ISSN: 2707-1146
e-ISSN: 2709-4189

https://doi.org/10.36719/2707-1146/47/23-37

Samadagha Rizvanli
Azerbaijan State Oil and Industry University
rizvanlisemedaga170@gmail.com
Bayim Shahpalangova
Azerbaijan State Oil and Industry University
bela_53@mail.ru

Assessment of the Hazard Risk That May Arise During the Transportation of Hazardous Chemicals by Vehicle Transport

Abstract

During our modern era, there are various types and numbers of chemically dangerous objects in the territory of our Republic, and they are constantly in operation. Thus, during the operation of these objects, significant reserves of dangerous chemicals of an emergency nature are used in a certain amount. According to information, thousands of tons of hazardous chemical substances are transported from one area to another in the Republic of Azerbaijan every year. So, the vehicles carrying those types of chemically dangerous substances have to pass through areas inhabited by people. Also, in case of accidents during the transportation, there may be a large number of people in the chemical contamination zone.

As we know, as a result of the spillage of dangerous chemicals, the environment, living beings, people, and animals are damaged in a huge amount. In order to prevent this, a plan of various measures should be implemented. In this article, special parameters were mainly used in the study of the dispersion of dangerous chemicals as a result of an accident and risk assessment, which are used for the main work:

1. Toxodose of dangerous chemicals according to distance and effect.
2. The average concentration of dangerous chemical substances entering the human body by inhalation.
3. Site of accidental spillage of chemical hazardous substances.
4. Area coefficient of distribution of known types of hazardous chemicals.
5. Infiltration.

Keywords: *hazard chemicals, vehicle, risk assessment, transportation, danger, harm*

Introduction

According to world statistics, 2/3 of man-made emergencies are characterized by accidents in the field of transport. Based on the conducted research data, chemical poisoning can occur in a total area of 0.08 thousand sq. km in the territory of our Republic, and approximately 231 thousand people live in that area. It should be noted that there have been more than a hundred accidents resulting in the release of dangerous substances into the environment in such facilities, and thousands of people have been injured. The goal was to ensure safety during transportation of dangerous goods by road and reducing possible accidents during transportation of that cargo. One in three industries and other businesses operating worldwide are closely related to hazardous chemicals, which are involved in technological processes, products, raw materials or intermediates that are released in those facilities (Aleksandrovich, 2020, p. 12-17).

Research. Complex measures to eliminate the consequences of accidents during transportation of dangerous chemicals by road include the following:

- predicting the consequences of probable chemical hazardous accidents,
- detection and evaluation of the consequences of hazardous chemical accidents,
- accident-rescue and other urgent work,
- prevention of chemical poisoning,
- special cleaning of technical equipment as well as sanitary cleaning of people.

Creative Commons Attribution-NonCommercial 4.0 International (CC-BY-NC 4.0)

ISSN: 2707-1146
e-ISSN: 2709-4189

In case of evacuation of people in the zone of possible pollution due to the flow (spill) of dangerous chemicals, emergency situations occur, the persons carrying out the transportation process should predict the possible emergency events that may occur and implement a plan of preventive measures to minimize the consequences of the accident.

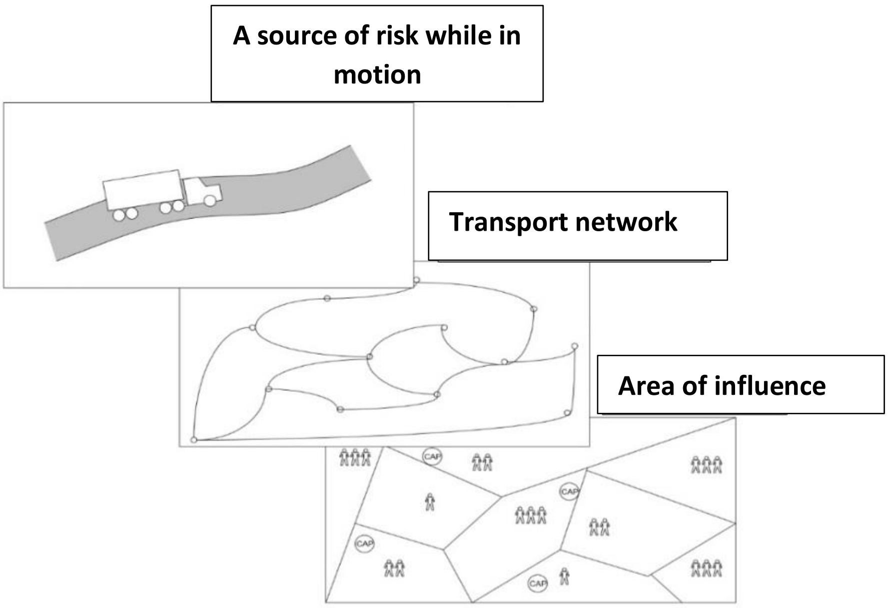

Figure 1. Interrelation between data sources for risk assessment of transportation of hazardous chemicals

The following measures should be taken to prevent accidents in the transport infrastructure and to minimize the risks of chemical hazards during the transportation of dangerous chemicals by road:

1. Research and improvement of ways to ensure the safety of the population and persons accompanying dangerous goods during accidents related to the spillage of hazardous chemicals.
2. Improvement and preparation of quick elimination methods and disinfection methods in the area of spilled dangerous substances.

All participants in the chain are responsible for the safety of transporting hazardous chemicals by road. Accidents during this can pose a significant threat to people's lives and health. They can damage infrastructure and cause environmental pollution and pollution (Gasimov, 2021, p. 54-62).

