МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ РОССИЙСКОЙ ФЕДЕРАЦИИ
Государственное образовательное учреждение высшего профессионального образования
«**НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ**»

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The course «Ecological Risk Assessment» deals with contemporary conditions in the sphere of assessment and analysis of technogenic and natural risk. Special attention is paid to hazard and risk assessment of environmental chemical pollution: soil, water, air as a result of anthropogenic activity.

The course objective is to develop the basic concept and technical approaches aimed at the problem solution of safety and sustainable interaction of man and nature; to form the idea of the scale and consequences of anthropogenic impact on the environment, to make students familiar with the principles of quantitative and qualitative assessment of natural and technogenic risks, to develop the complex way of thinking permitting for minimization of negative impact on human and the environment.

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Content

Chapter 1 General concepts about risk

1.1 Main definitions

During last years the term "RISK" became very popular in different areas: engineering, economics, environment, management, biology & medicine, etc. and different authors use this term in different senses. Below we consider some definitions of risk in different sources.

Definitions of risk

There are many definitions of *risk* that vary by specific application and situational context.

One is that risk is an issue, which can be avoided or mitigated

(where in an issue is a potential problem that has to be fixed now.)

Risk is described both qualitatively and quantitatively.

Qualitatively, risk is proportional to both the expected losses which may be caused by an event and to the probability of this event. Greater loss and greater event likelihood result in a greater overall risk.

In engineering, the definition risk often simply is:

$$\text{Risk} = (\text{probability of an accident}) \times (\text{losses per accident}).$$

Or in more general terms:

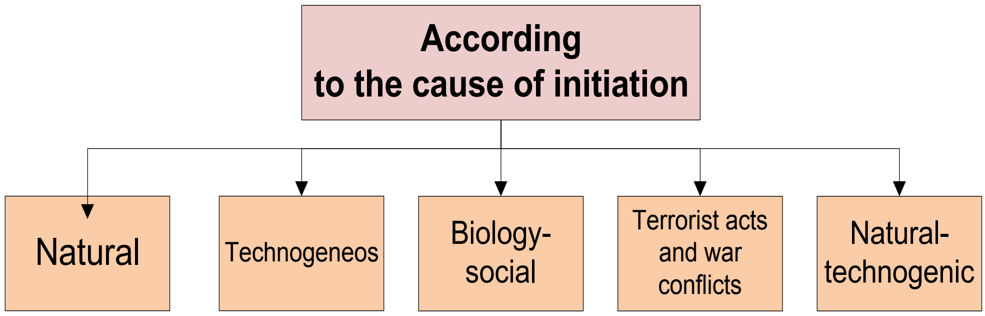
$$\text{Risk} = (\text{probability of event occurring}) \times (\text{impact of event occuring}).$$

In common risk is the chance that something undesirable will happen. Risk is described as a situation which would lead to negative consequences. *Risk* is considered as an indicator of threat, or depends on threats, vulnerability, impact and uncertainty.

1.2 Risk and hazard classification

There are a lot of classifications of hazards and risks. Scientists distinguish types, categories, and indexes of risk. Below the classification of hazards and risks connected with environment is presented.

1 Classification according to the cause of initiation



Natural risks are risks conditioned by catastrophic phenomena of the nature.

Technogenic risks are risks connected with danger resulting from industrial objects or threatening a man and nature in the process of industrial activity.

Biology-social risks are risks resulting from the threat of inflectional disease and group people's poisoning; inflectional diseases of food-producing animals; agricultural plant pest diseases.

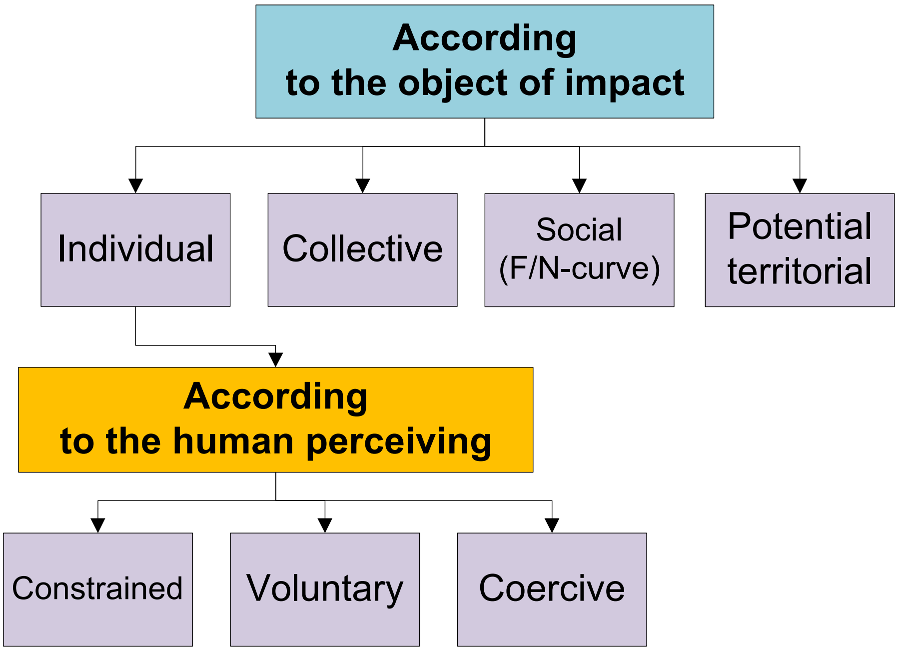
The causes of heavy ecological effects could be terrorist acts and war conflicts. In 1999, April, 17-18 as a result of aviation NATO attack against Yugoslavia near Belgrade several reservoirs with oil products and polyvinylchloride installation were destroyed at the refinery. The substances with cancerogenic and mutagen properties emitted into the atmosphere formed a large polluting cloud harmful for human health and life in the lower atmosphere layers.

Natural-technogenic risks are natural man-induced hazards. Thus, the earthquake in 1971 of 7-grade intensity at Starogroznenskiy oil field was a result of combination of natural and technogenic processes, induced by development of oil deposit. There are numerous examples of the processes conditioned by disturbance of the balance in the subsurface at oil and gas production (Nefteyugansk, 1987–1988).

On the contrary, technogenic accidents and catastrophes taking place nowadays could result from natural disasters. For instance, as a result of an earthquake a nuclear reactor or hydroengineering unit could be destroyed, the consequence of which would be radioactive contamination and area flooding, correspondingly.

The earthquake of 4.9 grade intensity in Richter scale in 1986, January, 31 is of no less interest. It took place in the region not considered as quake-prone – Pery city, Ohio state, the USA. Shortly before the earthquake shock the chemical company "Kalhio" located 11 km from the future epicenter pumped the industrial waste effluents under the pressure into specially drilled wells. The researchers assumed that physical impact made in this case on solid igneous rocks could result in their breakdown along the hidden fault of the Earth crust perceived as the earthquake.

2. Classification according to the object of impact



- **<u>Individual risk</u>** is a frequency of the affections of a single individual as a result of the danger factors investigated.

$\boldsymbol{R}_{\mathbf{ind}}. = \boldsymbol{N_{lo}/N},$

where N_{lo} – number of lethal outcomes in a group of a number N which is subjected to an influence.

- **<u>Collective (integral) risk</u>** determines the scale of expected consequences of potential accidents for people

$\mathbf{R}_{\mathbf{col.}} = \boldsymbol{R}_{\mathbf{ind}} \times \boldsymbol{N_R},$

where N_R – number of people subjected to a risk

• **Social (mean individual) risk** (set of numbers or functional relation) is the relation of a number of events, in which the number of injured persons is higher than a certain number, to this certain number of people.

• **Potential territorial risk** (set of numbers or functional relation) is the space distribution of the frequency of a negative influence of a certain level

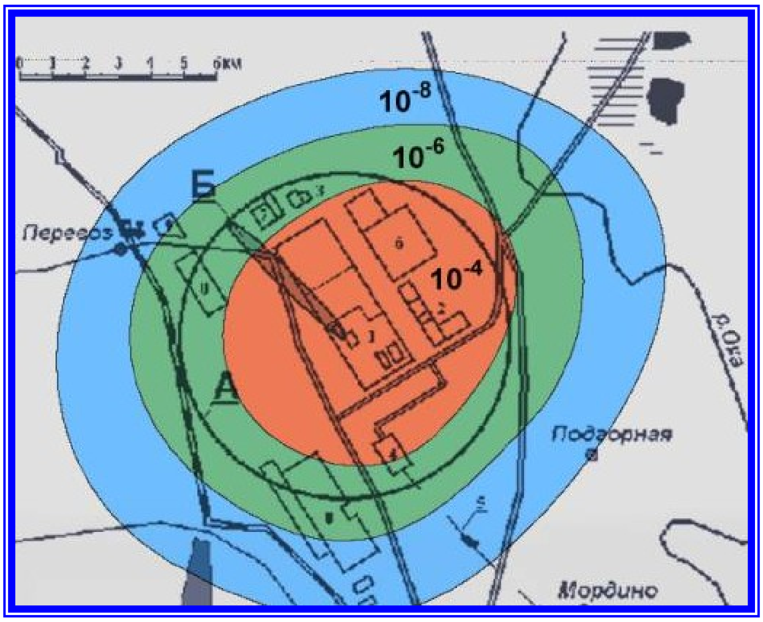
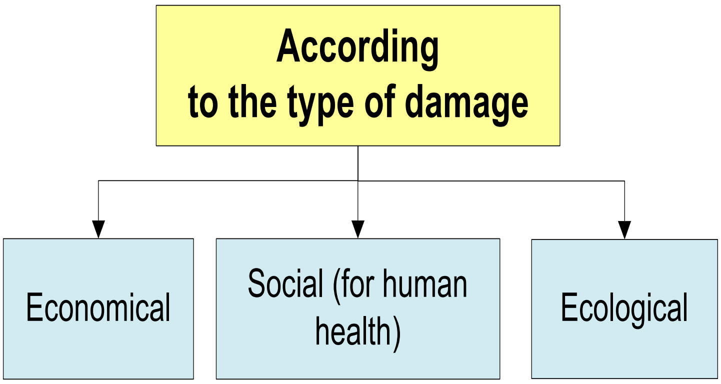


Fig. 1. Distribution of potential risk on territory

Distribution of potential risk on territory near to object on which failures with large emission of toxic substances are possible. By fig. 1 ures at isolines value of frequency of destruction the person (1/year), A – zone border of the people defeat calculated for scenarios of failure with identical weight of emission in all directions of a wind, Б – a zone of defeat for the separate scenario with the given wind direction.

3.Classification according to the human perceiving

- **Compulsory** – for example, habitation near to a dangerous oil refinery enterprise
- **Constrained** are connected with dangerous occupation (for example, working in coal mine)
- **Voluntary** – extreme sports and tourism

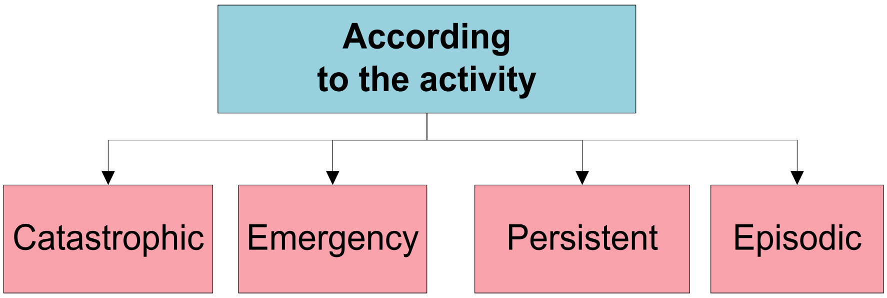


- **<u>Economical damage</u>** is a financial cost estimation of a negative impact on the economy

Or is loss of material assets or loss of profit as a result of nature management

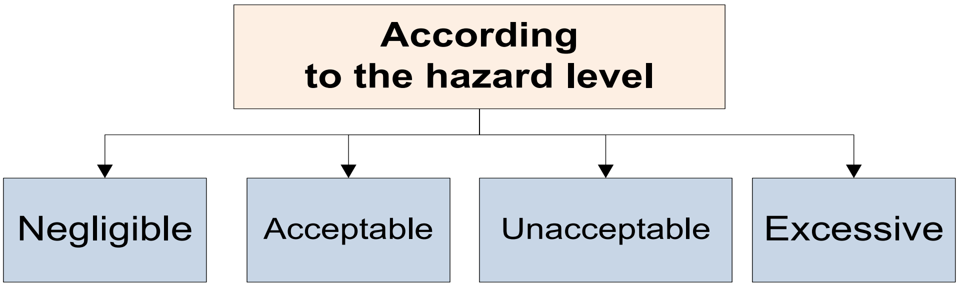
- **<u>Social damage</u>** is a damage or loss of the profit because of the deterioration of life quality, disease growth, mortality, decrease of the quality of recreation zones. It can be expresses as the number of sick, injured or died persons as a result of negative effects or in terms of money.

- **<u>Ecological damage</u>** is a damage for the environment as a result of the negative impact of both natural and anthropogenic processes which can be expressed in terms of money, as the amount of polluted area and as quantitative characteristics of damaged ecosystems



- **<u>Catastrophic risks</u>** are sudden accidents at industry or natural disasters which have mainly destructive effect and are characterized with substantial force
- **<u>Emergency risks</u>** appear as a result of accident (breakage, crash, emergency)
- **<u>Persistent risks</u>** are "creeping", slow processes which have a paralyzing or exhausting effect (radiation effect, destruction of flora and fauna, the consequences of which could be seen foe a long time)

- **Episodic risks** suddenly appear, they are unpredictable in force and form of influence.



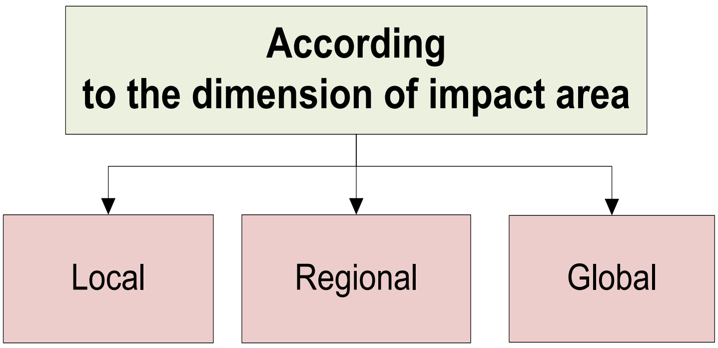
- **Negligible** level is the level of the individual risk which does not lead to the deterioration of the life quality and economical activity, and does not cause a trouble of an individual

- **Acceptable** level is the level of a risk which the society is ready to accept for the sake of certain welfare or benefits in their activity

Or it is the risk, the level of which is acceptable and reasonable in terms of economical and social considerations.

- **Unacceptable** level is the level of a risk determined by administrative or regulating authorities as the maximum, measures for its elimination are necessary in case it is higher.

- **Excessive** level is the level of the individual risk conditioned by economical activity, which exceeds the maximum permissible level**.**



They differ in the space distribution, extent of material damage, number of victims and cause of origin (table 1).

Table 1. Risk classification according to the dimension of impact area

Scale	Area distribution	The scale of damage, $	Death number	Causes
Local	distributed within the limited territories	less than 10^5	up to 1000	engineering
Regional	covers the regions, have a tendency to extend	10^5 -10^8	10^2 -10^4	chemical, engineering, transport
Global	do not have any political or administrative borders			nuclear, military, space rocket complexes, collision with asteroids

1.3 The concept of acceptable risk

The nature itself from one side and the human activity from the other side are sources of risks. The avoidances on large chemical enterprises, breaks in oil- and gas- pipelines etc. represent significant hazard and lead to high damage for population and environment. Since these risks are connected with reliability of appropriate equipment, their study directed to excuse the payment for the providing and support of the necessary level of reliability equipment

Over the years the risk concept has been introduced into the structures of government to provide safety and sustainable development of the country. The "risk" concept is used in a number of federal laws.

For a long period another concept – the so called concept of "absolute safety" or "zero risk" has been the bases of industrial enterprise operation.

The concept of "zero risk" implies such an organization of industrial plant that would exclude any probability of accident completely. Not long ago, 10-15 years ago it seemed that nearly all natural and technogenic hazards could be brought to naught due to improvements in engineering protection, increase in reliability of technical equipment. But after Spitak (07.12.88) and Neftegorsk (28.05.95) earthquakes, subsinking of atomic submarine "Kursk" (9.08.99), a number of accidents at oil- and gas pipelines (Komi republic, 17.08.94, Bashkiria, 03.06.89), leading to severe consequences, the inefficiency of zero risk concept or absolute safety was realized.

"Zero risk" concept does not meet the regulations of technosphere. The regulations of technosphere are of probabilistic nature. There is always a probability of emergencies and accidents. Zero accident probability could be achieved only in the systems without energy storage of chemically or biologically active components.

Besides, the presence of potentially harmful substances in the environment always produces some risk extent, different from zero.

The disadvantages of the concept are:

Firstly, its principal inaccessibility;

Secondly, very high cost of its implementation;

Thirdly, unpreparedness of the staff for efficient actions in case of emergency.

On the basis of assumption of complete accident exception, a lot of nuclear plants were built where efficient safety precautions were provided. Nevertheless, there a number accidents at those plants, the consequences of which were calamitous.

The concept of “zero risk” was replaced by the so-called concept of “acceptable risk”, the basis of which was formed by the principle “to foresee and to prevent”. This concept implies the probability of accident and, hence, the measures for prevention from accident occurrence and development.

Acceptable risk is an acceptable level of risk, justified from the point of view of economic, social, and ecological factors, which society could bear for the sake of gaining some positive outcomes of its activity.

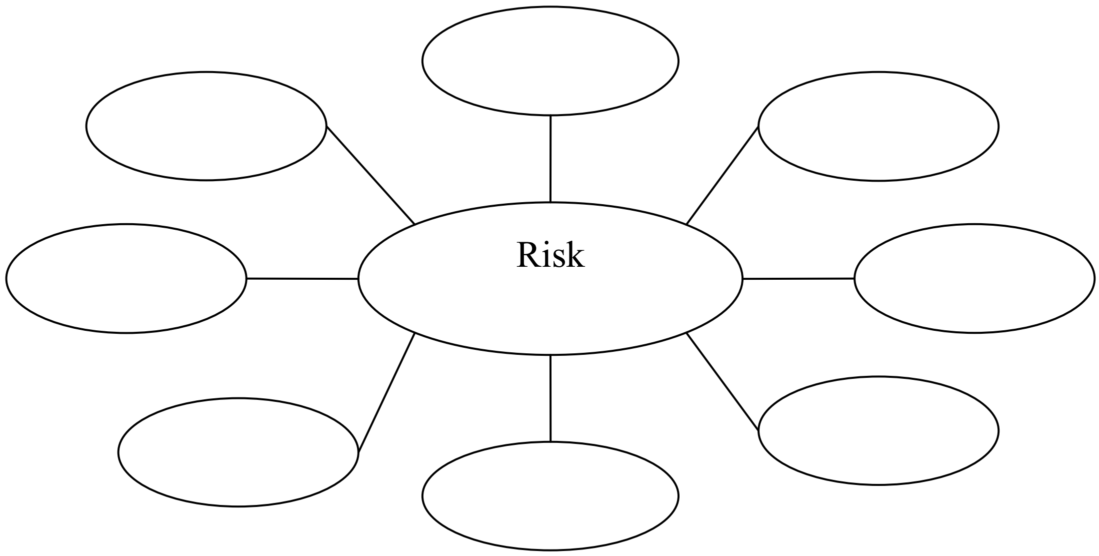
Quantitative characteristic of risk level is the numeric value of individual risk. Individual risk is characterized by one numeric magnitude, i.e. probability of deaths per one person a year. It is a universal feature of hazard for human being that constitutes the foundation of acceptable risk level standardization.

