Application development for accidental pollution assessment on chemical manufacturers (pollution from chemical waste)

V Nosov¹, M Tindova²*, K Zhichkin³, M Mirgorodskaya⁴

¹K.G. Razumovsky Moscow State University of technologies and management, Department of economics and management 109004, Moscow, Zemlyanoy Val, 73, Russia
²Yuri Gagarin Saratov State Technical University, Economics, Applied Mathematics and System Analysis Department, 410054 Saratov, Polytechnicheskaya street, 77, Russia
³Samara state agricultural academy, Department of Economic Theory and Economics of AIC, 446442, Samara region, Kinel, Uchebnaja str., 2, Russia
⁴K.G. Razumovsky Moscow State University of technologies and management, Department of economics and management 109004, Moscow, Zemlyanoy Val, 73, Russia

* Corresponding author: mtindova@mail.ru

Abstract. Considering that in recent decades there has been a dramatic increase in the amount of industrial disasters, among which accidents on chemical facilities retain a significant place, forecasting tasks and accident consequence assessment on hazardous chemical facilities are analyzed in this paper. The task of the emergency area size determination, as well as the determination of building destruction level, and the facility personnel and public expenses. The objective of the paper is to review the existing methodologies of forecasting and create a software system for accident consequence forecasting on hazardous chemical facilities. Methodology. The analysis of different methods of damage estimation, conducted by the author, allowed for the general scheme of damage from accidents on potentially hazardous facilities estimation to be made. Furthermore, the author analyzed potential objects of chemical pollution in the Saratov region. The paper demonstrates phases of theoretical development and implementation of software program for accident consequence assessment and modeling on hazardous chemical facilities. The developed software system has a connection with Google Maps GMap.NET, which allows to visualize the obtained assessment results. Results. The result of practical implementation of the application developed by the author is an accident model for a facility, using chlorine substances, the amount of pollution measurement and territory pollution determination. Conclusion. The paper shows that the implementation of the program system developed in the work of organizations will help the heads to minimize possible losses of working personnel, public and organization financial losses.. The author notes that the application developed is free from the main disadvantages of existing programs, more specifically, the absence of the possibility to estimate the physical damage caused by the accident.
1. Introduction
In recent decades there has been a dramatic increase in the amount of industrial disasters, among which accidents on chemical facilities retain a significant place. Accidents on chemical facilities may not only lead to inventory and human losses, but also to irreparable and inestimable damage for the environment. This is amply reflected in the Bhopal gas tragedy of 1984 and numerous accidents that have occurred across the world before or since [1]. After the Bhopal tragedy similar tragedies have also occurred. For example, the Buncefield disaster of 2005 has caused estimated losses of $500 billion, and the BPL refinery disaster of 2010 has harmed larger areas of marine environment than any other past accidents [2; 3; 4]. Unfortunately, there are many similar cases. Ever so often one accident triggers another accident or a series of accidents, thereby escalating the disaster by “domino effect» [5; 6; 7]. This has required development of mechanisms for accidents on chemical facilities protection, accident consequence assessment, and also for accidents forecasting. Many methods have been improved, and new methods have also been developed [8; 9; 10; 11]. The main task of accident consequence assessment and forecasting on hazardous chemical facilities is to determine the size of the emergency area, the level of building destruction, and the facility personnel and public expenses [12; 13].

For implementation of forecasting it is necessary to develop a software and design a three-phase mathematical model for analysis and estimation.

In the first phase forecasting of results of possible natural and man-caused emergencies is conducted, using average conditions (average weather conditions per year; average amount of people in buildings and on streets; average population density, etc.) This phase is conducted until emergencies.

In the second phase forecasting and analysis of the emergency are conducted immediately after the source of emergency is revealed according to updated information (emergency period, weather conditions during this period, etc.)

In the next phase results of forecasting and real situation according to emergency response service data are clarified [14].

The objective of the paper is to review the existing methodologies of forecasting and create a software system for accident consequence forecasting on hazardous chemical facilities.