In case of an accident, dangerous chemicals are scattered beyond the capacity, that is, the toxodose can be calculated for the distance of any element of the object falling into the poisoning zone, and in this case, the risk assessment is as follows:

$$R_{toxy} = \frac{200 \cdot Q}{\upsilon \cdot k_1 \cdot (k_2 \cdot X)^{3/2}}, \left(\frac{mq}{l} \cdot dəq\right),$$

From what is shown here, X – is the distance indicator between the capacity of the object and its element, m; k_1 – the roughness coefficient on the ground surface: $k_1=1$ – when the ground is open; $k_1=3.5$ – for city-like buildings; k_2 is the coefficient of the vertical stability of the atmosphere; $k_2=1$ – when the ground is open; $k_2=1.5$ – for urban areas; $k_2=2$ – for forest areas; υ – is surface wind speed, m/sec; Q – is the mass of hazardous chemicals, kg. (Gasimov, Abdullayeva, 2017, p. 63-75).

Hazardous chemicals are divided into different types according to the degree of danger, they are as follows:

- object,
- local,
- regional,
- global.

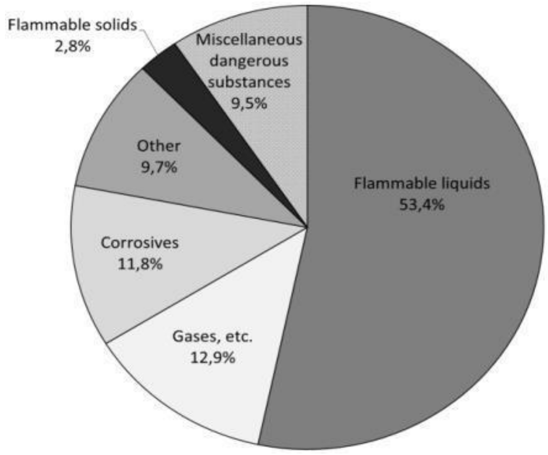

Figure 2. Case diagram of types of hazardous chemicals

Based on experience, the area of accidental substance spillage is calculated by the following formula:

$$P_{ds} = 3{,}14(3{,}018 \cdot E_y^{0{,}393} \cdot V_y^{-0{,}116} \cdot t_{yai}^{0{,}115} \cdot M_{ysə}$$

here, according to the indicators, E_y – is the volume of spilled (flowing) y-type hazardous chemicals, m^3; V_y – kinematic viscosity of dangerous chemicals of type y, m^2/s; t_{yai} – duration of diffusion of liquid, min. (Gasimov, Abdullayeva, Huseynov, 2009, p. 15-20).

Table 1. Types and effects of hazardous chemicals

Material	Energy ration	Efficiency factor
Hydrocarbons	10	0.04
Ethylene oxide	6	0.10
Vinyl chloride monomer	4.2	0.04
Acetylene oxide	6.9	0.06

When transporting hazardous chemicals, the person or persons must be aware of the high degree of danger involved in this type of activity and take all possible measures to prevent emergency situations that may cause casualties among the crew of the vehicle carrying hazardous chemicals.

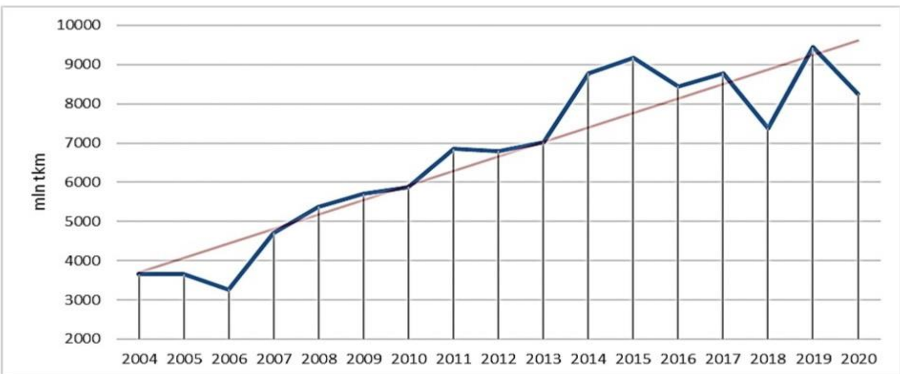

Figure 3. Dispersion distance of hazardous chemical substances during different years (2004-2020)

Quantitative risk during the transportation of hazardous chemicals is usually assessed as the probability of occurrence of an undesirable event (incident). In risk theory, such an indicator of the risk magnitude as mathematical expectations of the magnitude of undesirable consequences was used. It seems more rational to use this indicator for risk assessment during the transportation of dangerous chemicals and first of all to assess the danger degree of a certain cargo type. It should be noted that determining the mathematical expectation of damage in the transportation of hazardous chemical substances will require a new approach to the formation of the information base.

The amount of damage caused by the accidental release of hazardous chemicals and the quantitative risk assessment is calculated as follows:

$$R_{ziy} = \sum_{i=1}^{n}(P_i \cdot U_i)$$

here P_i – those that are likely to occur. risk events in Ch – M-S – G system; U_i – is the amount of damage during the i-th event. It should be noted that the feature of most technological processes related to the use of cars is the absence of well-defined technological operations that are stable in time and space. Under these circumstances, assessing the risk of the whole system seems to be a complex and often difficult task (Aksenov, 2020, p. 56-63).