The analysis of domestic and foreign documentation concerned with standardization of safety and risks indicates the fact that acceptable magnitude of one person death probability during a year (acceptable individual risk) ranges 10-5 ÷ 10-6. In this case the probability value 10-6 is sometimes called desirable (upper) level of individual risk, but the probability value 10-5 is acceptable (lower) level of individual risk.

Feasibility evaluation of risk levels (unacceptable, acceptable, negligible) requires careful consideration as a large complex of technical, economical, social, and psychological problems taking into account the local factor.

Questions for checking.

1. Lead-in. Fill in the spidergram with the words associated with the word “risk”. Explain your associations.



2. Give all possible definitions of risk. In what spheres could they be used?

Over to you:

2. The annual number of victims in road accidents all over the world amounts to 1.2 million a year. Estimate an individual risk of loss of life in road accidents in the world. Assume the population number is 6.5 billion according to 2006.
3. Estimate the probability of dearth (Personal risk, year $^{-1}$) caused by the events listed below.
   - Calculate the number of expected fatal outcomes for 1 million human beings.
   - Arrange the causes listed below in column 1 in the sequence according to descent of the degree of danger.

Table 2. Estimation of the number of sudden death events in USA in 1973

The cause of an accident	**Total number of deaths**	**Personal risk, year $^{-1}$**	**Number of expected fatal outcomes for 1 million human beings**
Background (natural) radiatione.g.solar radiation	7200		
Medicine radiodiagnosis and radiotherapy	3300		
nuclear industry	3		
Other causes isn't connected with radiation	398500		
Air pollution	20000		
aviation accident	1778		
rail disaster, train crash	798		

Take the population of the USA in 1973

Chapter 2 Development of research in the sphere of risk analysis and assessment

Legislation in industrial safety started to form in the developed industrial countries in the 70–80's. One of the key components for industrial safety law regulation is performance of risk or safety analysis.

At the European Community level there are several legal acts that directly or indirectly address risk through rules governing industrial establishments housing hazardous materials, landfill sites and waste treatment plants. Regulations that govern lifeline systems operations such as electrical power plants, gas and oil pipelines, and water resources and trans-boundary issues may also indirectly address risk reduction.

One of the first legislation documents containing the requirement for performing safety analysis, the guideline of European Community 82.501.EEC 1 Seveso II Directive. It requires for an employeer working in hazardous site to prove to the governmental authorities, members of the Community the fact that they have identified the risks, taken the necessary safety measures for employers working in the site, given the safety instructions. Risk analysis is supposed to be a part of Safety Report developed by an employers.

Requirements governing prevention of chemical accidents in the European Community appear in the Seveso II Directive (98/82/EC). The aim of the Seveso II Directive is to: "Prevent major accidents which involve dangerous substances, and to limit their consequences for man and the environment with a view to ensuring high levels of protection throughout the Community in a consistent and effective manner."

Under the Seveso II Directive industrial facilities that store, use or handle dangerous substances are required to set out a major-accident prevention policy, write and submit a safety report, and establish emergency plans in the case of an accidental chemical release. The requirements of these regulations are usually met by an industrial facility through the creation and implementation of the safety report. Typically, the safety report includes three components: identification of hazards, implementation of adequate safety measures to prevent chemical accidents, and establishing emergency response plans. The hazard assessment includes a process safety analysis; process safety information; evaluation of mitigation measures; external events analysis; and consequence analysis. The emergency response program incorporates measures taken to protect human health and the environment in response to an accidental release. The emergency response plan requirements also include notifying the public and local agencies; and reviewing and testing of the plans.

Although the Seveso II Directive does not have any specific requirements for natural and technogenic risk management, it is addressed indirectly. First, the Seveso II Directive calls for the analysis of external events in “The identification and accidental risk analysis and prevention methods” section (Section IV of Annex II). The analysis of “external events” which may lead to a chemical accident implies the consideration of the potential threat of natural hazards in the hazard analysis, and carrying out preventive measures to reduce the likelihood of an accident and to establish preparedness measures in case an accident occurs.

However, the Directive does not specify methodologies or actions that can be taken to achieve these requirements, therefore the levels of preparedness vary among countries. Second, Article 8 of the Directive calls for the analysis of potential domino effects. In the requirements of Article 8, the competent authority must study the likelihood of domino effects of a major accident given the location, the proximity of several establishments toone another, and their inventories of dangerous substances in order to reduce the consequences if an accident does occur.

And third, Article 12 of the Directive requires that prevention of chemical accidents and mitigation of their potential consequences be taken into account through the establishment of land use policies. Through land use policies competent authorities can assure that appropriate distances are kept between establishments, residential areas and areas of particular “natural sensitivity”.

Both Articles 8 and 12 are of particular importance when addressing natural - technogenic risk reduction. Several researchers have noted that domino effects may be more likely during natural disasters than during normal plant operation, particularly earthquakes. The likelihood of domino effects will depend among other factors on the proximity of vulnerable units containing hazardous substances within or at a neighboring establishment, and the consequences will undoubtedly increase with the proximity of residential areas.

The European Commission has published a set of Guidelines to help member states fulfill the requirements of the Seveso II Directive. The guidelines specifically recommend analyzing the potential effects of natural hazards (e.g. floods, earthquakes, extreme temperature changes, winds) and other external hazards in the hazard analysis. The guidelines however do not provide specific actions or methodologies that can be taken to prevent, mitigate or respond to natural-technogenic risk events. Therefore the particular problems associated with natural-technogenic risk such as loss of emergency water, prolonged power shortages, and other nonstructural related problems may be overlooked.

In Great Britain in 1985 the basic part of legislation to prevent large accidents called SIMAH was developed and approved as a system of legislation acts. It is an English version of Seveso Directive confirming the necessity to perform danger analysis. Probabilistic risk analysis is not mandatory in Great Britain, however, authorities have the right to consider the solution supported by calculations more acceptable. The booklet «Five stages of risk assessment» is published in Britain by the Health and Safety Department specially for industrial employees. Consideration of foreign approach to risk assessment permits for understanding the fact that risk is closely connected with the man, his activity, his assessment «for himself». The following procedure of risk assessment at the industrial enterprise has been commonly accepted.

An employee of Industrial Safety Department responsible for risk assessment is to complete the following form (Table 4), where there is such information as: evaluation of the exposure risk for the territory in vicinity of enterprise, the enterprise employees, equipment and installations; who and what hazard are exposed; what measures are to be taken to on the sites; what hazards are to be paid special attention to; what action are to be performed. The list of risk analysis includes the information of the date and person who makes risk assessment and checking; what positive outcomes are achieved as a result of taken measures etc.

Table 3. The list of risk analysis documents at an enterprise (Great Britain)

Area/Job/Machine………………………………………………..

HAZARD	WHO MIGHT BE HARMED	CONTROLES IN PLACE	WHAT MORE IS NEEDED	ACTION REQUIRED AND PRIORITY

ASSESSMENT BY……………..
DATE……………

TO BE REVIED BY………….. OR AFTER SIGNIFICANT CHANGE

Currently in the US the analysis and risk management scheme developed by Risk Assessment and Management Committee of the US Congress is widely used. The model includes six successive steps:

- Identification of the problem and its consideration in the context of concrete conditions;

- analysis of risk conditioned by the given problem in its context;
- thorough study of possible approaches to the problem solution and decrease in danger degree;
- taking decision on performance of this or that alternative;
- realization of the taken decision;
- evaluation of the results obtained.

Application of the given scheme is performed with repetition of necessary steps (iteration) in case of new data changing the nature itself of risk management or putting in doubt the necessity of the process.

At present in Russia the methods of risk analysis based on the experience of risk analysis and assessment in European countries, the USA have been also developed. The following factors contributed to the development of the research in the sphere of risk management in Russia:

1. Traditional fields of mechanics, the theory of machines and mechanisms in particular, deal with the study of reliability of various devices. Such methods as event tree and failure tree have been taken from this sphere into the theory of risk management that played significant role in risk investigation intensity.
2. The progress in the field of industrial and environmental safety was initiated due to some large industrial accident or catastrophe.
3. A wide circulation of foreign experience of risk analysis.
4. Development of managements as a science contributed to the comprehension of the process organization in risk analysis and assessment.

However, for its implementation it is necessary to develop the appropriate legislative documents. This process in Russia is gradually achieving the real pace. The greatest problem in adaptation of foreign experience in Russia consists in the difference in social and economic conditions, mechanisms of economic regulation in nature protection. The problems are worsened by the fact that in English sources the terms “risk estimation», «risk evaluation”, “risk assessment”, often having different meaning, but translated as “risk assessment are used. The approaches and methods of risk analysis and assessment developed in Russia are presented below.

Chapter 3 Technogenic hazards and risks

3.1 Contradictions in the interactions within system "nature – technosphere-society"

Development of technogenic sphere has resulted in the two directly opposite consequences:

On the one hand, great results are achieved in electron, atomic, cosmic, aviation, power, and chemical industries as well as in biology, genetic engineering, providing the humankind with opportunity to reach the crucially new levels in all spheres of life and production.

On the other hand, there appear previously unseen potential and real hazards and danger for a man, environment, and buildings not only in time of war but also in peace time.

These hazards appear in recent decades under the impact of great technogenic catastrophes on the enterprises of different profiles: nuclear (the USSR – Chernobyl, economic damage is about 400 bln. $, the USA – Three Mile Island, economic damage is about 100 bln. $ etc.), chemical (India, Italy etc.); cosmic and aviation (the USA – "Challenger", the USSR – rocket accidents at starts etc.); pipeline and transport systems and others.

Only in Russia there are about 100 000 dangerous enterprises. Nearly 2300 among them are nuclear and 3000 chemical plants of high hazard. In nuclear industry about 10^{13} , but in chemical about 10^{12} of lethal toxodoses are concentrated.

The statistic analysis of accidents and catastrophes in Russia made by the State Safety Service shows that the number of fatal cases has increased by 10-25%, and in some industries, for example in aviation – by 50% annually. Thus, according to the data of RF Emergency Control Ministry in 2001- 617 accidents of technogenic nature took place (apart from accidents with transport and industrial injuries) in which 3309 workers were injured, 1157 died. Economic damage because of accidents and catastrophes is constantly increasing, though not so drastically.

There is a shift of accident consequences towards the increase in the number of fatal cases at the relative stabilization of economic losses due to direct damage from accidents and recovery efforts. This phenomenon is observed against the decline in primary production and decrease in the number of potentially hazardous units. Hence, the specific incident rate for hazardous units is growing fast over the recent years.

Decline of industrial production, engineering and transport, decrease in the number of potentially hazardous units has improved the environmental conditions in general, but at the same time there appear a very dangerous tendency to the growth of portion and degree as well as absolute number of the severest accidents and catastrophes, which add social and physiological factors to usual economic losses, the former being sometimes of greater importance than economic factors.

The situation is worsened by the fact that most of the potentially hazardous units and industries are characterized by running out the project reserves and lifespan. Further operation results in sharp increase of failures. Shutting down the potentially dangerous units running out the reserves and lifespan poses a new and complex, scientific, economic, and social problem, the solution of which could not be avoided by the humankind.

Of no less concern is the problem of estimation of remaining reserves and lifespan. The problem is observed in other branches of industry including transport and construction. The life length of machines and equipment in the primary industries amounts: less than 10 years – 50%, from 10 to 20 years – 30%, more than 20 years – 20%.

Thus, a large number of foreign and domestic equipment with running-out lifespan and without calculated lifespan operates at chemical, petrochemical, refinery enterprises. Besides, there is an obvious tendency to the growth of failure (including emergencies) due to the reasons conditioned by the old age and installation damage.

In Russia the systems of main pipelines (MP) are of more than 200 000 klm. length, having about 6000 technically sophisticated surface units of extra hazard operate: compressor, pumping, and gas-distribution plants, tank batteries. Accident risk at MP plants is of rather high level and has a tendency to growth: the number of accidents in 1996 increased by 40% in comparison with 1995. The "aging" processes of pipelines (certain pipelines operate more than 40 years) are characterized by decrease in reliability due to metal corrosion and fatigue, defects of technological and operational origin (a kind of crimp, buckle, undercut and others). 40 000 kilometer of pipelines and 25% oil pipelines have run out their calculated lifespan.

The following data indicate the range of economic losses in technogenic accidents. These data include the analysis of 170 accidents with maximum economic losses over 30-years period (up to 1991), taken place in the field of mining, transport, and refining of hydrocarbons. Out of 170 accidents 123 took place in the course of every-day operation of enterprise, 43 – during the period of shutdown, start-ups, and repair. In this case the average damage of accidents in everyday operation is 1.5 times less than in accidents in the periods of shutdowns and start-ups.

Table 4. Distribution of economic losses in terms of accident processes types

Type of accident	Per cent of damage	Total number of accidents	Average damage per an accident, mln. $
Fires	36	62	36,1
Cloud explosions	35	59	59,6
Explosions	25	43	33,6
Others	4	6	24,7
Total	100	170	43,2

Table 5. Distribution of economic losses in terms of accident types at various enterprises

Enterprises	Explosions	Fires	Cloud explosions	Others
Refineries	15%	48%	31%	6%
Oil-chemical plants	46%	17%	37%	0%
Terminals	22%	44%	28%	6%
Gas-processing plants	0%	40%	60%	0%
Other plants	7%	50%	36%	7%

Table 6. Distribution of economic losses in terms of the causes of accidents

Accident cause	Per cent of losses	Average damage, mln. $
Mechanical destructions	41	39,0
Operational error	20	51,8
Unknown cause	18	38,6
Breach of operation order	8	51,1
Natural disasters	6	45,4
Project error	4	57,6
Sabotage	3	26,2

Table 7. Distribution of economic losses in terms of the types of equipment, at which the accident failure took place

Equipment	**Loss percentage**	**Average damage, mln. $**
Pipelines	29	47,6
Reservoirs, tanks	16	42,7
Reactors	13	67,9
Other installation	8	27,3
Drums	7	26,1
Sea crafts	4	35,5
Unknown equipment	7	39,6
Compressor-pumps	6	29,1
Heat exchange units	4	23,8
Surface casings	4	58,5
Heating boilers	2	18,6

3.2 Chemical accidents and spills

By their nature, the manufacture, storage, and transport of chemicals are accidents waiting to happen. Chemicals can be corrosive, toxic, and they may react, often explosively. The impacts of chemical accidents can be deadly, for both human beings and the environment.

Many if not most products we use in everyday life are made from chemicals and thousands of chemicals are used by manufacturing industries to make these products. The source of many of these chemicals is petroleum, which is refined into two main fractions: fuels and the chemical feedstock that are the building blocks of plastics, paints, dyes, inks, polyester, and many of the products we buy and use every day. Fuels and chemical feedstock made from petroleum are called organic chemicals. The other important class of chemicals is inorganic, which include acids, caustics, cyanide, and metals. Commercial products made from inorganic range from car bodies to computer circuit boards.

Of the more than forty thousand chemicals in commercial use, most are subject to accidental spills or releases. Chemical spills and accidents range from small to large and can occur anywhere chemicals are found, from oil drilling rigs to factories, tanker trucks to fifty-five-gallon drums and all the way to the local dry cleaner or your garden tool shed.

Fig. 2. A train derailment near Milligan, Florida. The train carried chemicals, which were spilled at the site.

One of the worst industrial chemical disasters occurred without warning early on the morning of December 3, 1984, at Union Carbide's pesticide plant in Bhopal, India. While most people slept, a leak, caused by a series of mechanical and human failures, released a cloud of lethal methyl isocyanate over the sleeping city. Some two thousand people died immediately and another eight thousand died later. Health officials, not informed about chemicals at the factory, were completely unprepared for the tragedy.

Congressional hearings that followed the Bhopal accident revealed that U.S. companies routinely discharged hazardous chemicals into the air, while emergency planners knew little about the potential for disaster at local industrial facilities. Less than a year later, a Union Carbide plant that produced methyl isocyanate in Institute, West Virginia, leaked a toxic cloud in the Kanawha Valley. While the West Virginia incident was not another tragedy, it was a shocking reminder that an accident such as the one that occurred at Bhopal could happen in the United States.

The hearings and media attention to institute led to enactment of the Emergency Planning and Community Right to Know Act of 1986 (EPCRA), requiring companies to provide information about their potentially toxic chemicals. At the same time, states were required to establish emergency planning districts and local committees to prepare for any emergency—a fire, an explosion, a flood that might result in the release of chemicals into the environment. In 2003, more than 31,000 industrial facilities must report more than 650 individually listed toxic chemicals and chemical categories to the U.S. Environmental Protection Agency (EPA) that is made public in the Toxic Release Inventory.

In 1990, amendments to the Clean Air Act required industrial chemical companies to submit a risk management plan that included "worst case" chemical accident scenarios. Industry leaders did not want these potential disasters made public and argued that they could alert terrorists which facilities to target. In July 2002, the Senate's Environment and Public Works Committee approved a bill to identify plants vulnerable to terrorist attacks that produce hazardous chemicals. Congress also voted against a landmark community right to know law that would have required some 6,600 chemical facilities to reveal their "worst case" accident scenarios. Although the major chemical accidents seem most threatening because they often kill people outright, it is the smaller, more routine accidents and spills that affect most people. Some of the most common spills involve tanker trucks and railroad tankers containing gasoline, chlorine, acid, or other industrial chemicals. Many spills occur during the transportation of hazardous materials; one study found that 18,000 hazardous materials spills occurred during 1976. In 1983, spills from 4,829 highway and 851 railroad accidents resulted in eight deaths, 191 injuries, and damages exceeding more than $110,000,000. The National Environmental Law Center reported that 34,500 accidents involving toxic chemicals were reported to the EPA's Emergency Response and Notification System between 1988 and 1992, meaning that on average, a toxic chemical accident was reported nineteen times a day in the United States, or nearly once every hour.

