteristics of explosion-damaged areas. To
Analyze the existing methods of creating digital relief models applied for modelling the areas
of damage;
• To analyze the procedures of creating geo-informational systems for oil and gas companies
taking into account the particularities of spatial data utilization;
• To develop a mathematical model to describe spatial data utilized for the calculation of areas
of damage. To develop a functional model for the process of designing the areas of damage at
the present moment ("as is") and with the utilization of the software product under development ("as it should be"). Design an informational model of accidents at OPS which
allows creating spatial database (SDB) thereupon.
• To develop the algorithms delivering the suggested mathematical model which ensure the
calculation and the design of explosion-damaged areas, caused by the explosion of oil vapors
and oil products, as well as the software implementation of these algorithms, based on geo-
informational technologies, in accordance with service-oriented architecture.

2. Calculation of the consequences of explosions
The automated creation and calculation of spatial data of the areas of possible damage of buildings and
structures and injuries of personnel and civilians at the adjacent territory caused by accidents and
emergencies allows increasing the efficiency of personnel of relevant departments of a company by
reducing time required for the preparation of the relevant sections of safety passport, industrial and fire
safety declarations, fire-fighting plans [3,6,12].
The performed analysis of conditions in the course of industrial accidents with explosion shows the
hazard level of the explosion of generated gas-vapor mixture (GVM) with regard to personnel,
buildings, structures, and process equipment, as a result of the destruction of tanks with combustible
materials and possible emission of mixture into the building or at the exposed area. The explosion of
GVM is more likely to occur at petrochemical and chemical facilities where significant volumes of
combustible gases (CG) and highly inflammable liquids are stored and utilized. The share of such
accidents in the Russian Federation is almost 96%.
The review of explosion types as well as the analysis of gas-vapor mixtures (GVM) at exposed
areas, namely knocking combustion within GVM cloud as well as outside GVM cloud and air shock
wave, are the basis for theme-based modelling of accidents occurring during storage and treatment of
highly inflammable and potentially hazardous chemicals. Further to mathematical modelling of the
initiation and development of thermal explosion based on differential equations of calculating oil and
oil vapors explosions and fires, both in tank and in tank farm dyke and rooms of OPS, the results were
gained pertaining to numerical modelling and the analysis of evolution of movement and dissipation of
the hazardous materials clouds generated by the leakage from storage tanks and machineries [3,8,11].

Figure
Figure 1 shows an extract from an informational model describing required data on parameters and
their attributes which are used for the calculation of explosion radius.
The factors that have an effect on the characteristics of explosion-damaged areas were analyzed. Based on the available published works, methods were chosen, which were on the one hand highly accurate, and on the other hand relatively simple. It allows using them for engineering calculations while evaluating fire and explosion hazard of the industrial facilities. The description is provided regarding the mathematical models of physical phenomena at the event of accidents involving fires and explosions. Criteria of people, buildings and equipment's damage with shock wave and thermal radiation are announced. The analysis was made on the existing methods of creating numerical relief models applied for modelling the areas of damage. The procedures for creating geo-informational systems of oil and gas companies were analyzed with the account of the particularities of spatial data utilization [10].

By means of the developed mathematical model describing spatial data utilized to calculate the areas of damage, the functional model of the process for the design of the areas of damage, an informational model was designed for the accidents at oil pumping stations which allows creating spatial database thereupon.

Figures 2 and 3 demonstrate a block diagram of the algorithm that calculates the mass of substance engaged in explosion and the radius of the areas of damage [2,3,9].
Figure 2. A block diagram of algorithm that calculates the mass of substance engaged in explosion and the radius of areas of damage.
Figure 3. A block diagram of the algorithm that calculates the mass of substance engaged in explosion and the radius of the areas of damage (continuation).

3. Conclusions
The implementation of the suggested mathematical model based on the developed algorithm ensures the calculation and the creation of the explosion-damaged areas caused by the explosion of oil vapors and oil products. The software implementation, based on geo-informational technologies and developed in accordance with service-oriented architecture in the form of web-services interacting under SOAP protocol, is increasing the efficiency of managers and professionals of oil and gas
companies by reducing time and human resources involved in preparing various documentation that contains data on the areas of damage and the impact at OPS and LODS by means of the automatization of designing the areas of damage while modelling explosions at stations [2,9].

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