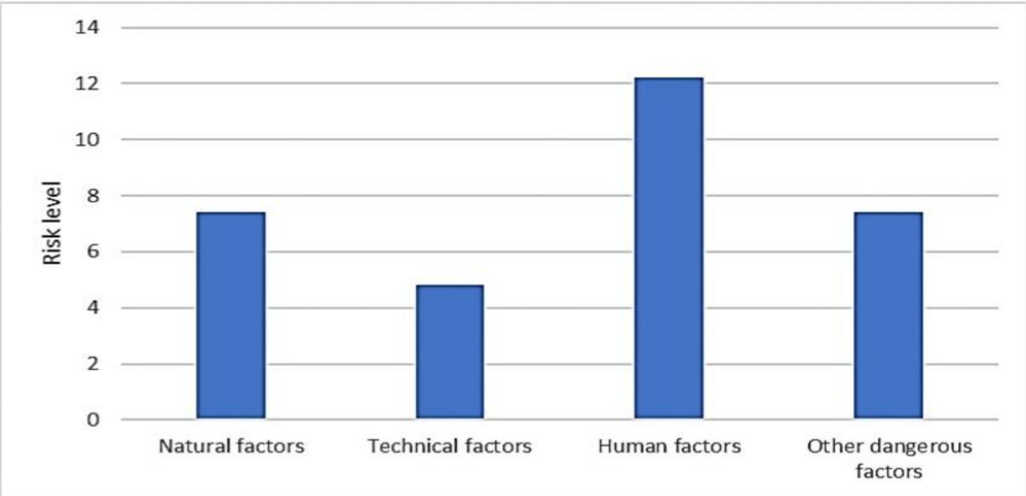

Figure 4. Levels of risks of hazardous chemical substances in hazardous areas

Accident In case of an accident during the transportation of hazardous chemicals, the characteristics of those hazardous substances differ according to the following:
- • ignition,
- • spontaneous combustion,
- • dangerous reactions with water or other substances,
- • explosiveness,
- • corrosiveness,
- • radioactivity,
- • risk of infection (Daineka, 2023, p. 17-21).

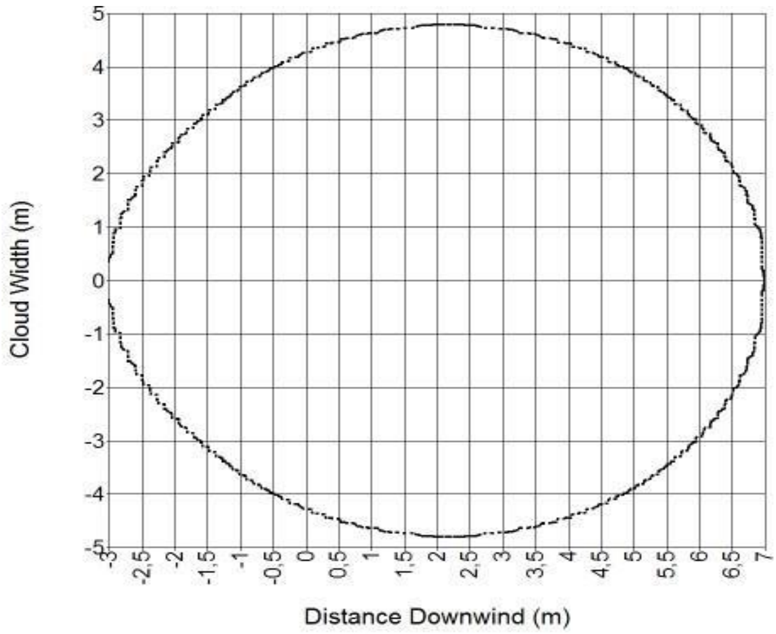

Figure 5. Evaporation of ammonia during the accident

The following parameters should be taken into account in the risk assessment during the accidental release of hazardous chemicals:

1. Meteorological conditions during the probable accident.
2. Norm rates for small pipes, large pipes and cylinders – taking into account different distribution probability of released quantities for each shipping container.
3. Day and time of the accident (affecting meteorological conditions).
4. Month of the year that affects relative accident probabilities (Rasulov, Badalova, Safarov, Ganiyeva, 2023, p. 277-278).

When planning routes for the transportation of hazardous products, the "risk factors" that must be achieved in order to achieve the goal of a route of minimal risk can be used as an expected result of an activity. With only one event (R) as a risk of potential factors, the probability of this event occurring is affected by the accident (P) that the event occurred (C). Accidental release of harmful substances is defined as a risk:

$$R = P \cdot C$$

Risk assessment during transportation of dangerous chemicals is carried out using the following formula:

$$\text{R}=\sum(P_i \cdot C_i)$$

here parameters P and C are the probability and outcome of the type i event. In general, the expression tree is as follows:

$$\text{R}=\sum(P_i \cdot C_i^{\alpha})$$

The people death risk as a result of the accidental release of dangerous chemicals is grouped as follows:

I. R ≤ 10-2 – extremely high level.
II. 10-3 < R ≤ 10-2 – high level.
III. 10-4 < R ≤ 10-3 – medium level.
IV. R ≤ 10-4 – low level (Surnikov, 2023, p. 385-397).

ISSN: 2707-1146
e-ISSN: 2709-4189

Before loading the vehicle, i.e. the special capacity of the car, with hazardous chemicals and sending it to the selected point, all the parameters, density, pressure, type and initial data of those substances should be checked.

When the amount of dangerous chemicals increases or decreases during the accident, the sensor is activated, a signal is issued and sent to the driver's cabin to stop the car urgently, and the signal about the accident is transmitted to the server and the data transmission system installed in the vehicle is activated.

Table 2.
Hazardous chemicals and their types

Classes	Description
I	Explosives and articles
II	Gases, flammable, non-flammable and toxic gases
III	Flammable liquids
IV	Combustible solids, self-reactive substances and solid desensitized explosives
V	Substances prone to spontaneous combustion
VI	Substances that emit flammable gases in contact with water
VII	Oxidizing agents
VIII	Organic peroxides
IX	Toxic substances
X	Infectious substances
XI	Radioactive material
XII	Corrosive substances
XIII	Various dangerous substances and objects

The width and length of the area where hazardous chemicals were spilled (flowed), taking into account their density and the height of the spillage on the bottom surface should be determined here (Javoronkov, 1985, p. 9-10).

Thus, the following are the main parameters influence of the recontamination cloud depth on a chemical waste facility and spilling (flowing) of chemicals during an accident:
- the area where the dangerous chemical substance was spilled (flowed),
- height of liquid layer (thickness of poured layer),
- degree of chemicals infiltration into the subsurface.