Emergency response workers are especially at risk. In 1988 six firemen were killed minutes after arriving at the scene of two burning pick-up trucks in Missouri, when more than 30,000 pounds of ammonium nitrate stored in a nearby trailer exploded. This incident led to the formation of the hazardous materials division of the Kansas City, Missouri, Fire Department, specializing in hazardous materials handling.

To help emergency responders know what they are dealing with, the Department of Transportation (DOT) has established a hazardous materials placard system. Rail cars and trucks carrying toxic or dangerous materials must display a diamond-shaped sign having on it a material identification number, which can be looked up to determine what hazardous materials are on board, and a hazard class number and symbol that tells whether the contents are flammable, explosive, corrosive, etc. Color codes also convey instant information: blue (health), red (flammability), yellow (reactivity), white (special notice). The placard system is as follows:

- Hazard class 1: Explosives (class 1.1-1.6, compatibility groups A–L)
- Hazard class 2: Gases (nonflammable, flammable, toxic gas, oxygen, inhalation hazard)
- Hazard class 3: Flammable liquids
- Hazard class 4: Flammable solids (flammable solid, spontaneously combustible, dangerous when wet)
- Hazard class 5: Oxidizer and organic peroxide

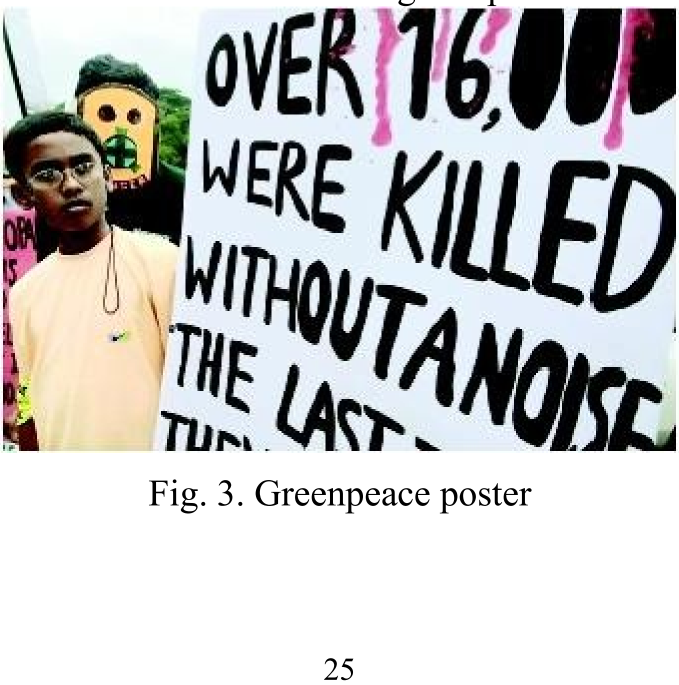


Fig. 3. Greenpeace poster

This boy is looking at a Greenpeace poster, which expresses solidarity for the victims of the Union Carbide chemical disaster in Bhopal, India, eighteen years after the incident (Fig. 3).

- Hazard class 6: Toxic/poisonous and infectious substances labels (PG III, inhalation hazard, poison, toxic)
- Hazard class 7: Radioactive (I, II, III, and fissile)
- Hazard class 8: Corrosive
- Hazard class 9: Miscellaneous dangerous goods

One of the most common concerns over chemical accidents and hazardous materials spills is acute, or short-term, toxicity. Acutely toxic contaminants, such as cyanide and chlorine released from hazardous materials spills, pose an immediate threat to public health. For example, a chemical accident in which chlorine gas or cyanide gas is released would likely result in widespread deaths as the plume, or toxic cloud, moved through a populated area. Another class of toxicity is chronic, or long term. One of the most common types of chronic toxicity is exposure to carcinogens that may result in cancer twenty to thirty years after the time of the spill. An example of such an exposure occurred on July 10, 1976, in Meda, Italy, a small town about 12 miles north of Milan, where an explosion occurred at the ICMESA chemical plant in a 2,4,5-trichlorophenol reactor. (2,4,5-Trichlorophenol is an industrial chemical used as a building block to make pesticides and antiseptics.) A toxic cloud containing dioxins, which are very potent cancer-causing chemicals, was released into the atmosphere and spread across the nearby densely populated city of Seveso. Exposure to such carcinogens does not result in short-term health problems, but the effects may be expressed decades later. An investigation of women who were exposed to high levels of dioxin in the ICMESA explosion was published in 2002. The researchers found that the women who developed breast cancer had a ten-fold increase of the toxic chemical in their blood.

Another very different effect of chemical spills and accidents is ecotoxicity, a toxic effect on the environment rather than on human health. The most dramatic ecotoxicity resulting from chemical spills results from petroleum spills at sea or in rivers or lakes. When such a catastrophe occurs, the toxicity often depends on the type of petroleum. The most common material spill, crude oil, contains some toxic chemicals that dissolve in the water. Most of the petroleum, however, floats on the water's surface. It causes environmental damage by coating the feathers of birds and the gills of fish, physically disrupting their movements and their ability to breathe. Oil washed ashore also disrupts marine life in fragile areas. One of the worst oil spill disasters in history occurred on March 24, 1989, when the oceangoing oil tanker Exxon Valdez ran aground on Bligh Reef in Alaska's Prince William Sound. Nearly eleven million gallons of crude oil spilled from the ship, and every trophic level of the biologically rich waters of Prince William Sound was severely impacted. Some residual oil remains to this day.

Emergency response personnel are involved in assessing the risk of hazardous material releases and working to avoid any harmful effects. Teams of workers evaluate the concentrations of the chemicals, where and how people might be exposed, and potential toxic effects on the exposed people. In many cases, emergency response teams are on twenty-four-hour call; if a spill occurs, they use source data (such as the hazmat placards on trucks and tanker cars), databases of chemical properties, and chemical movement models to rapidly predict the movement of contaminants and the toxicity of the spilled chemicals. If rapid spill cleanup is necessary, the emergency response team designs and implements cleanup measures to protect exposed populations and ecosystems from toxic responses. A wide range of cleanup systems has been developed for chemical spills. Small spills on land are cleaned up by simply excavating the contaminated soil and moving it to a secure landfill. Oil spills on water are contained using floating booms and adsorbents, or solid materials that capture the soil, so that it can be disposed of in landfills. Newer, more innovative methods for spill cleanup include bioremediation (using bacteria to metabolize the contaminants) and chemical oxidation (using oxidants, such as hydrogen peroxide and ozone to break the chemicals down). Although chemical spills represent potentially very large environmental problems from a wide range of chemicals, emergency response procedures developed by environmental scientists and engineers are providing solutions to the resulting human health and ecological effects.

Chemical accidents and spills can be devastating to humans, wildlife, and the environment. The best way to reduce the harm caused by chemical accidents is to design plants with better safety controls that operate at lower temperatures and pressures, and to use and manufacture less toxic compounds, a field that is being pursued by "green" chemists and engineers. But until toxic chemicals are routinely replaced by less harmful substitutes, the emergency response procedures developed by environmental scientists and engineers help lessen the human health and ecological effects of chemical spills and accidents.

3.3 Methods of qualitative hazard analysis

Hazards analysis can get pretty sophisticated and go into much detail. Where the potential hazards are significant and the possibility for trouble is quite real, such detail may well be essential. However, for many processes and operations — both real and proposed — a solid look at the operation or plans by a variety of affected people may be sufficient. The easiest and possibly most effective method is using the step-by-step process of the Job Hazard Analysis (JHA).

WHAT - IF Checklist: The what - if checklist is a broadly-based hazard assessment technique that combines the creative thinking of a selected team of specialists with the methodical focus of a prepared checklist. The result is a comprehensive process hazards analysis that is extremely useful in training operating personnel on the hazards of the particular operation.

The review team is selected to represent a wide range of disciplines — production, mechanical, technical, safety. The team is then provided with basic information on hazards of materials, process technology, procedures, equipment design, instrumentation control, incident experience, previous hazard reviews, and so on. A field tour of the process is also conducted at this time, assuming the process is in operation.

The review team methodically examines the process from receipt of raw materials to delivery of the finished product to the customer's site. At each step the group collectively generates a listing of what - if questions regarding the hazards and safety of the operation. When the review team has completed listing its spontaneously-generated questions, it systematically goes through a prepared checklist to stimulate additional questions.

Subsequently, answers are developed for each question. The review team then works to achieve a consensus on each question and answer. From these answers, a listing of recommendations is developed specifying the need for additional action or study. The recommendations, along with the list of questions and answers, become the key elements of the hazard assessment report.

Hazard and Operability Study (HAZOP): HAZOP is a formally structured method of systematically investigating each element of a system for all of the ways in which important parameters can deviate from the intended design conditions to create hazards and operability problems. The hazard and operability problems are typically determined by a study of the piping and instrument diagrams (or plant model) by a team of personnel who critically analyze the effects of potential problems arising in each pipeline and each vessel of the operation.

Pertinent parameters are selected — for example, flow, temperature, pressure, and time. Then the effect of deviations from design conditions of each parameter is examined. A list of key words such as more of, less of, none of, part of, are selected for use in describing each potential deviation.

The system is evaluated as designed and with deviations noted. All causes of failure are identified. Existing safeguards and protection are identified. An assessment is made weighing the consequences, causes, and protection requirements involved.

Failure Mode and Effect Analysis (FMEA): The failure mode and effect analysis is a methodical study of component failures. This review starts with a diagram of the process that includes all components which could fail and conceivably affect the safety of the process. Typical examples are instrument transmitters, controllers, valves, pumps, and rotometers. These components are listed on a data tabulation sheet and individually analyzed for the following:

- Potential mode of failure ... open, closed, on, off, leaks, etc..
- Consequence of the failure.
- Effect on other components.
- Effect on whole system.
- Hazards class ... high, moderate, low.
- Probability of failure.
- Detection methods.
- Compensating provision/remarks.

Multiple concurrent failures are also included in the analysis. The last step is analysis of the data for each component or multiple component failure and development of a series of recommendations appropriate to risk management.

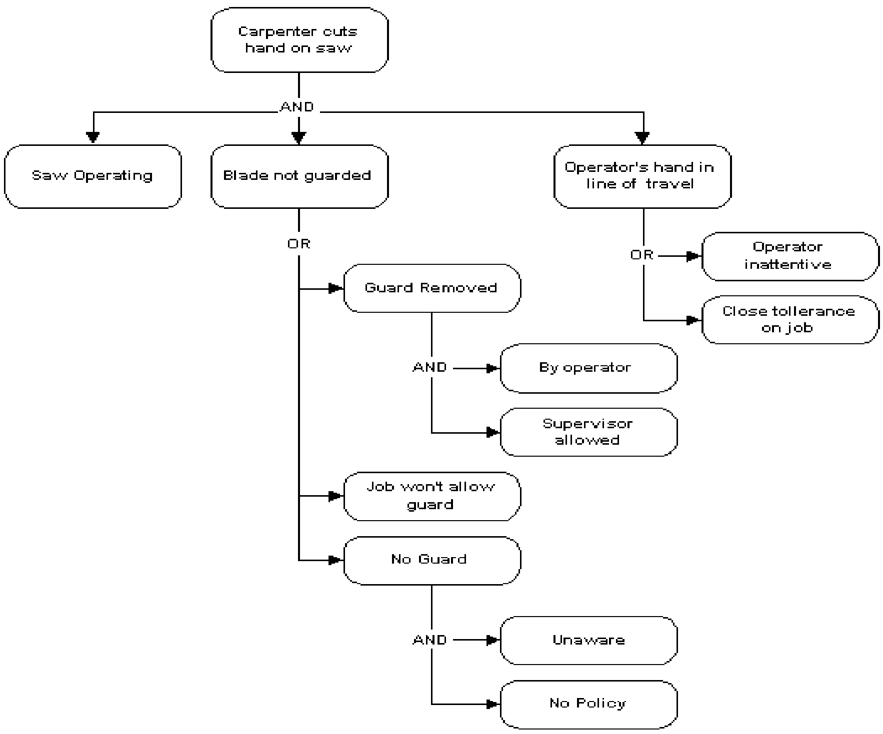


Fig. 4. Fault Tree Analysis

A fault tree analysis is a quantitative assessment of all of the undesirable outcomes, such as a toxic gas release or explosion, which could result from a specific initiating event. It begins with a graphic representation (using logic symbols) of all possible sequences of events that could result in an incident. The resulting diagram (Fig.4) looks like a tree with many branches — each branch listing the sequential events (failures) for different independent paths to the top event. Probabilities (using failure rate data) are assigned to each event and then used to calculate the probability of occurrence of the undesired event. A simple example of a fault tree analysis chart is shown before.

The main advantage of the fault tree method consists in the fact that the analysis is concerned with only those elements of the system and events that would result in a definite system failure or accident.

Event Tree Analysis – ETA is an algorithm of event sequence designing resulting from the main event (accident). The method is used to analyze the development of accident or emergency. The frequency of every scenario for development of accident is calculated by means of multiplying the frequency of the main event by the conditional probability of the final event (i.e., decompression accident, ignition accident). The risk assessment result is the list of outcomes for each event, in this case the frequency and consequences are calculated, i.e. the magnitudes of expected effect.

Do the following tasks

1. Analyze technical, social, and economic causes of increase in number of technogenic accidents and catastrophes.

2. Make conclusion on distribution of economic losses of technogenic accidents and catastrophes depending on the type of accident processes and equipment used, causes of accidents, types of industrial processes using Tables 4 – 7

Chapter 4 Natural risks and hazards

Major Natural Disasters according to the Number of Victims:
Ниже перечислены наиболее крупные природные катастрофы of the XX th century

Flooding in China in 1959 (2 million victims)
Drought in India in 1965-1967 (1,5 million victims)
Hurricane in Bangladesh in 1970 (300 thousand victims)
Earthquake in China in 1976 (240 thousand victims)
Collapse in Peru in 1970 (70 thousand victims)
Volcanic eruption on Martinique in 1902 (26 thousand victims)

4.1 Main definitions

- **NATURAL HAZARD –** process, quality or state of some parts of lithosphere, hydrosphere, atmosphere or space, harmful to people
- **NATURAL RISK –** natural danger probability measure (the sum total of dangers), determined for concrete object as possible looses at definite time
- **DANGEROUS NATURAL PHENOMENON–** non-artificial origin event or natural processes activities result which can cause harmful effect to people, economic facilities and environment due to their intensity, expansion scale, and length.
- **VULNERABILITY** – material object property to loose the ability to realise its natural or prescribed functions affected by dangerous process

Risk is a part of life, but natural disasters boggle the mind. The international impacts of the various types of natural hazards in terms of fatalities are shown in Table 8. Over the interval 1960-87, tropical storms were somewhat more devastating than earthquakes; however, mortality statistics are very closely correlated with specific events, such as the 1970 Bangladesh typhoon, and the earthquake of 1976 near Tangshan, China. Over the course of time, geologic and climatic disasters seem to be about equally deadly.

Table 8. The international impacts of the various types of natural hazards in terms of fatalities

Hazard type	Deaths*	Largest event and Date	Death Toll
Tropical cyclones	622,400	Eastern Pakistan (Bangladesh) 1970	500,000
Earthquakes	497,600	Tangshan, China 1976	250,000
Floods	36, 400	Vietnam 1964	8, 000
Avalanches, mudslides	30, 000	Peru 1970	25, 000
Volcanic eruptions	27, 500	Columbia 1985	23, 000
Tornadoes	4, 500	Eastern Pakistan (Bangladesh) 1969	500
Snow, hail, wind storms	3, 100	Bangladesh 1986 (hail)	300
Heat waves	1, 000	Greece 1987	400

Hazards are relatively sudden events (disasters) that endanger lives and property. The ultimate cataclysm for life throughout the solar system would be the explosion of our Sun as a supernova; nearly as devastating would be the terrestrial impact of a large asteroid. Two principle types of hazard may be distinguished: natural and technogenic. Geologic catastrophes such as earthquakes, avalanches, volcanic eruptions, and seismic sea waves (tsunamis), and meteorologic-oceanographic disasters such as typhoons, droughts, floods, and lightning-strike forest fires, constitute some of the main types of natural hazard. Technogenic, or human-induced, disasters reflect the unwise, or at least unlucky, impingement of human activities on the environment. Examples of technogenic hazards include the collapse of seawalls, levees, bridges, and buildings; dam failure; chemical and radiation pollution; and war. The anthropogenic-induced gradual degradation of the environment and loss of biodiversity are sure to be calamitous as well, and may have more far-reaching impacts on the planetary web of life. However, natural disasters are defined as characteristically sudden, brief, and in some cases, unexpected events.

Solar radiation impinging on the Earth drives the circulation of the atmosphere and the oceans. The dynamic flow patters we know as weather and ocean currents are manifestations of the redistribution of thermal energy among the fluid envelopes of our planet. Hurricanes, typhoons, and cyclones are simply extreme examples of this energy transfer process. Because the Pacific Ocean is the world's largest solar energy sink, this basin is the site of the most devastating tropical storms and ocean-induced droughts. Coastal erosion and flooding also constitute a major hazard in low-lying portions of the region. Climatic hazards are well-understood phenomena, however, the underlying reasons accounting for geologic hazards are much less obvious. Hidden from view, the imperceptible mantle circulation, which is driven by buried heat, produces the crustal motions collectively known as plate tectonics. Such processes are responsible for the differential motions of lithospheric slabs. The boundaries of the plates are marked by intense seismicity, volcanic activity, and land slumpage. Climatic and geologic disasters cause great human suffering and financial loss, especially within the Pacific Basin and around its margins. If global temperatures continue to climb as a consequence of an intensifying greenhouse effect, the ferocity and number of tropical storms will also rise, coastal erosion and flooding will accelerate, and the vulnerability of the world's burgeoning tidewater communities to devastation by tsunamis will increase. Millions of lives will be endangered, not to mention the economies of the nations affected.

Historically, humans typically have failed to consider natural disasters in the appropriate physical and historic context. Rather, each is viewed as a unique event – typically "act of God". Following an earthquake, landslide, flood, typhoon, structures are rebuilt by the survivor and life-style are resumed, in many cases exactly as before the disaster is the same vulnerability with regard to a future event perpetuated. Moreover, as populations grow, their expansion into, and utilization of, hazard-prone, marginal environments increases; consequently, the overall risk is heightened.

Sea-floor spreading, continental drift, and plate tectonics are inexorable manifestations of the transfer of thermal energy from the Earth's deep interior toward the surface and the cyclonic storms are a function of solar energy input. These processes will forever lie beyond the limits of human ability to modify them; we can never completely eliminate their accompanying natural catastrophes. Understanding the basic causes of these phenomena means for us to organize our lives and reinforce our structures to minimize the dangers. At all scales information can avert potentially devastating loss of lives through clear recognition and assessment of hazards, appropriate land use, construction of safe …, and timely, accurate warning of an impending danger, volcanic eruption, landslide, tsunami, coastal flooding, and hurricane force wind.