Hazardous chemical facilities (HCF) include [15]:
1) chemical industry companies, as well as chemical equipment (units) and plants, manufacturing and using emergency and hazardous chemical substances (EHCS);
2) petroleum refineries
3) railway stations, ports, terminals and warehouses at the terminal (intermediate) points of EHCS movement;
4) production in other industrial sector using EHCS
5) vehicles (containers and tank cars, tank trucks, river and sea tankers, pipeline transport, etc.)

Chemical production facilities and facilities using toxic substances in their production process seem to be of the greatest danger.

2. Methodology (hazardous chemical environment identification methods)
The chemical environment refers to the extent and degree of chemical contamination of the air (in the country), which affects human activity and industrial objects work [16].

The chemical damage zone may have one or several chemical contamination areas, defined as populated area in a chemical damage zone.

To identify the chemical environment means to determine chemical contamination zones and to map them (or to locate them on a diagram or on a plan). The chemical environment assessment is conducted using the forecasting method (using civil defense headquarters), and chemical intelligence data (commanders of paramilitary forces of civil defense).

Based on the assessment of the magnitude of a real danger that depends not only on the toxicity of substances, but also on the size of their reserves and their spread in the atmosphere, the list of EHCS from which protection should be ensured, includes nine basic substances: Chlorine, Ammonia,
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Phosgene, Sulfur dioxide, Hydrogen cyanide, Hydrogen sulfide, Carbon disulfide, Hydrogen fluoride, and Acrylonitrile [17].

It should be noted that in Saratov Region there are facilities using hazardous chemicals in their production: “Saratovgassynthesis” in Saratov (Hydrogen cyanide, Acrylonitrile, Sodium cyanide, etc.), “VK-3” in Saratov (Chlorine), and OJSC “Appatit” in Balakovo (Sodium fluorosilicate, Sulfuric acid and Phosphoric acid).

To assess the chemical environment means to identify the chemical damage scale (the depth, the chemical contamination area), and to define it on the location map.

Two types of the chemical environment can be distinguished: actual chemical environment, identified by the chemical intelligence using such instruments for control as gas analyzers, and potential chemical environment, identified by the forecasting, based on mathematical calculation and modeling and mapping the obtained situation.

The actual situation is identified after the accident and formation of the damage zone. The chemical environment, identified by the forecasting method, only conditionally describes the chemical damage.

The general scheme for definition of damage from accidents on hazardous facilities is presented in Figure 1 [18]. As we analyze this scheme we can see the necessity of using the software in the accidents in the chemical industry damage assessment process due to the need to quickly process large amounts of information.

3. Analysis of software programs for chemical pollution assessment existing

Today there are a few software programs for pollution assessment on the Russian market that are in the public domain. The CJSC "Scientific Engineering Research Center" 2011 software program "Risk Study and Safety Assessment" is the most commonly used (judging by the number of downloads). This program unit allows forecasting of contamination zones sizes in case of accidents on reservoirs and storages during transportation by railway, pipeline and other means of transport, and also in case of destruction of chemically hazardous facilities. It also allows mapping the zones of possible contamination and sectors of EHCS spreading depending on the speed and direction of wind, and to generate extended reports with the displaying of the calculations performing. Inability of estimating the accident damage and choosing the statistical data for affected communities estimation is the main disadvantage of this software program (data must be entered manually).

Another software program is the RD 52.04.253-90 project, developed by the LLC Scientific Engineering Research and Production Enterprise "Aviainstrument" based on the 1990 standard scale of...
contamination forecasting procedure. This program can be applied to accidents and scenario calculations (potential accidents and their consequences modeling) in cases of spreading of highly hazardous chemical (HHC) in the atmosphere in gaseous or aerosol state. It allows forecasting of contamination zones sizes in case of accidents on reservoirs and storages during transportation by railway, pipeline and other means of transport, and also in case of destruction of chemically hazardous facilities. This software has the same disadvantages as the first one, moreover, the methodology of accident forecasting for accident estimation is quite old-fashioned.

Therefore, the main disadvantage of both software products is the lack of damage definition. This function will help the heads of economic entities to define potential losses in case of emergency, and to allocate financial resources correctly for depreciation charges calculation.