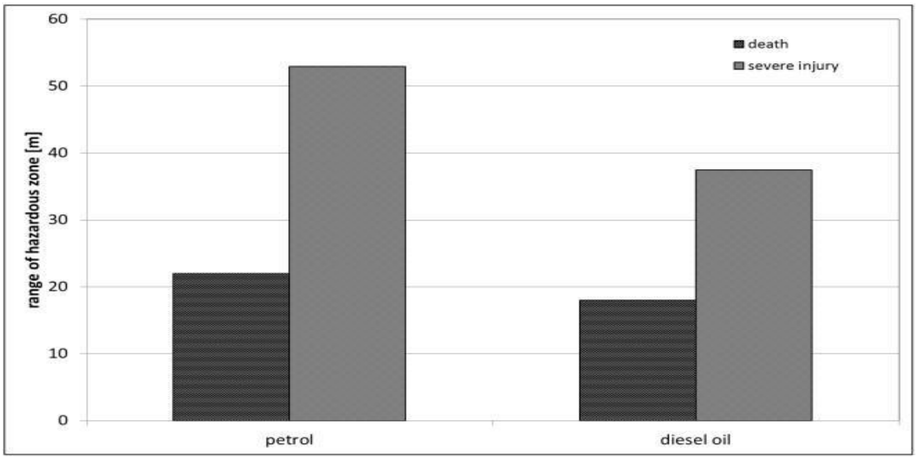

Figure 6. Danger indicators during the combustion of gasoline and diesel chemicals during an accident

The transport of hazardous chemicals can be defined as the elements (people, goods and infrastructure) affected during and after an accident. There are two types of risk mitigation measures:

1. On reducing the level of damage and losses and on their prevention.
2. Protection, which consists of reducing the level of danger.

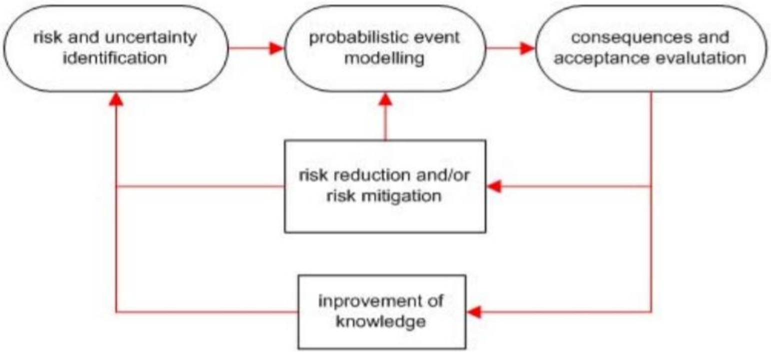

Figure 7. The main principle scheme of risk assessment

The process of optimizing the route for transporting hazardous chemicals, a cost-benefit analysis is performed that does not take into account the effects of a possible accident on the biotic and abiotic components of a specific area. These effects are associated with pollutant effects on people and energy caused by emissions of pollutants around the crashed vehicle. This pollutant activity is highly complex and stochastic, largely controlled by the meteorological conditions (mainly winds) prevailing at the time and at the site of the accident. In this case, the affected area is relatively large. Consequently, quantifying and evaluating the associated sequelae is a difficult challenge (Savchuk, Kreitor, Aksenov, 2018, p. 2-4).

According to the duration of the effectiveness of their damaging effects, hazardous substances are divided into different components:

a) fast-acting unstable dangerous chemicals (cyanic acid (HCN), ammonia (NH_3), carbon monoxide (CO));

b) slow-acting unstable ones (phosgene ($COCl_2$), nitric acid (HNO3));

c) quick-acting persistent ones (phosphorus-organic compounds ($RP(OH)_2$), aniline ($C_6H_5NH_2$);

d) slow-acting persistent ones (sulfuric acid ($H2SO_4$), dioxin (belongs to the group of the most toxic substances), etc.).

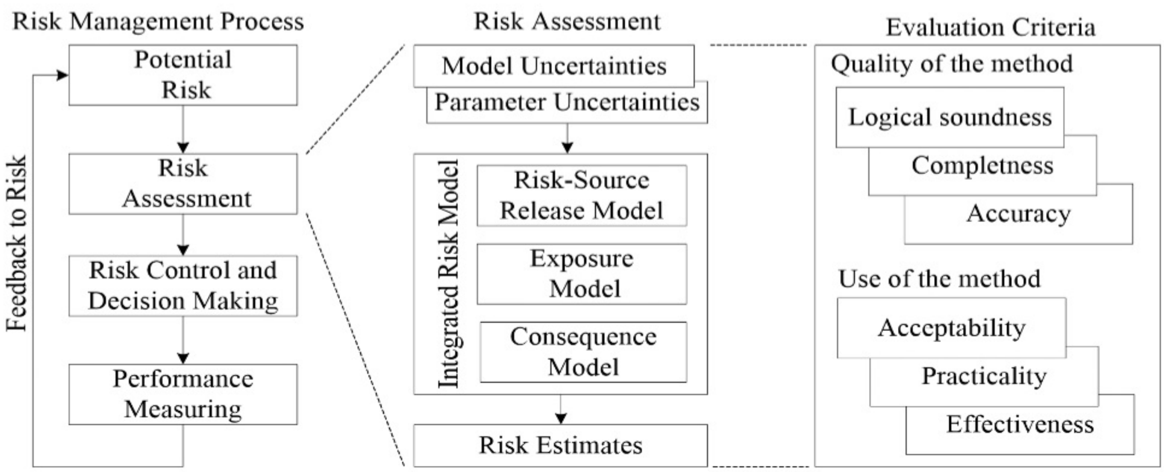

Figure 8. Evaluation criteria of risk assessment as a part of risk management process

ISSN: 2707-1146
e-ISSN: 2709-4189

The following are the main criteria used when selecting routes within the methodology:

1. Considering the current distribution of source destinations.
2. Partial use of the most used roads for the movement of vehicles for the transportation of dangerous goods.
3. Greater use of roads reserved for freight transportation.
4. Minimize the distance between the source and destination points as much as possible.
5. Reduce the size of the potentially affected area by narrowing the choice of roads under existing conditions (Ojagov, 2009, p. 377-381).