Avoidance or alleviation of the adverse impacts of hazard necessitates their clear recognition, qualification of the processes involved, accurate assessment of associated risk, an avoidance or technologic mitigation. The first three steps require Earth system scientific and engineering investitions; the fourth involves preventive procedures such as redesigning and reinforcing buildings, bridges, and dams, and constructing all-weather shelters and seawalls. Absolutely crucial to the fourth, sociopolitical process is wide-spread public understanding and appreciation of the problems of natural hazards. Once the potential danger properly assessed, mitigation can take place through the implementation of engineering solutions, the optimization of wise land use, effective public education, and continuous planning for emergencies. However, effective implementation of our scientific knowledge and engineering capacities requires widespread public understanding and support, something that is largely lacking at present around the world.

4.2 Classification of natural hazards

A **natural disaster** is the consequence of a natural hazard (e.g. volcanic eruption, earthquake, or landslide) which affects human activities. Human vulnerability, exacerbated by the lack of planning or appropriate emergency management, leads to financial, environmental or human losses. The resulting loss depends on the capacity of the population to support or resist the disaster, their resilience. This understanding is concentrated in the formulation: "disasters occur when hazards meet vulnerability". A natural hazard will hence never result in a natural disaster in areas without vulnerability, e.g. strong earthquakes in uninhabited areas. The term *natural* has consequently been disputed because the events simply are not hazards or disasters without human involvement.

Natural hazards divide according to the activity on the events of the catastrophic and long movement.

Natural risks of catastrophic character are

- the geophysical dangerous phenomena (earthquakes, eruptions of volcanoes)
- the dangerous geological phenomena (landslips, mud flow, collapses, taluses, avalanches)
- the meteorological dangerous phenomena (storms, hurricanes, squalls, tornadoes)
- the sea dangerous hydrological phenomena (cyclones, a tsunami)
- the hydro-geological and hydro-geological dangerous phenomena (flooding)
- natural fires.

Catastrophic processes are mostly dangerous for human life because of their unexpectedness, power, and uncertainty. In the order of the victims decreasing number they are arranged in the following way: drought, vortexes (hurricanes), floods, earthquakes, eruptions of volcanoes, snowfalls, tsunami, landslip, mud flow, snow-slip, rockslide

Specific features of low-intensity processes are as follows: long-term preparation period and prolonged ecological consequences.

In the order of area size decreasing where they can impair living conditions and make discomfort they are arranged in the following way: desertification, fluctuations of level world ocean, a new growth and frozen ground degradation, a deflation, change of level of reservoirs, bogging, thermokarst, linear erosion, karstic processes, abrasion, suffosion, icing mound.

4.3 Causes of natural hazards

«The Earth's surface is not only an area of matter, it is also an area of energy» (V.I. Vernadsky). In fact, the development of numerous complex physical, physical-chemical, and biochemical processes take place on the Earth's surface and in its adjacent layers, this process is accompanied by exchange and transformations of various energy forms. The energy source is the processes of matter rearrangement occurring in the interior of the Earth, physical and chemical interactions of its outer shells and physical fields as well as heliophysical effects. Those processes form the basis for the Earth's evolution and its natural environment, being the source of continuous transformations of the planet appearance – its geodynamics. A man is not capable of stopping or changing the process of evolutionary transformations, he can only forecast their development and in some cases influence their dynamics. Within the last few decades dangerous natural processes are activated by the growing anthropogenic pressure on the environment.

4.4 The main tendencies in the development of natural hazards.

Every year the number of natural hazards, the number of victims as well as economic losses is growing in the world. According to the data of the International Conference on Natural Hazards (Iokogama, 1994), the number of victims has increased annually on average within the period from 1962 to 1992 by 4,3%, injured – by 8,6%, and the value of economic losses – by 6%. The number of died people from seven types of disasters on the Earth within 35 years amounts 3,8 mln. These data demonstrate the decrease in people and industrial object protection from natural hazards.

The consequences of natural hazards are closely connected with social-economical factors. Continuous growth of poverty in developing countries is one of causes of increase in human society vulnerability for natural hazards.

The rise in the number of natural disasters in the world is conditioned by some global processes in social, natural, and technogenic spheres, that determine the intensification of natural hazard development and decrease in people protection. Accelerated growth of critical conditions is connected with not only uncontrolled increase in human population but also the growth of technogenic impact on the environment.

As a result of climate changes explained by increase in temperature on the Earth the intensification of natural dangerous processes is observed. Even regular forecast for Ocean level rise could result in floods of some countries and inundating of low coastal areas, increase in flooding frequency and area of flooded zone, intense development of coastal erosion, destruction of dams, strengthening of waves etc.

4.5 General regularities in natural hazard development

In spite of variety of natural hazard processes, there are some general regularities in their development.

- Definite spatial coincidence
- The higher intensity, the rarer occurrence
- Some specific phenomena are followed by definite type of hazard
- Possible prediction at all unexpectedness
- Possibility of predicting and planning active and passive measures
- Human activity results in intensity of natural hazards

Among natural hazards there is interconnection. One event could be a reason, a starting point for the other one. The peculiarity of natural hazards consists in the fact that each of them causes a chain of quickly or slowly developing processes, some of which could be momentary and catastrophic, the other – with remote environmental effect.

Main characteristics of the most common scales of natural hazards and universal scale of disaster categories are presented in tables 9, 10.

Table 9. Main characteristics of the most common scales of natural hazards

Phenomenon	The parameter measured	The name of the scale	Estimated characteristic	The range of measurement	Scale structure	The number of grades
Earthquake	Shaking the earth's surface	Magnitude scales (different)	Magnitude	About 10 orders (in amplitude)	Logarithmic	9
	The same	MSK	Intensity	The same	Logarithmic	12
Wind	Wind velocity	Beaufort wind scale	Intensity	300-fold	Mixed	13
Hurricane	Wind strength	Saffir–Simpson Hurricane Scale	Magnitude of intensity	3-fold	Mixed	5
	The same	Hurricane detailed scale	Magnitude of intensity	2-fold	Nearly logarithmic	9
Tornado	Wind strength	Fujita scale	Magnitude of intensity	5-fold	Nearly logarithmic	6
	The size of exposed area	Parson	Magnitude	Up to 3 orders	Logarithmic	7
Tsunami	Wave amplitude	Inda scale	Magnitude of intensity	30-fold	Logarithmic	6
Eruption	Volume f erupted material	VEI index	Magnitude	About 8 orders	Logarithmic	8
Land slide	The same	Fedotov's scale	Magnitude	about 8 orders	Logarithmic	12
Land slide	Volume of shifting rock	Volume	Magnitude	7 orders	Logarithmic	7
	Shifting speed	Speed	Magnitude (energy)	10 orders	Logarithmic	7

Table 10. The project of universal scale of disaster categories

Category	Name	Number of victims	Damage at «quick» hazards in dollars (the USA)	Damage at «slow» hazards in dollars (the USA)	Recommended level of taking decisions
I	Global disaster	31 mln – 3 billion people	151 billion– 15 trillion	601 billion – 60 trillion	Safety Committee of UNO
II	Continental disaster	301 th. – 30 mln. people	1,4 billion – 150 billion	6,1 billion – 600 billion	Committee of Country Regional Union
III	National disaster	3001 people. – 300 th. people	14 mln –1,5 bil	61 mln–6 billion	Government of country
IV	Regional, territorial disaster	31–3000 people	151 th.– 15 mln	601 000– 60 000 000	Head of local administration
V	Regional disaster	1–30 people	1,6 th.–150 th.	6,1 000 – 600 000	Head of regional administration, mayor
VI	Local disaster	No victims	Less than 1,5 000	Less than 6 000	Chairman, prefect

4.6 Natural risk analysis

The process of natural risk analysis is ultimately aimed at decrease in social, economic, and ecological damages from dangerous natural impacts. An ideal procedure of such an analysis is a permanent cyclic process including:

1) identification and prediction of natural hazard development in time and space;

2) vulnerability assessment of damaged objects for all stated genetic types and kinds of natural hazards;

3) assessment of partial and integral risk losses from hazards;

4) natural risk management.

The general scheme – a sequence of natural hazard analysis is presented in the Table 11.

Table 11. The general scheme – a sequence of natural hazard analysis

Identification and prediction of natural hazards .	**Vulnerability assessment of industrial objects and population**
1. What natural hazards, where and in what circumstances could damage the territory involved? 2. What is their intensity, frequency and impact duration? 3. Mapping of natural hazard forecast	1. How is or will the territory used (be used)? 2. What object are there on the territory or are supposed to be built? 3. What is the number, composition, distribution in objects and motion of the population? 4. What is vulnerability of some objects and population under the impact of hazards of definite type and intensity?
Natural risk management	**Natural risk assessment**
1. What measures are supposed to be taken to decrease the risks? 2. What levels of risk are taken as acceptable ones? 3. How will the information exchange and natural hazard, risk and conditions management be performed? 4. What is the attitude of population to the stated hazards, risks, precaution measures and control? 5. What additional measures are necessary to be taken to decrease and control the risks?	1. What scenarios of development and consequences of natural hazards are possible? 2. What is the probability of these scenarios development? 3. What would be the losses in case of separate hazards? 4. What would be the summary losses?

Answer the questions

1. Why do natural hazards boggle the mind?
2. What is hazard?
3. What types of hazards are there? What are the examples of natural hazard?
4. What impact does Solar radiation have on the Earth?
5. What processes are responsible for the differential motions of lithospheric slabs?
6. What are the consequences of intensifying greenhouse effect?
7. How do humans view natural disasters?
8. How does the population grow influence the hazard risk?

9. What processes lie beyond the limits of human ability to change them?
10. What should be done to minimize the danger of hazards?
11. What does the avoidance or alleviation of the hazard impact necessitate?
12. What preventive procedures does the fourth step involve?
13. Why does implementation of scientific knowledge and engineering capacities require widespread public understanding and support?

Discuss the following questions:

1. Which of the natural disasters learnt in the Unit seems most easily mitigated in terms of time? Money? Decreased threat to life? Ease of public awareness and willingness to plan for mitigation? Which appears to be most intractable, and why?
2. In a region with which you are familiar, identify three geologic and/or climatic hazards. Pick one and, as spokesperson for the local Natural Hazards Mitigation Board, indicate how you would proceed in order to alleviate its dangers to the populace. What obstacles might hinder the adoption of your recommendations by local decision makers?
3. Why is the Circum-Pacific region at significantly greater risk from natural disasters than most other areas – for example, the Atlantic coast? What special precautions would you make with regard to buying a house or starting up a business in the specific Pacific Rim location?
4. Describe and justify the emergency plans you would recommend for your family and for your community in order to survive a geologic catastrophe if you resided in one of the following cities: Hilo (Hawaii), Tokyo (Japan), Los-Angeles (California), Dallas (Texas), Santiago (Chile), London (England). Identify the hazards, their attendant risks, and the likelihood and magnitude of potential damage.
5. Earthquake forecasts generally consist of four elements: likelihood, location, intensity, and timing of the seismicity. Compare the specific societal value to the citizens of San-Francisco of the following predictions of an impending magnitude

Chapter 5 Classification and effect of air pollutants

Pollutants are the main creators of pollution which cause damage to the target or receptor. Target is always adversely affected by pollutant. It may be man, plant, tree, building, or material.

Air pollutants occur either as gases or particulate matter (PM). PM pollutants are very small particles (1-10% the diameter of a human hair) of solid or liquid substances. All pollutants may be divided into two main categories: Primary and secondary air pollutants. Primary air pollutants are emitted directly into the air. They include particulates, sulphur dioxide, carbon monoxide, nitrogen oxides, and hydrocarbons. Secondary pollutants are produced by reactions between primary pollutants and normal atmospheric compounds. For example, ozone forms over urban areas when primary pollutants react with sunlight and natural atmospheric gases. Thus, ozone is a secondary pollutant.

According to their sizes and scale stationary sources of pollution are grouped into three categories: point sources, fugitive sources, and area sources. Point sources emit pollutants from one or more controllable sites, such as smokestacks at power plants (Fig. 5). Fugitive sources include dirt roads, construction sites, farmlands, surface mines, and other exposed areas where fire and wind can inject material into air (Fig. 6). Area sources (also called non-point sources) include urban areas, agricultural areas sprayed with herbicides and pesticides, and similar well-defined areas.

Mobile sources emit pollutants while moving from place to place. These include automobiles, trucks, buses, aircrafts, ships, and trains (Fig. 7).

Pollutants are generally classified into the following categories:

1. Gaseous pollutants.
2. Particulate pollutants.
3. Aerosol pollutants
4. Pesticides.
5. Metallic contaminants.
6. Carcinogens.
7. Radioactive pollutants.
8. Biological contaminants.

Gaseous pollutants are gases in nature at normal temperature and pressure. These also include vapors of compounds whose boiling points are below 200^0C. These pollutants include a variety of inorganic and organic gaseous materials.

Inorganic gases include noxious gaseous pollutants like oxides of nitrogen (NO), oxides of sulphur (SO), oxides of carbon, hydrogen sulphide (HS), ammonia, chlorine, hydrogen fluoride, hydrogen chloride, oxides of phosphorus, hydrogen cyanide, bromine and mercaptans, etc. these primary pollutants are emitted and as such are not found in the atmosphere. Secondary pollutants are also formed in the air and are mainly generated by exhaust of automobiles and industrial emissions.

Organic gases include hydrocarbons and other compounds such as formaldehyde, acetone vapors, alcohols, organic acids, methyl isocyanide, chlorinated hydrocarbons, etc.

Particulate matter is present in atmosphere in fairly large numbers and poses a serious air pollution problem. Particulate pollutants are classified according to their particle size and nature into fumes, dust, ash, carbon smoke, lead, asbestos, mist, spray, oil, grease etc.

Aerosol pollutants remain suspended in air and consist of fine particles of different organic and inorganic compounds having diameter less than 100 μ.

Pesticides are released into the atmosphere mainly by man-made agricultural practices and industrial waste disposal. Run-off from agricultural land contributes these pollutants to water. Today damage from pesticides is increasing enormously and newer hazards are still created. Insecticides, fungicides and pesticides cause considerable environmental deterioration.

Metallic contaminants occur in the atmosphere as a result of industrial activity discharging metals into air, water and soil. Wind or rain also releases metals from soils and rocks of earth's crust to rivers and seas. Various metals creating environmental hazard are essential dietary trace elements required for growth and development of plants, animals and human beings. These elements are Ca, Al, Ba, Co, Pb, Ag, Ti, Zn etc. Most of the metals are indestructible poisons to living organisms and are ubiquitous in the environment. Examples are Cd, Pb, Cr, Be, Ba, Mn, etc. These are most toxic.

Carcinogens such as benzidine, vinyl chloride, ethylene dichloride etc. present in air cause cancer in man and animal affecting DNA and cell growth.

Radioactive pollutants include particulate and electromagnetic radiations which cause chronic cellular damage in man and animals. Naturally occurring radiations like cosmic and terrestrial radiation enter into biosphere and affect the whole biota. The adverse known effects of radiation are numerous and varied. Radioactive pollution results from nuclear experiments, radioactive elements, drainage from hospitals, industries, and research institutions. Since aquatic flora and fauna can absorb and concentrate radioactivity, the man and animals dependent on them accumulate dangerous amounts of radioactive isotopes.

Biological contaminants deteriorate the atmosphere and their impact on human health is still worst. There exists numerous air borne microorganisms, pathogens, bacteria, viruses, and parasites which are added as air pollutants in the atmosphere. Their effect on living organisms is obviously undesirable.

Fig. 5. Smokestack pollution

Fig. 6. Fugitive sources of air pollution

Fig. 7. Mobile sources of air pollution

Through its interdisciplinary environmental teams, industry is directing large amounts of capital and technological resources both to define and resolve environmental challenges. The solution of the complex environmental problems requires the skills and experience of persons knowledgeable in health, sanitation, biology, meteorology, engineering and many other fields.

Each air and water problem has its own unique approach and solution. Restrictive standards necessitate high retention efficiencies for all control equipment. Off-the-shelf items, which were applicable in the past, no longer suffice. Controls must now be specifically tailored to each installation. Liquid wastes can generally be treated by chemical or physical means, or by a combination of the two, for removal of contaminants with the expectation that the majority of the liquid can be recycled. Air or gaseous contaminants can be removed by scrubbing, filtration, absorption or adsorption and the clean gas discharged into the atmosphere. The removed contaminants, either dry or in solution, must be handled wisely, or a new water- or air-pollution problem may result.

Industries that extract natural resources from the Earth, and in so doing disturb the surface, are being called upon to reclaim and restore the land to a condition and contour that is equal to or better than the original state.

Air quality management. The air contaminants which pervade the environment are many and emanate from multiple sources. A sizable portion of these contaminants are produced by nature. The greatest burden of atmospheric pollutants resulting from human activity comprises carbon monoxides, hydrocarbons, particulates, sulphur oxides and nitrogen oxides, in that order. About 50 % of the major pollutants come from the use of the internal combustion engine.

Industrial and fuel combustion sources together contribute approximately 30 % of the major pollutants.

The general trend in gaseous and particulate control is to limit the emissions from a process stack to a specified weight per hour based on the total material weight processed to assure compliance with ambient air regulation. Process weights become extremely large in steel and cement plants and in large nonferrous smelters. The degree of control necessary in such plants can approach 100 % of all particulate matter in the stack. Retention equipment can become massive both in physical size and in cost. The equipment may include high-energy venturi scrubbers, fabric arresters, and electrostatic precipitators. Each application must be evaluated so that the selected equipment will provide the retention efficiency desired.

Sulphur oxide retention and control present the greatest challenges to industrial environmental engineers. Ambient air standards are extremely low and the emission standards calculated to meet these ambient standards place an enormous challenge on the affected industries. Many copper smelters and all coal-fired utility power plants have large volume, weak-sulphur-dioxide gas streams with limestone slurries or caustic solutions is extremely expensive, requires prohibitively large equipment, and creates water and solid waste disposal problems of enormous magnitude. Installations employing dry scrubbing have been used on very low-sulphur-dioxide gas streams.

Copper smelters are required to remove 85-90 % of the sulphur contained in the feed concentrate. Smelters using the old-type reverbatory furnaces produce large volumes of gas containing low concentrations of sulphur dioxide which is not amenable to removal by acid making. However, gas streams from newer-type flash and roaster-electric furnace operations can produce low-volume gas streams containing more than 4 % sulphur dioxide which can be treated more economically to obtain elemental sulphur, liquid sulphur dioxide, or sulphuric acid. Smelters generally have not considered the scrubbing of weak-sulphur-dioxide gas streams as a viable means of attaining emission limitations because of the tremendous quantities of solid wastes that would be generated.