4. Practical application design for chemical pollution assessment

Based on the fact that the most popular operating system nowadays is Windows, it would be appropriate to develop the program for it on the first step, and, having considered the leading programming languages and their advantages and disadvantages, the C# language was chosen as the programming language. The programming environment, developed by the founding company of the chosen programming language - Microsoft, and their product - Visual Studio 2017, were chosen as the development environment [19].

The next step was the development of the program system structure, which, according to the ultimate goal - the potential damage area forecasting - would consist of units, each of which would be implemented in separate forms. It should be noted that EHCS can be chosen from the list which contains 33 substances (Fig. 2B).

The first unit is responsible for the possibility of data entry into the form (Fig. 2A). In the form it is also necessary to choose the state of matter for the substance, the amount of EHCS in the environment, type of spill, weather conditions at the time of the accident and statistical data, as well as to choose the amount of people suffered from the accidents on the economic entity or outside.

![Figure 2. A) Data-entry form; B) The list of substances in the box](http://example.com/image.png)

This form includes three additional buttons. When clicking "Calculate", all the attributes chosen are considered, clear structure of mathematical calculation is created and implemented, and the new form with the calculation data is opened. The "Exit" button is responsible for the program shutdown and deleting it from the operating system processes. When clicking the question mark button the online help is opened.

Moreover, for all text boxes the event handler was created, which does not allow incorrect data to be entered. In this case the program does not block the "dot", "comma" and figures entry, the entry of other...
symbols is not available. If the user tries to enter non-existent data, then after clicking "Calculate" a message window will be opened, showing the line where the mistake was made.

The next unit (form) demonstrates the outcome with some source data for the better calculation reliability analysis (Fig 3A).

![Figure 3. A) Calculation data form; B) Area affected by the accident map modeling](image)

It is further proposed that the user sets additional parameters for the accident consequences map modeling. For this the accident location must be chosen. If the user wants to choose from the list of standard economic entities in the Saratov Region ("Saratovgassynthesis", "VK-3" and OJSC "Appatit"), the "Economic Entity" button should be clicked. When choosing the place of an accident, launch coordinates are the central part of Saratov.

The next parameter needed for modeling implementation is the wind direction measurement, which can be done by a compass (Fig. 3A) [20].

The Google GMap.NET framework was used in our program for the map rendering. This library is free, cross-platform has an open source code, and allows to define objects geolocations. Fig. 3B illustrates the example of the damage zone visual display. The yellow marker shows the accident area and defines the contaminated air cloud route direction; the potential EHCS contamination zone is displayed as a red circle, semicircle or sector depending on the speed of wind in the ground air; the potential chemical contamination zone is shaded semi-transparent red.

5. Results
Let us consider the developed program system operation using the example of an accident on the industrial facility using chlorine substances in their production activities. For this the area of hazardous chemicals contamination in case of an accident on a hazardous chemical facility should be identified, as well as the time in which the chemical cloud reaches the populated area given the following source data: the EHCS type - Chlorine; the amount of EHCS (Q0) - 96 tons; the EHCS storage conditions - compressed fluid; the bund wall height (H) - 2 meters; time after the accident (N) - 4 hours; weather conditions - homeothermy; air temperature (T) - 10ºC; the wind speed (V) - 2 meters per second; distance from the EHCS emission source to populated area (X) - 2 km; statistical data - cities of the Saratov Region; gas masks availability for population - 30%. The result is shown in the Fig. 3A.

To define the affected area it is necessary to add some data to the form with the obtained result: "Saratovgassynthesis" is chosen as the accident scene; the wind direction is north-east (NE). The result is shown in the Fig. 3B.

6. Conclusion
The software developed is not cross-platform and operates only on Windows 7, 8, 10 operating systems, the minimum system requirements for a computer comply with the system requirements for the operating systems. The 4.0 .NET Framework is also required for the operation. In conclusion it should be noted that the application developed for the accidents on chemical facilities pollution assessment lacks the main disadvantage of the similar programs on the market, specifically the lack of possibility to assess the physical damage at the facility where the accident took place, and in the polluted territory. The implementation of the program system developed in the work of organizations will help the heads to minimize possible losses of working personnel, public and organization financial losses.

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