Experimental studies were conducted in order to detect the leakage rate of the spilled area and known types of hazardous chemicals to the subsurfaces. The data collected as a result of experimental studies in order to find out the area where the spill happened are shown in Figure 1. On the basis of various types of experiments, the spread area coefficient (D_{nmb}) of known types of hazardous chemical substances is determined by the following formula:

$$D_{nmb} = \frac{C_{iasds}}{C_{isctds}}$$

according to the coefficients shown here, C_{iasds} – dispersion (flow) area of b-type dangerous chemicals on m-type subsurface, m^2; C_{isctds} – is the y-type dispersion area of hazardous chemicals on an ideal smooth surface (glass), m^2.

When organizing the transportation of hazardous chemicals, the main activity is to ensure safety. The organization as a whole must be protected from various types of threats and dangerous events. Prevention of damages and losses that may occur as a result of the accidental spillage of hazardous chemicals, as well as hazard risk assessment should be conducted regularly. All environmental factors must be taken into account during risk assessment. The supply or area where the second source of danger is created must be controlled.

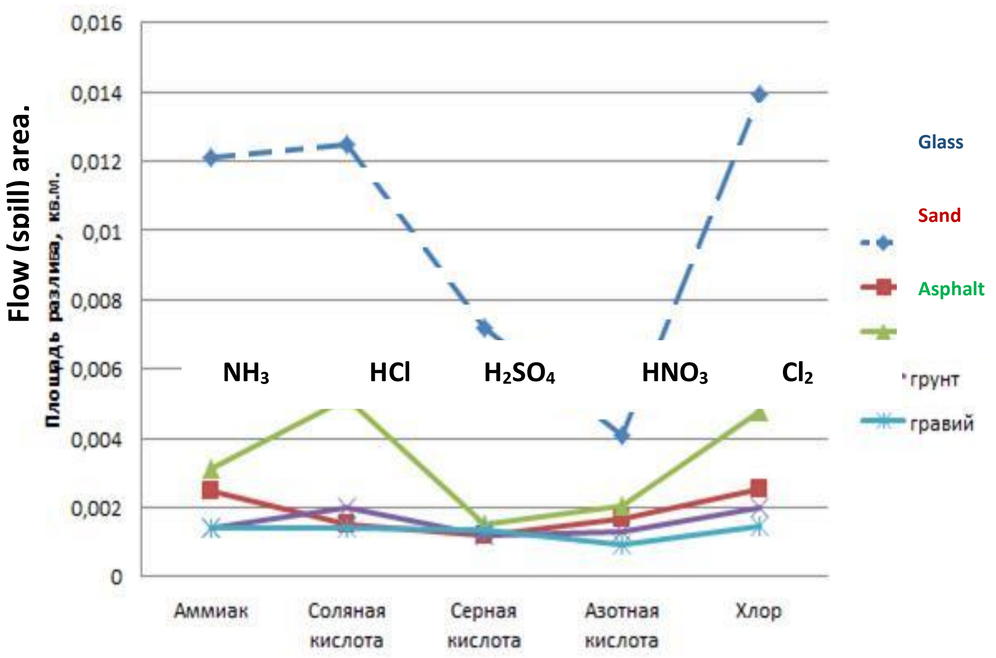

Figure 9. The main results of experimental studies to determine the area of flow (spill) of hazardous chemicals on different surfaces

Mathematical models of the optimized method for the hazard risk assessment during the substance transportation by road vehicles and the implementation of the software on electronic computers are presented. The probability of chemicals release during an accident is a result of the speed of motor vehicle accidents involving hazardous materials and the probability of release of the hazardous chemical (Savchuk, Kreitor, Aksenov, 2018, p. 2-40).

So, based on the experimental data, it is possible to calculate the infiltration coefficient using the following formula (N_{in}):

$$N_{in} = \frac{S(t_e)}{S_{beg}}$$

according to the coefficients indicated here, $S(t_e)$ – the volume occupied by hazardous substances in the cylinder during the exposure period, m^3;

S_{beg} – initial volume of dangerous chemical substances in the cylinder, m^3; te is the exposure time calculated from the beginning of the experiment, min.

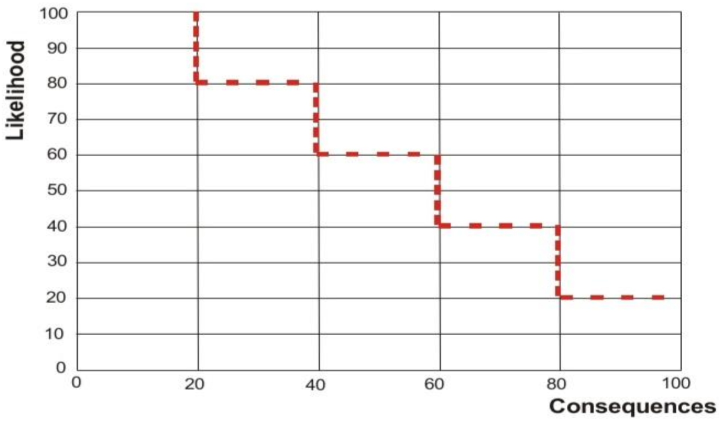

Figure 10. Risk matrix

During the conducted experiment, the rate of infiltration of dangerous substances into the deeper surfaces after partial leakage into the ground was determined. In many cases of accidents, several chemicals are transported in the same container. Therefore, it is possible for several chemicals to be released into the atmosphere at the same time, either when there are several chemicals in one spilled container, or when several containers are broken (Moroz, 2020, p. 124-135).