The task of upgrading weak smelter gas streams to produce products which have no existing market has led to extensive research into other methods of producing copper. A number of mining companies piloted, and some have constructed, hydrometallurgical plants to produce electrolytic-grade copper from ores by chemical means, thus eliminating the smelting step. These plants have generally experienced higher unit costs than smelters and a number have been plagued with operational problems. It does not appear likely that hydrometallurgical plants will replace conventional smelting in the foreseeable future. Liquid ion exchange followed by electrowinning, is also being used more extensively for the heap leaching of low-grade copper. This method produces a very pure grade of copper without the emission of sulphur dioxide to the atmosphere.

Questions for checking

1. Name some of the pollutants.
2. What harm can they do to the environment?
3. How can they affect the human health?
4. According to what criteria can they be classified?
5. How are pollutants generally treated? Name four different processes referred to in the text.
6. What are the main causes of air pollution?
7. What is the usual way to control emissions of gas and particles into the atmosphere?
8. Which gas is mentioned as being particularly difficult to control?
9. What industries are affected by regulations to control the emissions of this gas?
10. What kinds of air pollution are found in your area? What could be done to control them?

Chapter 6 Soil Pollution: Classification and Effects

6.1. Soil Pollution

With rapidly advancing technology man's impact upon the world of natural resources is beginning to prove overwhelming. Rapid urbanization with the consequent increase in population and building has resulted in the reduction of lands for the wastes to be disposed. Every year solid wastes are increasing tremendously all over the world depending on living standards of people. Moreover, several hazardous chemicals and mountains of wastes are ultimately dumped on the land. Dumping of industrial and municipal wastes causes toxic substances to be leached and seep into the soil and affects the ground water course (Fig. 8).

The crux of the waste problems in land lies in the leachates and great amount of wastes. Such leachates percolate out of garbage heap are known to move slowly through the layers of soil beneath and contaminate the water resources deep down the land. However, the problem of soil pollution differs from air and water pollution in the respect that the pollutants remain in direct contact with the soil for relatively longer periods. The wide-spread industrialization and increasing consumption have changed the very complexion of soil. Thus, soil is getting heavily polluted day by day by toxic materials and dangerous microorganisms released into air, water, and food chain. For all this man is the original and basic pollutant responsible for pollution hazards and toxic effects.

Soil pollution results mainly from the following sources: industrial wastes, urban wastes, radioactive pollutants, agricultural practices, chemical and metallic pollutants, biological agents, mining, resistant objects, soil sediments.

Disposal of industrial waste is the major problem responsible for soil pollution. Industrial pollutants are mainly discharged from pulp and paper mills, chemical plants, oil refineries, sugar factories, tanneries, textiles, etc. Many industrial effluents are either discharged into streams or dumped into surrounding area. Industrial wastes mainly consist of organic compounds along with inorganic complexes and non-biodegradable materials. These pollutants affect and alter chemical and biological properties of soil. As a result, hazardous chemicals can enter human food chain from soil or water; disturb the biochemical processes finally leading to serious effects on living organisms.

Urban wastes (Fig. 9) comprise both commercial and domestic wastes consisting of dried sludge of sewage. All urban solid wastes are commonly referred to as refuse. Solid waste or refuse contribute to soil pollution. They contain garbage (or rubbish) materials like plastics, glasses, metallic cans, fibers, paper; street sweepings, fuel residues, leaves, containers, abandoned vehicles and other discharged products. Soil gets enormous quantities of waste products each year. Much of sulphur dioxide evolved during burning of sulphur containing fuel ends up on soil as sulphates which react with soil water to form sulphuric acid.

Modern agricultural practices pollute soil to a large extent. Today with advancing agro-technology huge quantities of fertilizers, pesticides, herbicides and soil conditioning agents are employed to increase the crop yield. Many agricultural lands have now excessive amounts of plants and animal wastes which pose soil pollution problem. Apart from farm wastes manure slurry, debris, soil erosion containing mostly inorganic chemicals are reported to cause soil pollution.

Nowadays the most commonly anticipated problem is soil contamination with toxic chemicals. Well documented constituents include mercury, chloride, nitrite, zinc, iron and cadmium which have adverse effects on crop productivity. Toxic metals may be absorbed by plants grown in contaminated soil and then accumulate in animals eating the plants reaching the chronic toxic levels. However pollution control methods significantly reduce indiscriminate dumping into sewer lines. Sewerage sludge could become a product with lesser extents of potential hazards.

But soil gets also large amount of human, animal and birds excreta constituting the major source of land pollution by biological agents. Digested sewage sludge as well as heavy application of manures to soil without periodic leaching could cause chronic salt hazard to plants within a few years. Besides, faulty sanitation, municipal garbage, waste water and wrong methods of agricultural practices also induce heavy soil pollution. Sludge contains harmful viruses and viable intestinal worms. In developing countries intestinal parasites constitute the most serious soil pollution problems.

Another source of pollution is mining activity. In surface and strip mining the top and sub soil is removed. So, soil damage and environmental degradation during mining is inevitable as vegetation has to be removed too, and huge amount of top soil and waste rocks are to be shifted to a new location. That's why mining leads to loss of grazing and fertile lands, soil erosion from waste dumps, sedimentation and siltation, danger to aquatic life, damage to flora and fauna as well as soil pollution.

To solve these problems the rehabilitation strategy needs to be broad based and made interdisciplinary. Appropriate cost effective measure includes storage of top soil, selection of ecologically and socio-economically suitable species, improvements in hydrological regime, support in afforestation, fuel wood conservation etc.

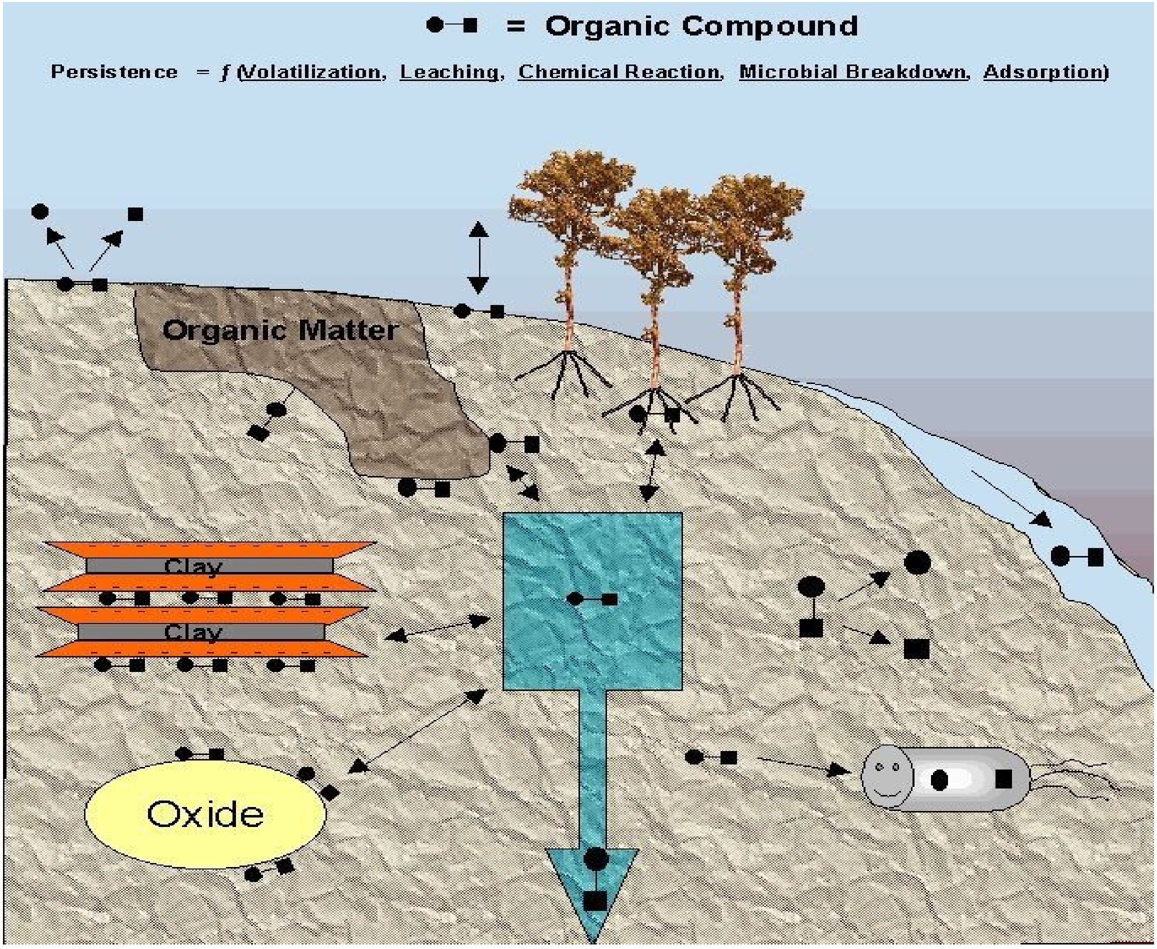


Fig. 8. Process of soil pollution

Fig. 9. Urban wastes

6.2 Soil erosion and soil sustainability

Soil eroded from one location has to go somewhere else. A lot of it travels down streams and rivers and is deposited at their mouths. U.S. rivers carry about 3.6 billion metric tons per year of sediment, 75 % of it from agricultural lands. That's more than 25 000 pounds of sediment for each person in the United States. Of this total, 2.7 billion metric tons per year are deposited in reservoirs, rivers, and lakes. Eventually, these sediments fill in these bodies of water, destroying some fisheries. In tropical waters, sediments entering the ocean can destroy coral reefs near a shore. The sediment deposits on the reefs block out the sunlight that photosynthetic reef organisms need, and can also cause other damage to the reefs, especially if the sediments contain toxic chemicals.

Soil eroded from farms carries chemicals that affect the environment. Nitrates, ammonia, and other fertilizers carried by sediments increase the growth of algae in water downstream (a process called eutrophication) just as they boost the growth of crops, but people generally do not want algae in their water. The water develops a thick, greenish-brown mat, unpleasant for recreation and for drinking. In addition, because the dead algae are decomposed by bacteria that remove oxygen from water, fish can no longer live in that water. Sediments also can carry toxic chemical pesticides. Efforts to limit soil erosion have reduced the amount of agricultural sedimentation since the 1930's. Even so, taking into account the costs of dredging and the decline in the useful life of reservoir, sediment damage costs the United States about $ 500 million a year.

It's not enough for crops to be sustainable – the ecosystem must be, too. At this point in our discussion we have arrived at a partial answer to the question: How could farming be sustained for thousands of years, while the soil has been degraded? However there is a difference between the sustainability of a product (in this case crops) and that of the ecosystem. In agriculture, crop production can be sustained while the ecosystem may not be. And if the ecosystem is not sustained, then people must provide additional input of energy and chemical elements to replace what is lost.

Soil forms continuously. In ideal farming the amount of soil lost would never be greater than the amount of new soil produced. Production of new soil is slow – on good lands the formation of a layer of soil 1 millimeter deep (thinner than a piece of paper) may take 10-40 years. Sustainability of soils can be aided by fall plowing and no-till agriculture – that is, planting without plowing. More than 250 acres of farmland are treated one way or another to improve soil conservation.

Plowing creates furrows and if they go downhill, then the water pours down these paths carrying a lot of soil with it. In contour plowing the land is plowed not up and down but as horizontally as possible across the slopes. Contour plowing has been the only most effective way to reduce soil erosion. This was demonstrated by an experiment on sloping land planted in potatoes. Part of the land was plowed in rows running downhill, and part was contour-plowed. The up-and-down section lost 32 metric tons of soil per hectare (14.4 tons per acre). The contour-plowed section lost only 0.22 metric ton per hectare (0.1 ton per acre) as shown in Figure 10. It would take almost 150 years for the contour-plowed land to erode as much as the traditionally plowed land eroded in a single year!

An even more efficient way to slow erosion is to avoid plowing altogether. No-till agriculture (also called conservation tillage) involves not plowing the land, using herbicides and integrated pest management to keep down weeds, and allowing some weeds to grow. Stems and roots that are not part of the commercial crop are left in the fields and allowed to decay in place. In contrast to standard modern approaches, the goal in no-till agriculture is to suppress and control weeds but not to estimate them if doing so would harm the soil. Worldwide no-till agriculture is increasing. Of course, like so many things are done, no-till involves trade-offs – for example, it requires greater use of pesticides. But decreased erosion means that a small percentage of these pesticides will be transported off the agricultural fields, and the pesticides will have a longer time to decompose in place.

Fig. 10. Plowing

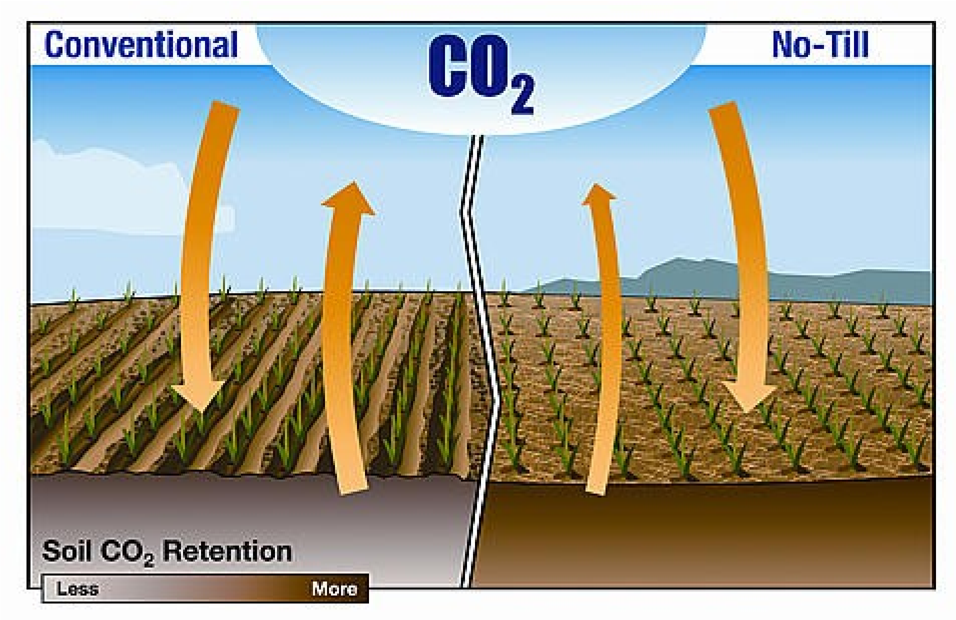


Fig. 11. Comparison of conventional and no-till agriculture

Fig. 12. No-till agriculture

Questions for checking

1. What have urbanization and population growth resulted in?
2. What does dumping of industrial and municipal wastes cause?
3. What is the main problem in land?
4. How does soil pollution differ from air and water pollution?
5. What are the main sources of soil pollution?
6. What do industrial wastes consist of?
7. How do they affect the human organism?
8. Why do agricultural practices pose soil pollution problems?
9. What are the reasons of heavy soil pollution by biological agents?
10. What is the effect of mining on land?
11. What measures should be taken to solve the problems of soil pollution?

Chapter 7 Types of risk assessment and practical achievements

7.1 Human health risk assessment

Human health risk assessment is the process of determining potential health effect on people exposed to environmental pollutants and potentially toxic materials. In accordance to the National Research Council for human risk assessment (USA, 1983). such an assessment generally includes four steps:

1. *Identification of the hazard (or Problem formulation phase)*. Is the planning and problem definition phase. It includes:

- Integrate available information assembling and summarizing data concerning sources, contaminants, effects, and the receiving environment.
- Assessment endpoint – definition of the environmental values to be protected in operational terms.
- Conceptual model – development of description for the hypothesized relationships between the wastes and the endpoint receptors.
- Analysis plan – development of a plan for obtaining the needed data and performing the assessment.

2. *Dose-response assessment (or Analysis).* This is a phase in which technical evaluation of the data concerning exposure and effect is performed. This involves figuring out whether and how the dose of a chemical (therapeutic drug, pollutant, or toxin) affects people's health and environment.
3. *Exposure assessment.* In this step we evaluate the intensity, duration, and frequency of human exposure to a particular chemical pollutant or toxin. This phase consists of:

- Measures of exposure – results of measurements indicating the nature, distribution, and amount of the waste and its components at points of potential contact with receptors.
- Exposure analysis – a process of estimating the spatial and temporal distribution of exposure to the contaminants.
- Exposure profile – a summary of the results of the exposure analysis.

4. *Risk characterization.* Using what we learned in the first three steps, we attempt to determine the percentage of the population at risk and the probability of individual suffering ill effects. In this phase the results of analysis are integrated to estimate and describe risks. It consists of:

- Risk estimation – the process of using the results of the analysis of exposure to parameterize and implement the exposure-response model and estimate risk and of analyzing the associated uncertainty.
- Risk description – the process of describing and interpreting the results of the risk estimation for communication to the risk manager.

Risk management requires us to make scientific judgments and decide what actions we should take to help minimize health problems related to exposure to pollutants and toxins. Risk management takes into account our risk assessment plus technical, legal, political, social, and economic issues. It appears at two points in the framework.

- at the beginning of assessment, the risk manager provides policy input to the problem formulation;
- at the end of the assessment, the risk manager learns the results of the risk analysis and makes decision.

Risk assessment and risk management can lead to arguments. Scientific opinions about toxicity of a substance are often to debate, and so are opinions about what actions to take. The appropriate action may be to apply the Precautionary Principle that is to take cost-effective measures to protect ourselves even when we are not entirely certain about the risk. For example, although we cannot be absolutely certain how hormonally active substances such as the weed killer atrazine may affect us that should not keep us from taking cost-effective steps to protect ourselves and the environment from the pesticide. The precautionary principle is emerging as a powerful ideology that is shifting the burden of proof from those who claim a substance is dangerous to those who manufacture, distribute, and use it. In short, it is not up to you to prove it's harmful, it is up to them to prove it's not – before they use it.

7.2 Ecological risk assessment

Ecological risk assessment (ERA) is a process for collecting, organizing, and analyzing information to estimate the likelihood of undesired effects on nonhuman organisms, populations, and ecosystems. It was developed in the early to mid-1980's to provide a basis for environmental decision making equivalent to human health risk assessment. It was derived from practices in human health risk assessment, environmental hazard assessment, and environmental impact assessment. However, the concept of estimating risk as a means of managing financial hazards through insurance, options, and other instruments dates at least to the late 17th century. All varieties of risk assessment are based on the recognition that decisions must be made under conditions of uncertainty and that the desirability of alternative outcomes depends on their likelihood as well as their utility.

The primary purpose for conducting ecological risk assessment of contaminated sites is to provide information needed to make decisions concerning site remediation.

Ecological risk assessment is more complex than human health risk assessment and is fundamentally different in their approaches. The greater complexity is mainly due to the large number of species and diversity of routes of exposure that must be considered in ecological risk assessment. However, the differences in approaches and part of the greater complexity are due to the fact that ecological risk assessments for waste sites may be based on epidemiological approaches while human health risk assessment for the waste sites are nearly always based on modeling. This discrepancy (отличие) raises the question, why not just model ecological risk as well? The reasons are as follows:

- Epidemiological approaches, when they are feasible (возможный, выполнимый), are fundamentally more reliable than modeling, because they address real observed responses of real receptors. Human health risk assessments are based on epidemiology when possible, but epidemiology is not feasible for most sites because there are no observable effects in human populations.
- Ecological epidemiology is feasible in practice, because nonhuman organisms reside (проживать) on most sites and are, in some cases, experiencing observable exposures and effects.
- Ecological epidemiology is feasible in principle, because the levels of effects that are considered to be significant by most regulatory agencies are observable in many populations and communities.

- Because of the assumption (предположение) that must be made to model risks, the uncertainties in model-generated risk estimates are large. These uncertainties can be accepted in practice by human health assessors because the effects are not observable. However, it is common for modeled ecological risks to be manifestly incorrect because the predicted effects are not occurring or effects are observed where they are not predicted. Therefore, it is incumbent to use an epidemiological approach to avoid mistakes.
- Because of the great value placed on human life, remedial actions may be taken on the basis of highly uncertain estimates of hypothetical risks. Therefore, if ecological risk assessments are to be useful, they must be compelling.
- Biological surveys and ecological toxicity tests are highly cost-effective, because they are inexpensive relative to chemical analyses and provide more direct evidence concerning ecological risks.

Even in those cases when ecological epidemiology is not feasible, the process of determining that to be the case is instructive (поучительный) and assists in the interpretation of modeled risks. For example, if contaminants on a site would cause reproductive failure in robins feeding on that site, counting robins would not indicate the effect, because the number of breeding pairs is limited by habitat availability relative to territory size, and loss of production on the site would easily replaced by birds produced elsewhere. This example also suggests that the potential effect (i.e. reduced reproduction on the site) would not be significant at the population level for a species that is not limited by production.

7.3 Methods of human health risk assessment from chemicals

The methods of human health risk assessment have been intensively developed lately in some European countries, Great Britain, USA, Russia. The modern science testifies the absence of a threshold impact for a lot of chemical contaminants. Risk is the likelihood that a harmful consequence will occur as a result of an action. Human health risk assessment evaluates the probability of health effects as a result of potentially hazardous behaviors.

Traditionally, such assessments have focused on the probability of increased disease in human populations. The approach follows the four steps described before in paragraph 7.1.

The assessment method includes separate estimation of health risk from the substances possessing cancerogenic properties.

According to Environmental Protection Agency USA Approach and Guideline of the State Committee for Sanitary and Epidemiological Oversight under the Russian Ministry of Public Health, one mathematical formula that determines an individual cancerogeneous risk from chemical exposures is

$$R_{ind} = 1 - \exp^{(-SF \times LADD)}$$

R_{ind} – individual cancerogeneous risk,

SF - Slope Factor, or Unit Risk, $(mg/kgxday)^{-1}$, reference date are used;

$$LADD = [\, C \times \mathit{CR} \times ED \times EF] / [BW \times AT \times 365]$$

LADD - Living Average Daily Dose, mg/kgxday,

C – the average concentration of the chemical substances, affecting during the exposure, mg/m^3;

CR- Contact Rate, for inhallation affect – inspiratory rate, m^3/day;

ED- Exposure Duration, years;

EF -Exposure Frequency, day/year;

BW – Body Weight, kg;

AT - Average Time, or average life expectancy, years

The noncancerogeneous risk, or Index Damage (HQ) is calculated by the equation

$$HQ = LADD/RfD$$

HQ - Index Damage

LADD - Living Average Daily Dose, mg/kg x day,

RfD **–** Referent (harmless) Dose, mg/kg x day, reference date are used.

Risk characteristic is performed by means of comparison of calculated values with acceptable risk criteria (presented in the Table 12).

Table 12. Risk levels

Risk level	R_{ind}	HQ	
Extremely high	10^{-1}	More than 5	Unacceptable neither for the population, nor for professionals. Other actions for risk decrease
High	10^{-1}-10^{-3}		Carrying out of emergency improving and other actions for risk decrease is necessary
Average	10^{-3}-10^{-4}	1 - 5	Acceptable for professionals and unacceptable for the population as a whole; occurrence of such risk demands planned improving actions in the conditions of the inhabited sites
Low	10^{-4}-10^{-6}	0,1 - 1	Corresponds to a zone of conditionally (admissible) risk; at this level the majority of hygienic standards recommended by the international organizations for the population as a whole is established
Minimum	Less than 10^{-6}	Less than 0,1	Corresponds to one additional case of serious disease or death per 1 million persons suffered from the effect. Such risks are perceived by people as negligibly small, do not differ from usual, daily ones. Do not demand for additional measures in their decrease, are subject to only the periodic control

Software package “RISK ASSISTANT” – commercial software to assess health risk from toxic contamination at local sites (fig. 13). It is used for the risk evaluation for health, caused by the chemical substances in drinking, surface, underground water, soil and atmospheric air. It is necessary to determine the chemical substances concentrations in water, soil and atmospheric air and know the impact conditions for using RA. Conceptual models, ecological effects, and other factors are incorporated into this software for the definition of assessments.

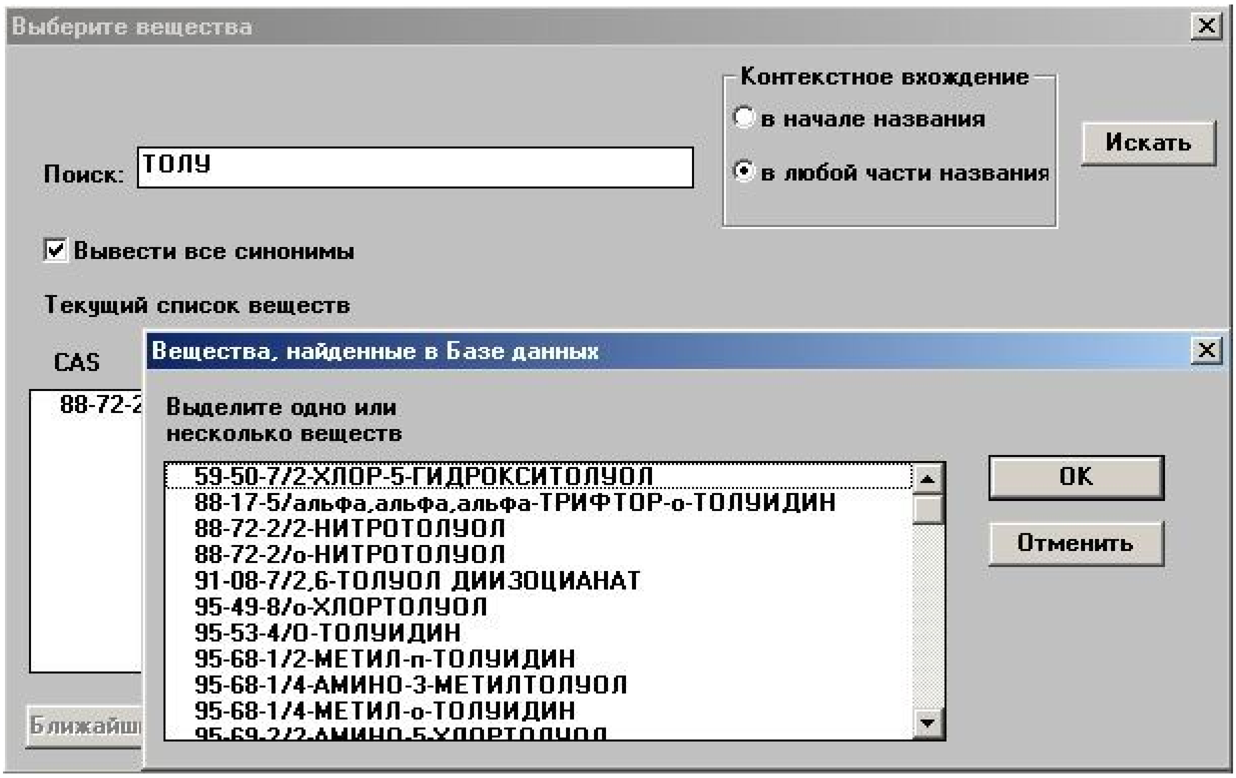


Fig.13 The screenshot of the soft ware “Risk Assistant”

7.4 Example of assessment of human health risk for the population of Tomsk caused by chemical pollutants of the atmosphere

Risk assessment of the toxicants or carcinogens effect on a population health with the help of computer software was conducted.

Figure 14 demonstrates the places, where Tomsk Hydrometeorology and Environmental Monitoring Center takes the atmospheric air for analysis. Observation posts cover all territory of Tomsk.

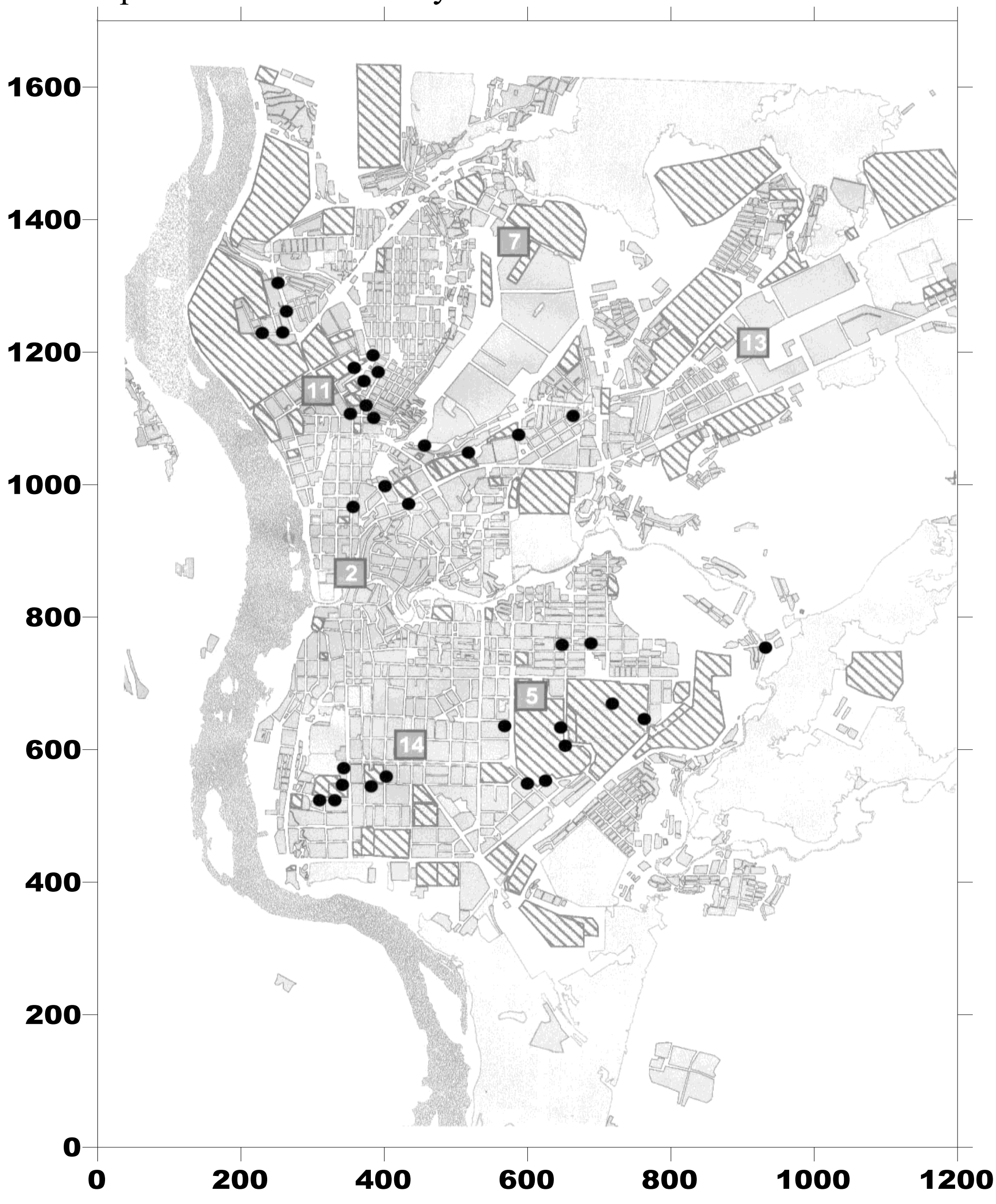
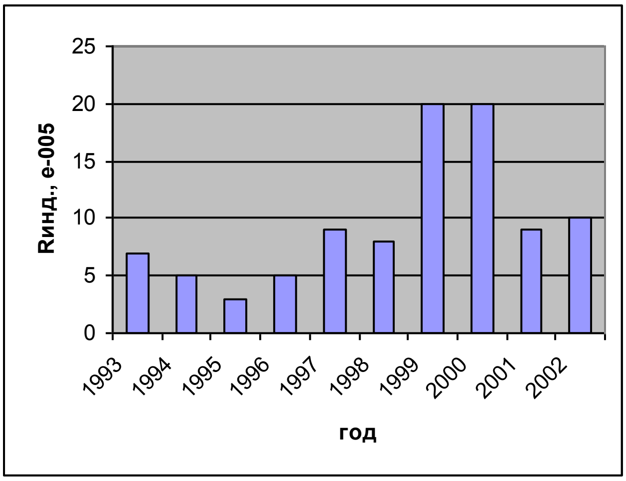


Fig.14. The observation network for atmospheric air state: 2- Lenin Square, 5- Gerczen Street, 7- Tomsk Petrochemical Plant area, 11- Cheremoshniki area, 13- Lazo Street, 14 – Vershinin street

Based on this data, the diurnally average, annually average, and maximal concentrations of the main substances polluting atmospheric air of Tomsk from 1993 to 2002 were calculated. Cancer risk was assessed by help EPA USA well-known approach, "RISK ASSISTANT" software and normative documents of the State Committee for Sanitary and Epidemiological Oversight under the Russian Ministry of Public Health (Fig.15).



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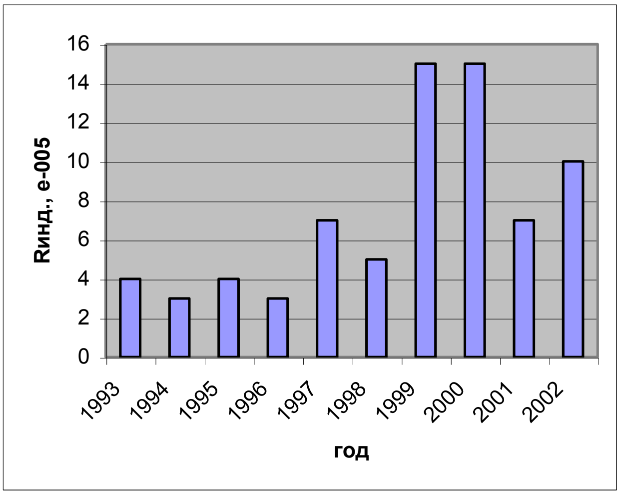

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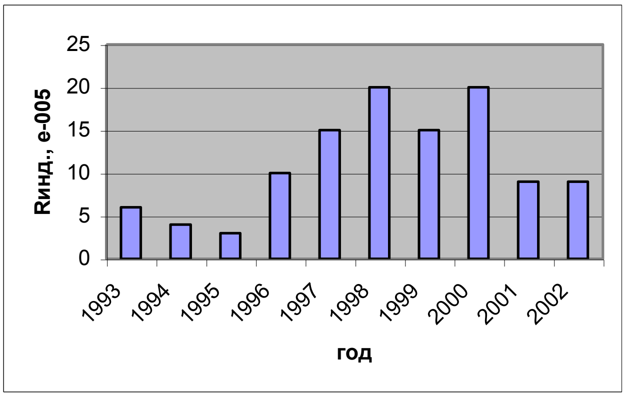

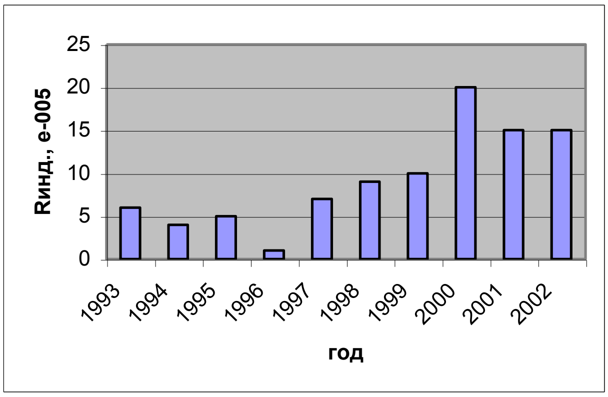

Fig.15 Individual cancerogenic risk at the observation posts
(a - 11; b - 13; c – 14; d – 2) over 1993-2002 y.y.

Areas with medial and low level of the cancer risk are identified in according to the risk level classification.

The individual additional cancerogenic risk of disease by reason of the formaldehyde contents in atmospheric air is in a range from (8,4 - 9,3)10-5 for city areas 5, 14. Considering that the Environmental Protection Agency (EPA) USA classifies risks within the limits of $1*10^{-4}$ - $1*10^{-6}$ as *low*, such risk level can be regarded as conditionally acceptable or admissible. At this level the majority of hygienic standards recommended by the international organizations for the population are set.

Values of the individual additional cancerogenic risk more than 10^{-4} (from 1,1 10^{-4} to 2,3 10^{-4}) for other areas are considered as medium risk level (table 13). It is estimated to be, according to classification EPA, that such risk is acceptable to professionals and unacceptable for the population as a whole. Occurrence of such risk demands development and carrying out planned health-improving actions in conditions of the occupied places.

Table 13. The city territory ranking in accordance to the risk level

Observation post	**The individual cancerogeneous risk**	**The additional expecting death quantity (approximately) Per every 100000 people**	**The risk level**
2 (Lenin Square)	$1.5*10^{-4}$	15	medium
5 (Gerczen Street)	$8,4*10^{-5}$	8	low
11 (Cheremoshniki area)	$1,1*10^{-4}$	11	medium
7 (Tomsk Petrochemical Plant area)	$2,3*10^{-4}$	23	medium
13 (Lazo Street)	$1,4*10^{-4}$	14	medium
14 (Vershinin street)	$9,3*10^{-5}$	9	low

It is obvious that the formaldehyde content in atmospheric air brings the certain contribution to the population disease. At the same time it is impossible to underestimate some other factors influences on the quality of population life and health, including drinking water and soil pollution that is a subject of the further researches.