Industrial requirements as well as a number of human activities depend on the daily transportation of dangerous goods. The percentage of traffic accidents involving hazardous chemicals is increasing every year. The consequences of those accidents cannot be compared with simple collisions in terms of seriousness. Due to the dangerous properties of the cargo (toxicity, flammability, corrosiveness, etc.), the risks arising during transportation can extend a wide radius to the affected area in the event of an accident. The risk assessment methodology during road transportation of hazardous chemicals has been developed. Two critical factors were considered. The first is the probability of consequences (release of toxic materials, various types of fires and explosions of flammable materials) in the event of an accident, which is calculated by analyzing the consequences. The second is the consequences of the result (thermal radiation, overpressure, toxic load) and calculated by modeling.

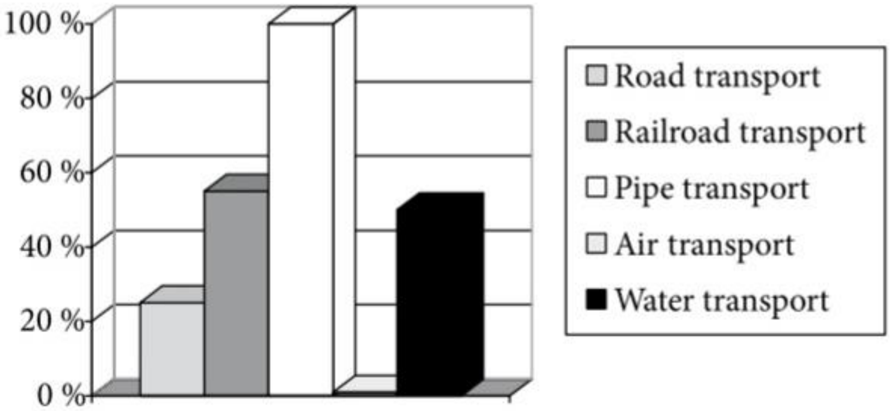

Figure 11. Statistics of vehicles causing dangerous chemical accidents

One of the important conditions is the assessment of the area width where hazardous chemicals are spilled (flowing) and its height in the braking area, which ultimately affects the depth of chemical pollution and is determined by the amount of substances flowing into this area (Smith, 2019, p. 124-135).

For transporting dangerous chemicals, the following measures should be taken into account and the hazard risk assessed:

1) the technical basis of the type of transport (for example, the basis for road transport is better than for railway transport),
2) security guarantees,
3) the length of the road,
4) shipping cost,
5) cost of cargo,
6) chemical properties and amount of material,
7) personnel training and knowledge base,
8) route,
9) climatic conditions.

Risk management process is a set of procedures that can be used in the chemicals transportation to reduce risks. The first step in the risk management process is to identify all potential risks. The next step, which is the objective of the present work, is to assess the identified risks to provide decision makers with powerful tools for the third step of the process. In the third step, decision makers must consider the results of the risk assessment before selecting appropriate and effective security control measures that lead to the necessary risk reduction. Finally, measuring the performance of proposed and implemented security controls completes the risk assessment process by providing feedback for the first step. In general, risk exists when three conditions are met. First, there must be a risk source, which can be a system, process or activity that can release the risk indicator. Second, there must be an exposure process through which people can be exposed to the released risk indicator. Third, there must be a causal process by which exposure to the risk indicator leads to undesirable consequences. The final output will be estimates of possible undesired human health outcomes, including a characterization of the probabilities and uncertainties associated with these estimates. Based on the above, a complete risk assessment consists of four interrelated but distinct steps:

• assessment of releases,
• exposure assessment,
• impact assessment and risk assessment.

The future, attempts will be made to incorporate these uncertainties in a more extensive uncertainty analysis using Monte Carlo techniques. The Monte Carlo analysis included not only probability distributions for a number of key variables, but also several proposed improvements to the methodology considered for the deterministic approach. Notable among these changes in approach is the recognition that vehicle accidents will result in spills of the same or different chemicals from the vehicle. The inhalation health effects of a mixture of vapors of various chemicals were included in a Monte Carlo analysis.

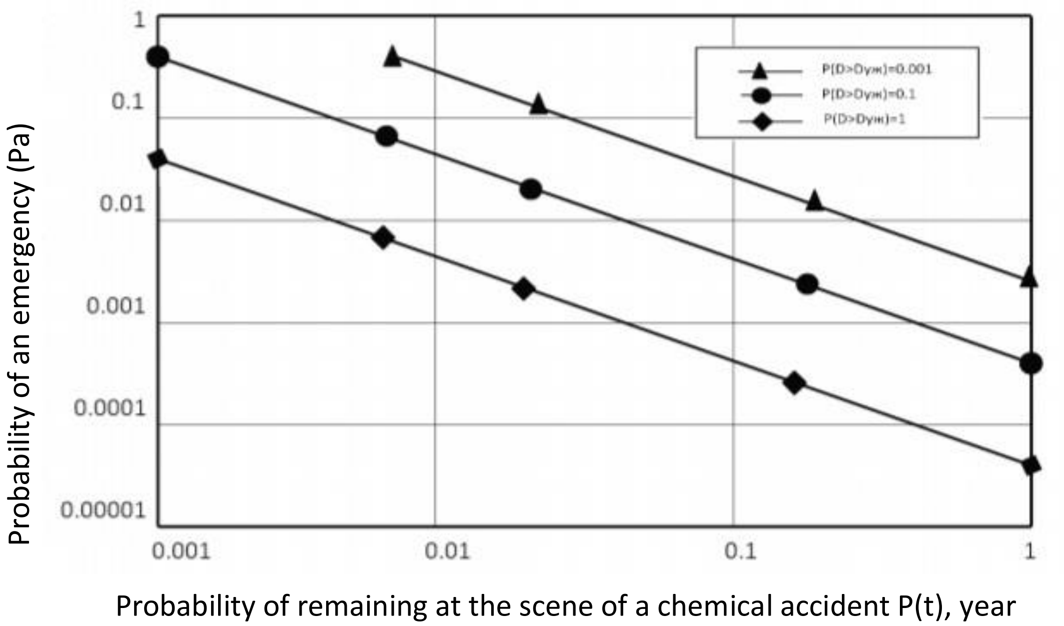

Figure 12. **Scale for assessing the adverse effects risk of hazardous substances**

Damages and losses depend on many factors, such as the amount and type of hazardous chemicals released, the extent of contamination, etc. Both dangerous goods transport risk factors are related to each other because damage will occur in an accident, but damage is not always the direct cause of the accident, so the first factor is more important and plays a bigger role in the justification. transport choice problem; but the second factor should not be forgotten, because it also plays an important role. The probability of loss factor is directly related to the loss of money, because now much attention is paid to their protection (Garcia, 2018, p. 300-308).

The risk criteria have been determined for the specified cities and are expressed as follows:

- Severe risk F>0,1/N
- Mild risk $F<10^{-4}/N$

Transportation of hazardous chemicals and risk assessment of stationary facilities for the population and the environment is carried out as follows:

- Severe risk $F>10^{-3}/N^2$ və ya $10 \leq N \leq 10000$ fatalities
- Mild risk $F<10^{-5}/N^2$ və ya $10 \leq N \leq 1000$ fatalities

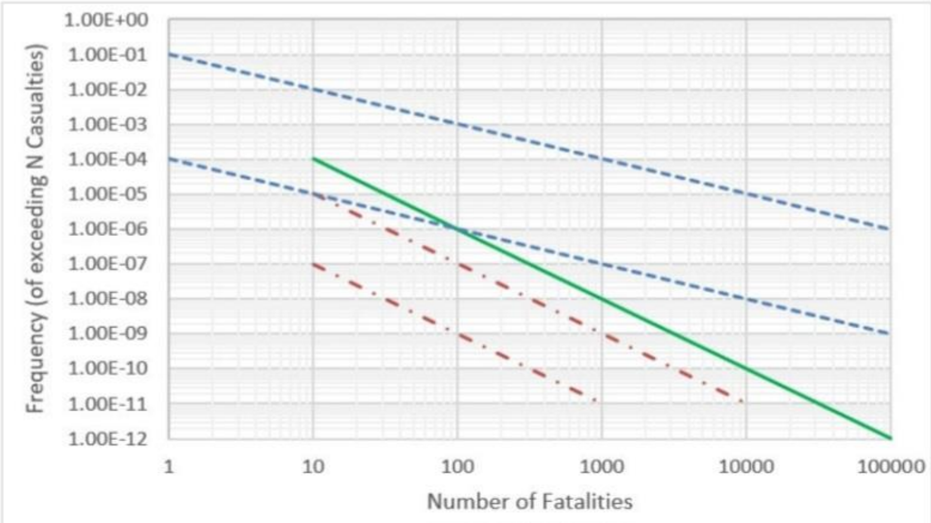

Figure 13. Public risk values for transportation of hazardous chemicals

In order to design an information system that can manage the transportation infrastructure of hazardous chemicals, it is necessary to organize a classification hierarchy that can be related to management. This classification is as follows:

- strategic level,
- tactical level,
- operational level,
- level of control real-time.

Figure 14. Risk classification

The individual risk is defined as the probability in a year that an exposed person, positioned at a precise distance to the source of risk, is hit by the undesired effects of the event. This is formally defined by the following expression:

$$I_r = P_f \cdot P_{df}$$

here P_f – is the probability of accident happening; P_{df} – is the probability of death of the individual if the accident happened.

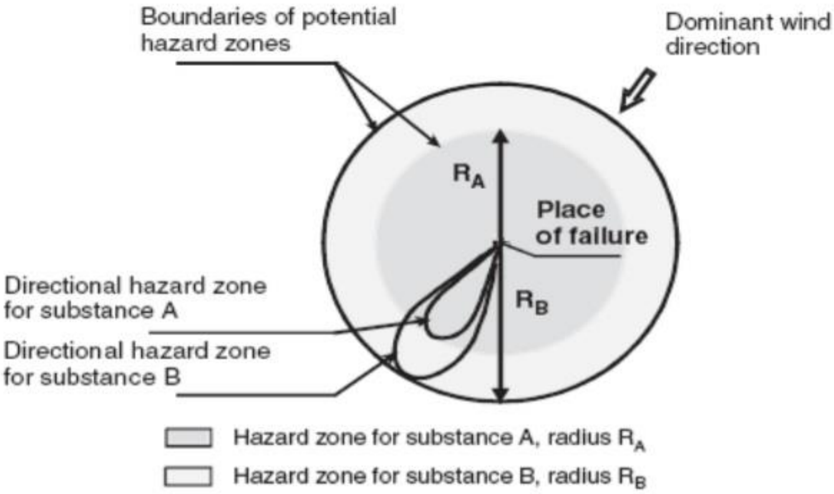

Figure 15. Potential hazard zone, defined after an accidental release of a dangerous goods into the air

The frequency of accidents during the transportation of dangerous chemicals is determined by the following expression:

$$f_i = \gamma_i \cdot L_i \cdot n_i \text{ or } \gamma_i = \gamma_0 \cdot \sum_{j=1}^{6} h_j$$

here γ_i – frequency expected on the i-esimo stretch of roa, (accidents km-1 per vehicle); L_i – road length, km; n_i – number of vehicles; γ_0 – basic frequency (accidents km-1 per vehicle); h_j – parameters of amplification / local mitigation.