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Appendix 1 The topics for project work

1. The natural hazards and risks. Earthquakes. Technogenic earthquakes. (Why, when, how and where they occur, what consequences we can expect, how to prevent them, which precautions we have to take against them, how to reduce risk,…)
2. The natural hazards and risks. Volcanic eruptions.(Why, when, how and where they occur, which consequences we can expect, how to prevent them, which precautions we have to take against them, how to reduce risk,…)
3. The technogenic accidents and risks in common (the causes, damage, appearance, the characteristic features, typical examples…) or in some kinds of activity, industry.
4. The ecological risk in oil industry.
5. The ecological risk in chemical industry.
6. The ecological risk in coal mining.
7. The ecological risk in nuclear industry
8. The regional aspects of ecological risk. Natural and man-made hazards.
9. The landslides in Tomsk region (in the world, in Russia, in any area – you can choose).
10. The flooding in Tomsk region (in the world, in Russia, in any area – you can choose).
11. The forest fires in Tomsk region (in the world, in Russia, in any area – you can choose).
12. The radiation risk induced by Tomsk Chemical Combine.
13. The impact of chemical pollution of environment on human health.
14. The risk assessment for human health from chemical exposure in atmosphere.
15. Contaminated sites and the associated ecological risks.

16. Petroleum-contaminated sites and the associated environmental risks.
17. Radionuclides and the associated ecological risks.
18. Air pollutants and their environmental fate and effects.
19. Wastewater treatment risks for on-site treatment systems.

Appendix 2 Major Air Pollutants

Pollutant	Sources	Effect
Ozone. A gas that can be found in two places. Near the ground (the troposphere), it is a major part of smog. The harmful ozone in the lower atmosphere should not be confused with the protective layer of ozone in the upper atmosphere (stratosphere), which screens out harmful ultraviolet rays.	Ozone is not created directly, but is formed when nitrogen oxides and volatile organic compounds mix in sunlight. That is why ozone is mostly found in the summer. Nitrogen oxides come from burning gasoline, coal, or other fossil fuels. There are many types of volatile organic compounds, and they come from sources ranging from factories to trees.	Ozone near the ground can cause a number of problems. Ozone can lead to more frequent asthma attacks in people who have asthma and can cause sore throats, coughs, and breathing difficulty. It may even lead to premature death. Ozone can also hurt plants and crops.
Carbon monoxide. A gas that comes from the burning of fossil fuels, mostly in cars. It cannot be seen or smelled.	Carbon monoxide is released when engines burn fossil fuels. Emissions are higher when engines are not tuned properly, and when fuel is not completely burned. Cars emit a lot of the carbon monoxide found outdoors. Furnaces and heaters in the home can emit high concentrations of carbon monoxide, too, if they are not properly maintained.	Carbon monoxide makes it hard for body parts to get the oxygen they need to run correctly. Exposure to carbon monoxide makes people feel dizzy and tired and gives them headaches. In high concentrations it is fatal. Elderly people with heart disease are hospitalized more often when they are exposed to higher amounts of carbon monoxide.

Nitrogen dioxide. A reddish-brown gas that comes from the burning of fossil fuels. It has a strong smell at high levels.	Nitrogen dioxide mostly comes from power plants and cars. Nitrogen dioxide is formed in two ways—when nitrogen in the fuel is burned, or when nitrogen in the air reacts with oxygen at very high temperatures. Nitrogen dioxide can also react in the atmosphere to form ozone, acid rain, and particles.	High levels of nitrogen dioxide exposure can give people coughs and can make them feel short of breath. People who are exposed to nitrogen dioxide for a long time have a higher chance of getting respiratory infections. Nitrogen dioxide reacts in the atmosphere to form acid rain, which can harm plants and animals.
Particulate matter. Solid or liquid matter that is suspended in the air. To remain in the air, particles usually must be less than 0.1-mm wide and can be as small as 0.00005 mm.	Particulate matter can be divided into two types—coarse particles and fine particles. Coarse particles are formed from sources like road dust, sea spray, and construction. Fine particles are formed when fuel is burned in automobiles and power plants.	Particulate matter that is small enough can enter the lungs and cause health problems. Some of these problems include more frequent asthma attacks, respiratory problems, and premature death.
Sulfur dioxide. A corrosive gas that cannot be seen or smelled at low levels but can have a "rotten egg" smell at high levels.	Sulfur dioxide mostly comes from the burning of coal or oil in power plants. It also comes from factories that make chemicals, paper, or fuel. Like nitrogen dioxide, sulfur dioxide reacts in the atmosphere to form acid rain and particles.	Sulfur dioxide exposure can affect people who have asthma or emphysema by making it more difficult for them to breathe. It can also irritate people's eyes, noses, and throats. Sulfur dioxide can harm trees and crops, damage buildings, and make it harder for people to see long distances.

Lead. A blue-gray metal that is very toxic and is found in a number of forms and locations.	Outside, lead comes from cars in areas where unleaded gasoline is not used. Lead can also come from power plants and other industrial sources. Inside, lead paint is an important source of lead, especially in houses where paint is peeling. Lead in old pipes can also be a source of lead in drinking water.	High amounts of lead can be dangerous for small children and can lead to lower IQs and kidney problems. For adults, exposure to lead can increase the chance of having heart attacks or strokes.
Toxic air pollutants. A large number of chemicals that are known or suspected to cause cancer. Some important pollutants in this category include arsenic, asbestos, benzene, and dioxin.	Each toxic air pollutant comes from a slightly different source, but many are created in chemical plants or are emitted when fossil fuels are burned. Some toxic air pollutants, like asbestos and formaldehyde, can be found in building materials and can lead to indoor air problems. Many toxic air pollutants can also enter the food and water supplies.	Toxic air pollutants can cause cancer. Some toxic air pollutants can also cause birth defects. Other effects depend on the pollutant, but can include skin and eye irritation and breathing problems.

Stratospheric ozone depleters. Chemicals that can destroy the ozone in the stratosphere. These chemicals include chlorofluorocarbons (CFCs), halons, and other compounds that include chlorine or bromine.	CFCs are used in air conditioners and refrigerators, since they work well as coolants. They can also be found in aerosol cans and fire extinguishers. Other stratospheric ozone depleters are used as solvents in industry.	If the ozone in the stratosphere is destroyed, people are exposed to more radiation from the sun (ultraviolet radiation). This can lead to skin cancer and eye problems. Higher ultraviolet radiation can also harm plants and animals.
Greenhouse gases. Gases that stay in the air for a long time and warm up the planet by trapping sunlight. This is called the "greenhouse effect" because the gases act like the glass in a greenhouse. Some of the important greenhouse gases are carbon dioxide, methane, and nitrous oxide.	Carbon dioxide is the most important greenhouse gas. It comes from the burning of fossil fuels in cars, power plants, houses, and industry. Methane is released during the processing of fossil fuels, and also comes from natural sources like cows and rice paddies. Nitrous oxide comes from industrial sources and decaying plants.	The greenhouse effect can lead to changes in the climate of the planet. Some of these changes might include more temperature extremes, higher sea levels, changes in forest composition, and damage to land near the coast. Human health might be affected by diseases that are related to temperature or by damage to land and water.

Appendix 3 Methodical aids for Practical work №1 (course: "Technogenic systems and ecological risk")

The objectives of the work:
- to learn to perform calculation of death individual risk from different causes in domestic and production activities;
- to compare individual risks from different causes depending on the type of activity in regions, countries;
- to learn to assess individual risk in terms of statistic data on emergencies of natural and technogenic origin on the territory of Russia;
- to perform comparative characteristic of individual risk.

Theoretical part

Individual risk is a frequency of the affections of a single individual as a result of the danger factors investigated.

$\boldsymbol{R_{ind.}= N_{lo}/N}$,

where N_{lo} - number of lethal outcomes in a group of a number N which is subjected to an influence.

Collective (integral) risk determines the scale of expected consequences of potential accidents for people

$\mathbf{R_{col.}} = \boldsymbol{R_{ind}} \times \boldsymbol{N_R}$,

where N_R – number of people subjected to a risk

If it is known for what definite cause $R_{ind} = 10^{-6}$, it means then that one person out of a million subjected to this cause would die of this impact. Usually all risk assessments are given per a unit of time – a year.

In this case individual risk is calculated not for each person, but individual risk for the groups of people characterized by approximately the same time of being in different unfavorable zones is estimated. It commonly takes into account the individual risk for working people and population of adjacent regions or smaller groups, e.g. workers of different profiles. Numerical value of individual risk is a quantitative characteristic of the risk level. Individual risk is characterized by one numerical value – a probability of deaths in terms of per one person a year. It is a universal feature of hazard for a man that makes it a basis for standardization of acceptable risk level. At the same time one should bear in mind that this value is far from being sufficient for complete characteristic of an event with undesirable consequences.

The level of acceptable individual risk is standardized only in some countries. In Netherland in 1985 the concept of "acceptable risk" became a basis for the state legislation. According to this law the death probability connected with hazards in technosphere more than 10^{-6} is considered unacceptable, less than 10^{-8} - acceptable (probability of dam destruction separating the most part of the country from the sea). At the risk level 10^{-6} — 10^{-8} decisions are made taking into account economical and social aspects.

In Russia the value of unacceptable risk accounts > 10^{-4}, but acceptable one is < 10^{-6}. At the risk value 10^{-6} - 10^{-4} all decisions ate taken taking into account economical and social conditions. Between these values there is a region of acceptable risk.

Group risk (or integral) determines the scale of expected consequences of different hazard factors for people

$R_{gr.} = R_{ind} N_R$

where N_R is the number of people subjected to risk.

Examples of problem solutions

1. The annual number of victims in road accidents all over the world amounts to 1.2 million a year. Estimate an individual risk of loss of life in road accidents in the world. Assume the population number is 6.5 billion according to 2006.

$R_{ind.} = N_d/N = 1{,}2 \cdot 1000000 / 6{,}.5 \cdot 1000000000 = 0.185 \cdot 10^{-3} = 1{,}85 \cdot 10^{-4}$

This number means that approximately 2 men die out of 10000 due to road accidents in the world annually.

2. Estimate the probability of dearth (Personal risk, year $^{-1}$) caused by the events listed below.

- Calculate the number of expected fatal outcomes for 1 million human beings.
- Arrange the causes listed below in column 1 in the sequence according to descent of the degree of danger.

Take the population of the USA in 1973 equal to 219 mln.

Estimation of the number of sudden death events in USA in 1973

The cause of an accident	**Total number of deaths**	**Personal risk, year $^{-1}$**	**Number of expected fatal outcomes for 1 million human beings**
Background (natural) radiation e.g. solar radiation	7200	$3{,}3 \cdot 10^{-5}$	33

Medicine radiodiagnosis and radiotherapy	3300	$1,5 \cdot 10^{-5}$	15
Nuclear industry	3	$1,4 \cdot 10^{-8}$	Less than 1
Other causes not connected with radiation	398500	$1,8 \cdot 10^{-3}$	1800
Air pollution	20000	$9,1 \cdot 10^{-5}$	91
Aviation accident	1778		
Rail disaster, train crash	798		

Solution:

$$R_{ind.} = N_{ли}/N = 7200/218000000 = 3,3 \cdot 10^{-5}$$

$$R_{кол.} = R_{ind}\, N_R = 3,3 \cdot 10^{-5} \times 1000000 = 33$$

3. Calculate K_d – the coefficient of accident frequency in mines, if the number of death is 27 accidents per 1000 of workers at 40-hour working week during 50 weeks a year during 50 years.

Solution: When it is assessed the risk of some people group of definite occupation or profession, it is preferable to refer their risks to one hour of work or a technologic cycle. Individual risks of professional activity are expressed in $K_л$ – coefficient of accident frequency. It expresses the number of deaths per 1 person during 1 hour of work (d/per. hour.).

27 accidents happen per 1000 of employers at 40-hour working week during 50 weeks a year during 50 years, hence, per a person during an hour of work is

$$K_л = 27/1000 \times 40 \times 50 \times 50 = 27 \cdot 10^{-8} \text{ d/per. hour}$$

4. Analyze the data in the Figure. Calculate the death individual risk from natural disasters taking into account the average statistical data for 1965-1999. Take the population of the world is equal to 6,5 billion.

Solution:

The general number of people died in the world from seven types of accidents during 35 years is 3.8 mln. people. If one analyzes the dynamics of changes in the number of people died within 5-year intervals, it turns out that the number of victims changes unevenly from year to year: from 25 to 359 000 people a year. The maximum was in 1970-1974, when draughts in Africa resulted in the deaths of 1793 thous. people. One more death peak connected with the draught in some countries of Asia was in 1980-1984. At the end of the 80's and beginning of the 90's the number of victims from natural disasters remained approximately at the same level (52-58 000 people a year), but within the last 5-year period (1995-1999) it decreased up to 33 000 people a year. There was the growth in the number of victims due to floods, whereas the distribution of victims from other types of accidents over the years was not regular.

Calculate the average number of deaths from natural disasters per year within the period from 1965 to 1999.

$N_{ли}$ = 25+359+71+107+58+52+33/5x7 =705 тыс.чел. = 705000 чел.

Calculate the individual risk of the death from natural accidents

R ind = $N_{ли}/N$== $705000/6{,}5 \cdot 10^9 = 1{,}08 \cdot 10^{-4}$

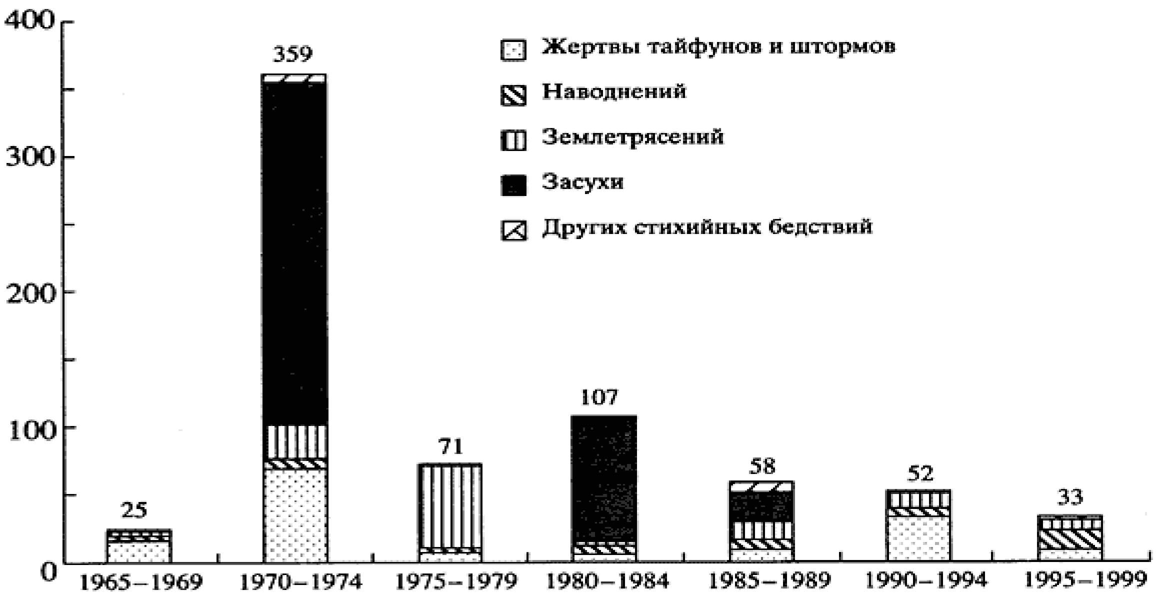


***Fig.* The number of people died in the world from different natural disasters within the period from 1965 to 1999, thous. people**

Tasks on the theme «Calculation of individual risk»

VARIANT 1

1. Calculate the risk of lethal road accident, if in the former USSR annually 60 000 people died because of this cause.
2. Using the data from the Table determine the approximate number of accidents (the number can be rounded off to the nearest whole number) with lethal outcomes per year in average which can be expected in a city with population of a million from the cause listed in the Table.

Table. Probabilities of death individual risk calculated for one year

Causes of deaths	Probability of one death a year (personal risk)
All causes	$1,19 \times 10^{-2}$
All «internal» causes (diseases)	$1,04 \times 10^{-2}$
All «external» causes (accidents, poisoning, violence etc.)	$5,1 \times 10^{-4}$
All road accidents	$2,7 \times 10^{-4}$
Accidental poisoning	$2,3 \times 10^{-5}$
Avalanches	1.8×10^{-7}
Aviation accidents	3.4×10^{-6}

These probabilities are obtained by dividing the number of annual deaths into the number of the country population.

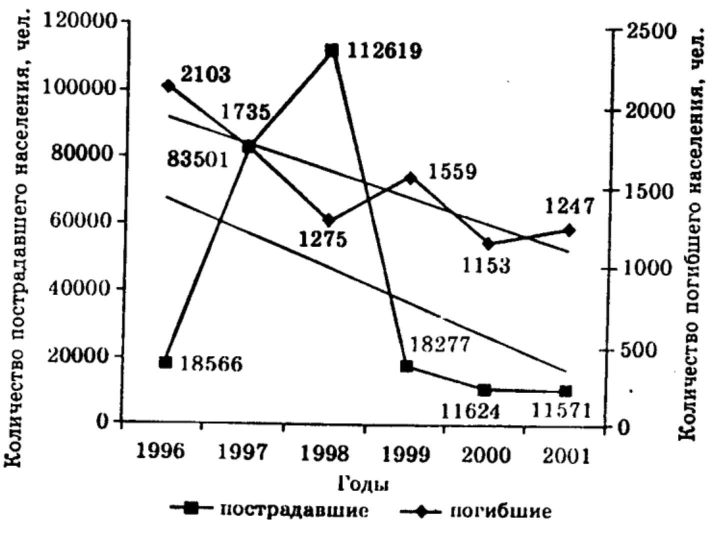
3. Assess the human death risk at production in Russia per a year, if annually 14 000 people die.

When it is assessed the risk of some people group of definite occupation or profession, it is preferable to refer their risks to one hour of work or a technologic cycle. The following data allow for comparison of

professional risks which are expressed by $К_л$ – the coefficient of accident frequency. It expresses the number of deaths per 1 person during 1 hour of work (d/per.hour.).
Calculate $К_л$ different professional activities in terms of the number of deaths given below, if 1000 people work 40 hours a week during 50 weeks a year during 50 years.

Type of activity	Number of deaths	Type of activity	Number of deaths
Mining	30		
Building	20	Electrical engineering, mechanics, optics	4
Metallurgy	6	Textile, leather industry	3
Food industry	6	Health protection	2

4. On the basis of statistical data on Russia for 1996 – 2001, (Fig.1), calculate the death risk (average death probability) in accidents.



Reference data for the problems:
The population of the former USSR is 300 mln. people.
The population of Russia is 145 mln. people.

The number of working people in Russia is 138 mln. people.
The population of the USA, 1969 is 190 mln. people

VARIANT 2

1. Knowing the general number of victims in 1969 as a result of accidents (see Table) in the USA from different causes,

- assess the death probability from these causes a year.
- What is the death number per 1 million people?
- Arrange the causes listed below in an order of decreasing the degree of danger.
- Compare the risks of natural and technogenic disasters.

Cause of accident	Total number of victims in 1969	Death risk, a year $^{-1}$	The number of expected deaths per a million of people
Transport	55791		
Fire	7451		
Lightning	160		
Hurricane	90		
Airplanes	1778		

2. Annually in the former USSR 330 000 people died due to different accidents. Determine the death risk from different types of danger. What is the number of deaths a year per a million of people?

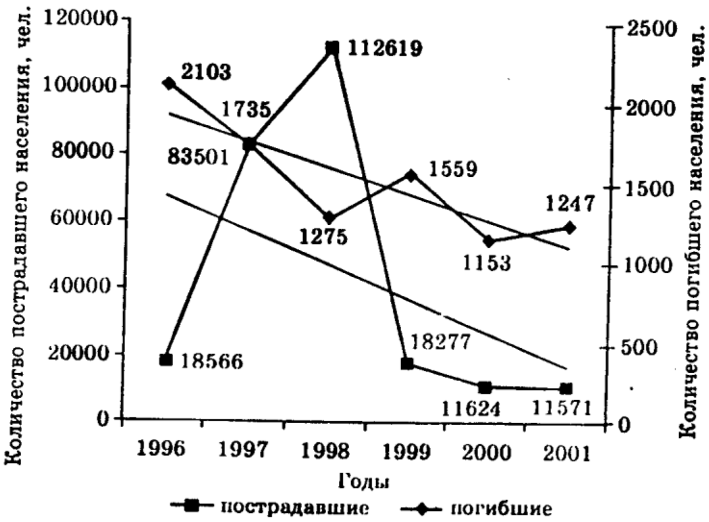
When it is assessed the risk of some people group of definite occupation or profession, it is preferable to refer their risks to one hour of work or a technologic cycle. The following data allow for comparison of professional risks which are expressed by $К_л$ – the coefficient of accident frequency. It expresses the number of deaths per 1 person during 1 hour of work (d/per. hour.).

Calculate $К_л$ of different types of professional activities in terms of the number of deaths given below, if 1000 people work 40 hours a week during 50 weeks a year during 50 years.

Types of activity	Number of deaths	Type of activity	Number of deaths
Transport	30	Paper and polygraph industry	5
Non-ore mineral mining	10	Jobs dealt with chemical substances	4

Gas-pipeline and hydro-engineering operations	6	Trade, finance, insurance, commerce	4

4. In the USA according to statistics 50 000 people die in road accidents annually. What is the probability of death due to this cause for the USA citizen?
5. According to statistic data in Russia within 1996 – 2001, (Figure.1), calculate the exposure risk in accidents.



Reference data for the problems:

The population of the former USSR is 300 mln. people.
The population of Russia is 145 mln. people.
The number of working people in Russia is 138 mln. people.
The population of the USA, 1969 is 190 mln. people.

Appendix 4 Practical work «Human health risk analysis under harmful chemical substance exposure in the environment»

The methods of human health risk assessment have been intensively developed lately in some European countries, Great Britain, USA, and Russia. The modern science testifies the absence of a threshold impact for a lot of chemical contaminants. Risk is the likelihood that a harmful consequence will occur as a result of an action. Human health risk assessment evaluates the probability of health effects as a result of potentially hazardous behaviors.

Traditionally, such assessments have focused on the probability of increased disease in human populations. The approach follows the four steps recommended by the United States National Academy of Sciences:

1. Hazard identification;
2. Dose-response assessment;
3. Exposure assessment;
4. Risk characterisation.

In this work students are required to analyze human health risk for a man living in a city (or settlement) during his lifelong under the action of harmful substances.

Students have to apply the common technique described in lectures and course manual.

1. Assume the first stage is danger identification has been carried out, on its base the dominated environmental pollutants have been revealed, in terms of which the risk assessment should be performed. In the appendix for the work there are the names and concentrations of substances selected for risk assessment. At this stage students are to describe the process of identification, which criteria are fundamental for composing the list of substances in terms of which the risk assessment should be performed, their toxic properties. The characteristics of their toxicity are to be found in the database. Suggest the possible sources of compounds found in drinking water or air.

2. The second stage is risk assessment. Calculate it according to theory given in the lecture. Estimate the risk of cancerogenic and/or non-cancerogenic effects at inhalation (with air) and/or peroral (with drinking water) intake of pollutants in to human organism at chronic effect. The results of this part are presented in the form of numerical values of individual cancerogenic risk and danger coefficient of all substances separately and totally. The total risks are calculated by adding the values obtained both in different environments and for different substances. But cancerogenic and

non-cancerogenic risks are not added by no means! The reference data are given below.

2.1 Estimation of cancerogenic effects is a calculation of individual cancerogenic risk (CR).

According to Environmental Protection Agency USA Approach and Guideline of the State Committee for Sanitary and Epidemiological Oversight under the Russian Ministry of Public Health, one mathematical formula that determines an individual cancerogeneous risk from chemical exposures is

$$R_{ind} = 1 – \exp^{(-SF \times LADD)} \quad (1)$$

R_{ind} – individual cancerogeneous risk,
SF - Slope Factor, or Unit Risk, $(mg/kg \times day)^{-1}$, reference data are used, Table 3;
LADD - Living Average Daily Dose, mg/kg x day,

At low values of LADD this formula is simplified

$$R_{ind} = SF \times LADD \quad (2)$$

2.1.1 At inhalation intake R_{ind} is calculated by the formula

$$R_{ind\ ing} = SF_1 \times LADD \quad (3)$$

SF_1- Slope Factor at inhalation exposure, reference data are used, Table 3;

At inhalation intake the Living Average Daily Dose (LADD) is calculated by the formula:

$$LADD = [\ C_{atm} \times \mathit{CR} \times ED \times EF] / [BW \times AT \times 365] \quad (4)$$

C – the average concentration of the chemical substances, affecting during the exposure, mg/m^3;
CR- Contact Rate, for inhalation affect – inhalation rate, m^3/day;
ED- Exposure Duration, years;
EF -Exposure Frequency, day/year;
BW – Body Weight, kg;
AT - Average Time, or average life expectancy, years

2.1.2 At carcinogenic intake with drinking water (peroral intake)

$$R_{ind\ wat} = SF_0 \times LADD \quad (5)$$

SF_0 = Slope Factor at peroral intake, reference data are used, Table 3;
At intake with drinking water the LADD is calculated by the formula:

$$LADD = [C_{wat} \times V \times ED \times EF] / [BW \times AT \times 365] \quad (6)$$

C_{wat}– concentration of substance in drinking water, mg/l,;
V – the value of daily water consumption, l/day
ED- Exposure Duration, years;
EF -Exposure Frequency, day/year;
BW – Body Weight, kg;
AT - Average Time, or average life expectancy, years

When solving the problem the standard exposure factors are used:

Exposure factor	Water Consumption	Contact Rate inh	Exposure Duration	Body Weight	Exposure Frequency,	Average Time
Designation	V	CR_{inh}	ED	BW	EF	AT
Numerical value	2,2	20	70	70	365	70
Units of measurement	l/day	m^3/day	years	kg	day/year	years

2.1.3 Total individual cancerogenic risk

$$R_{ind} = R_{ind\ ing} + R_{ind\ wat} \quad (7)$$

2.2 The non-cancerogeneous risk, or Index Damage (HQ) is calculated by the equation

$$HQ_{ing} = \mathbf{C}_{atm} / RfC \quad (8)$$

HQ_{ing} - Index Damage at inhalation intake
LADD - Living Average Daily Dose, mg/m^3,
RfC– Referent (harmless) concentration mg/m^3, reference data are used (Table 2)

$$HQ_{wat} = \mathbf{C}_{wat} / RfD \quad (9)$$

RfD – Referent (harmless) Dose at chronic peroral intake, mg/kg , reference data are used (Table 1)

Total HQ = $HQ_{ing} + HQ_{wat}$

3.
3.1 Risk characteristic is made on the basis of comparison with risk acceptability criteria (Table). According to the Table in terms of risk assessment results (both cancerogenic and non-cancerogenic risk separately), determine the risk level and its acceptability.

3.2 What number of additional cancerogenic diseases per 100 000 population should be expected at the exposure of studied factors in the given residence area?

3.3. Calculate population risk.

4. Risk management. If risk is not acceptable develop the measures to decrease the risk level (administrative, legislative, research, engineering, political etc).

The report has to contain all necessary parts: title page, objective of the work, initial data, and the work procedure (the entire technique of risk analysis is described successively according to points 1 -4, all calculations, designation deciphering is necessary), list of references.
Problem.

Characterize cancerogenic risk at benzol exposure when entering human organism all his lifelong at inhalation intake as a result of chemical enterprise operation. Average daily benzol concentration amounted 0,074 mg/m^3 in air of the residential area. Solving the problem use the standard exposure factors. The population of the city is 670 000 people.
Solution
Characterize a risk means to determine its level. Cancerogenic risk assessment level includes the calculation of R_{ind} – individual cancerogeneous risk,

1. Substitute the numerical values and calculate LADD and R_{ind}

LADD benzol= (0,074 mg/m^3 x 20 m^3 x 70 years x 365 / 70 kg x 70 years x 365 = 0,021 mg/kg daily

2. $R_{ind} = 2{,}7 \times 10^{-2} \times 0{,}022 = 0{,}000638 = 6{,}38 \times 10^{-4}$

3. The value of individual cancerogenic risk obtained accepts the probability of the fact that during 70 years it is possible for 6 additional cancer cases among the population to occur equal to 10000 people, exposed to inhalation intake of revealed benzol level. Per 100000 people

approximately 60 additional cancerogenic diseases should be expected at the exposure of the studied factors in the given residential area.

5. Calculate collective risk

R_{col}= 6,38 x 10 $^{-4}$x 670000 = 426

According to the classification there is the average level of individual lifetime cancerogenic risk at benzol exposure entering the body with automobile exhaust. The given risk level is acceptable for professionals, but unacceptable for population in general; such risks require some arrangements and planned curative measures in the condition of residential areas. Benzol contained in exhaust gases in comparatively low amount – up to 4%, is, nonetheless, one of dangerous components in the complex mixture of automobile exhausts. It is well known that benzol influences central nervous system, results in leukemia, according to classification of International Cancer Agency belongs to the 1-st cancerogenic group.

Possible measures for decreasing benzol air concentration: decrease in losses in gasoline distribution system, decrease in limited acceptable benzol concentration in non-ethylene gasoline etc.

Reference data

REFERENCE DOSES
AT CHRONIC PERORAL INTRODUCTION (Table.1)

CAS	Substance	RfD, mg/kg	Damaged organs and systems
71-43-2	Benzol	0,003	blood, CNS, hormone system, cancer
107-02-8	Acraldehyde	0,0005	blood, death
7440-43-9	Cadmium	0,0005	kidneys, hormone system.
7440-02-0	Nickel	0,02	liver, cardio-vascular system, gastrointestinal tract, blood, body weight
14797-55-8	Nitrate Nitrite	1,6 0.165	blood (MetHb), heart system
7439-96-5	Manganese	0,14	CNS, blood
7440-38-2	Arsenic	0,0003	skin, CNS, nervous system, cardio-vascular system, immune system, hormone system, (diabetics), gastrointestinal tract
7439-98-7	Molybdenum	0,005	kidneys
7439-92-1	Lead	0,0035	CNS, nervous system, blood, development, reproduction, hormone system.
50-00-0	Formaldehyde	0,2	gastrointestinal tract, CNS, liver, kidneys
7782-41-4	Fluorine	0,06	teeth, bones
16984-48-8	Fluoride, inorganic, easily soluble	0,06	teeth, bones
7782-50-5	Chlorine	0,1	mucous coat, immune system
18540-29-9	Chromium (VI)	0,003	
67-66-3	Хлороформ	0,01	liver, kidneys, CNS, hormone system, blood

REFERENCE CONCENTRATIONS AT CHRONIC INHALING EXPOSURE (Table.2)

CAS	Substance	RFC, mg/m^3	Damaged organs and systems
10102-44-0	Nitrogen dioxide	0,04	respiratory organs, blood (formation of MetHb)
10102-43-9	Nitrogen oxide	0,06	respiratory organs, blood (formation of MetHb)
107-02-8	Acraldehyde	2,00E-05	respiratory organs, eyes
106-99-0	1,3-Butadiene	0,002	reproduction, respiratory organs, heart-vascular system, blood, cancer
50-32-8	Benzapyrene	1,00E-06	cancer, risk 1E-5, 1 ng/ m^3, immune system, development
71-43-2	Benzol	0,03	development, blood, red bone marrow, CNS, immune system, heart-vascular system, reproduction.
7440-41-7	Beryllium	2,00E-05	respiratory organs, immune system (sensible)
	Suspended substances	0,075	respiratory organs, death.
7440-48-4	Cobalt	2,00E-05	respiratory organs
2228840	Oil and petroleum products	0,071	kidneys
7440-02-0	Nickel	5,00E-05	respiratory organs, blood, immune system, cancer, CNS
7439-96-5	Manganese	5,00E-05	CNS, nervous system, respiratory organs
10028-15-6	Ozone	0,03	respiratory organs
7439-97-6	Mercury	0,0003	CNS, hormone system, kidneys
22967-92-6	Mercury (1+)метил-ион	2,00E-05	
7487-94-7	Mercury (II) chliride	0,0003	
	Soot	0,05	respiratory organs, teeth

7439-92-1	Lead	0,0005	CNS, blood, development, reproduction system, hormone system, kidneys
108-88-3	Toluene	0,4	CNS, development, respiratory organs
108-95-2	Phenol	0,006	heart-vascular system, kidneys, CNS, liver, respiratory organs
50-00-0	Formaldehyde	0,003	respiratory organs, eyes, immune system. (sensible)

FACTORS OF CANCEROGENIC POTENTIAL (Table 3)

CAS	Substance	Carcinogenic group according to IARC	Carcinogenic group according to EPA	SF_O(mg(kgxday))$^{-1}$	SF_I (mg(kgxday))$^{-1}$
630-20-6	1,1,1,2- tetrachloroethane	3	C	0,026	0,026
79-06-1	Acrylamide	2A	B2	4,5	4,5
107-13-1	Acrylonitrile	2B	B1	0,54	0,24
62-53-3	Aniline	3	B2	0,0057	0,0057
75-07-0	Acetaldehyde	2B	B2	-	0,0077
8006-61-9	Benzine	2B	B2		0,035
71-43-2	Benzol	1	A	0,055	0,027
7440-41-7	Beryllium	1	B1	4,3	8,4
7440-43-9	Cadmium	1	B1		6,3
7440-02-0	Nickel	2B			0,91
7440-38-2	Arsenic	1	A	1,5	15
7439-92-1	Lead	2B	B2		0,042
18540-29-9	Chromium ((VI)	1	A	0, 42	42
50-00-0	Formaldehyde	2A	B1	-	0,046

Risk level ranking

Risk level	R_{ind}	HQ	
Extremely high	10^{-1}	More than 5	Unacceptable neither for the population, nor for professionals. Other actions for risk decrease

High	10^{-1}-10^{-3}		Carrying out of emergency improving and other actions for risk decrease is necessary
Average	10^{-3}-10^{-4}	1 - 5	Acceptable for professionals and unacceptable for the population as a whole; occurrence of such risk demands planned improving actions in the conditions of the inhabited sites
Low	10^{-4}-10^{-6}	0,1 - 1	Corresponds to a zone of conditionally (admissible) risk; at this level the majority of hygienic standards recommended by the international organizations for the population as a whole is established
Minimum	Less than 10^{-6}	Less than 0,1	Corresponds to one additional case of serious disease or death per 1 million persons suffered from the effect. Such risks are perceived by people as negligibly small, do not differ from usual, daily ones. Do not demand for additional measures in their decrease, are subject to only the periodic control

Standard exposure factors
Data for calculation

Number of variant	Name of settlement (city)	Population, th. people	Concentration of prior pollutants in the environment	
			Air, mg/m^3	Drinking water, mg/l
1	Tomsk	620	Formaldehyde – 0,0072 Toluene – 0,065	
2	Novokuibyshevsk (Samara Oblast)	470		Arsenic - 0,005 Chromium – 0,03 Manganese – 0,28
3	Kuibyshev region of Samara city	780	Acraldehyde – 0, 000035 1,3 – butadiene - 0,03 Soot – 0,08	
4	N city of Samara Oblast	870		Lead – 0,46 Cadmium –

				0,013 Molybdenum – 0,08 Nickel – 0,1
5	Strezhevoy (Tomsk Oblast) ground water of the Ob-Tomsk interfluve before entering the distribution network	280		Nitrate -2,4 Fluoride – 0,33 Manganese -0,09 Residual chlorine -0,72
6	Aktobe (Kazakhstan)	760	Lead -0,00377 Benzol – 0,074	
7	Aktobe (Kazakhstan)	760	Lead -0,00053 Benzol – 0,074	
8	Novosibirsk	1100		Arsenic – 0,0004 mg/l Lead – 0,003 mg/l Trichloroethene – 0,03 mg/l
9	Pervomaiskoye settlement according to Vidyaikina's data	6000		Nitrate -0,26 Nitrite 0,42 Manganese – 0,52
10	V city	55	Benzapyrene 9,4E-10 Nickel 7,8E-08 Cadmium 1,4E-08	
11	V city	55	Lead 2,4E-08 Arsenic 3,5E-09 Hydrogen oxide (II) 0,00061	
12	Tomsk	620	Sulfur dioxide 0.097 Soot 0.00748 Ethylbenzene 0.00284	
13	Tomsk	620	Trichoromethane	

			0.00285 Toluene 0.0397 Xylene 0.0084 Manganese 0.0002	
14	Tomsk	620	Benzol 0.0407 Nitrogen dioxide 0.074 Manganese 0.0002	
15	Tomsk	620	Formaldehyde – 0,0072 Toluene – 0,065	
16	Novokuibyshevsk (Samara Oblast)	470		Arsenic - 0,005 Chromium – 0,03 Manganese – 0,28
17	Kuibyshev region of Samara city	780	Acraldehyde – 0, 000035 1,3 – butadiene - 0,03 Soot – 0,08	
18	N city of Samara Oblast	870		Lead – 0,46 Cadmium – 0,013 Molybdenum – 0,08 Nickel – 0,1
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25	V city	55	Benzapyrene 9,4E-10 Nickel 7,8E-08 Cadmium 1,4E-08	