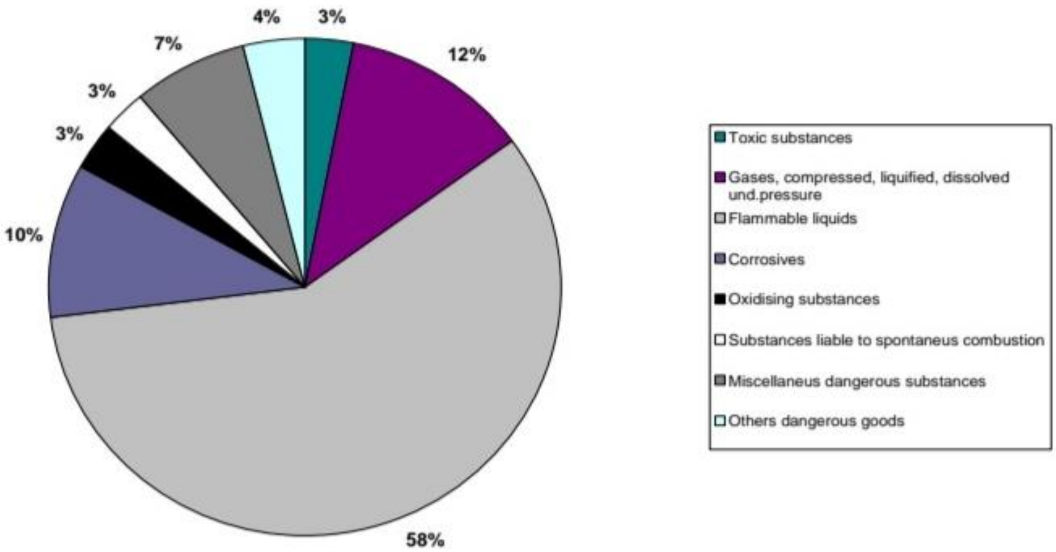

Figure 16. Dangerous goods transported by road

Conclusion

1) A digital procedure for calculating individual and public risks arising from the transportation of hazardous chemicals by road has been presented. It is designed to support decision makers in safety management and safety control activities as well as to transport toxic and flammable substances. In particular, the proposed equation for calculating the individual risk takes into account both the prevailing wind and the current seasonal condition. With regard to social risk,

population distribution modeling is described that takes into account the presence of the population in closed spaces as well as the differences between off-road and on-road populations.

2) During the study, a new man-made risk prevention system was proposed, which revised the risk assessment criteria and included the analysis of existing measures, and had a clearer formulation of the criteria and a simpler methodology of the risk calculation form. It allows employees to assess possible risks while performing work at each stage and to determine preventive measures in advance.

3) For the transportation of dangerous goods, we must consider and evaluate these key aspects:

- the technical basis of the type of transport; the length of the road;
- shipping cost;
- chemical properties of the material and its amount;
- staff training and knowledge base, route;
- climatic conditions;
- the level of probable damage.

4) Risk assessment allows carriers to choose basic transportation criteria, flexibility, and use alternatives. Using risk assessment, it is possible to reduce the probability of an accident and increase traffic safety.

5) Solving risk assessment tasks will allow finding the minimum risk using the same technical and technological means.

6) The causes of accidents are usually man-made, including transport accidents involving dangerous chemicals that expose people to risks with serious consequences. The accident risk is characterized by the local source of danger (leakage of dangerous substances or fire), the magnitude of the danger depends on the distance from the center of the accident. As a large number of people often suffer from accidents, it can be shown as both an individual and a social risk.

References

1. Alexandrovich, A. A. (2020). Chemical hazard risk assessment during road transport of hazardous chemicals. Topic and abstract of the dissertation at the Higher Attestation Commission of the Russian Federation.
2. Gasimov, C. N. (2017). *Emergencies and the environment (textbook).*
3. Gasimov, C. N., Abdullayeva, N. Z. *Dangerous factors of emergencies (teaching material).* Printing house of AzTU.
4. Gasimov, C., Abdullayev, M., Huseynov, A. (2009). *Civil defense. Synopsis of lectures (tutorial for higher schools).* Printing house of AzTU.
5. Aksenov, A. A. (2020). Ways to improve measures to ensure the safety of transportation of dangerous chemically dangerous substances by road transport in the Republic of Mordovia based on the risk assessment of chemical hazards. *"Problems of risk management in the technosphere" scientific-analytical magazine*, 1(53), 56-63.
6. Daineka, A. D. (2023). Increasing the efficiency of transportation of dangerous goods using information technologies. *Transport technic and technology*, 28(475), 17-21.
7. Rasulov, S. R., Badalova, A. N., Safarov, S. H., Ganiyeva, R. Y. (2023). *Transport ecology (textbook).* ASOSU Publication.
8. Snurnikov, A. S. (2023). Risk minimization strategies for transporting dangerous goods on highways. *Occupational safety in industry*, 52(499), 385-397.
9. Javoronkov, N. Yu. (1985). *Risk assessment of chemical hazards of substances and materials transported by water transport.*
10. Savchuk, O. N., Kreitor, V. P., Aksenov, A. A. (2018). Ways to improve the methodology of risk assessment of chemical hazards based on the transport of damage by motor vehicles. 27(10), 2-4.
11. Ojagov, H. O. (2009). *Eliminating the consequences of emergencies (textbook for higher schools).* Printing house of "TI-MEDIA" company.

12. Moroz, E. V. (2020). *Problems of legal regulation of international road transport of dangerous goods.*
13. Smith, J. (2019). *Transportation of Hazardous Materials: Risk Mitigation Strategies*. Wiley.
14. Garcia, L. (2018). *Strategies for minimizing risks in the transportation of dangerous goods.*

Received: 12.05.2024
Revised: 05.07.2024
Accepted: 20.07.2024
Published: 20.08.2024