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# METHODOLOGY, ANALYSIS AND RISK ASSESSMENT IN ENVIRONMENTALIST

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**Abstract**: Issues related to environment have become an integral part of our everyday life and they represent a relentless tax for the comfort that most of the world can afford today. These issues affect all components of the environment, i.e. water, air, soil, and man is no exemption. Social development has resulted in an extreme increase of anthropogenic pressures on the individual components of the environment. The consequences of these pressures lead to the devastation of the environment, to the degradation of its components and to a significant reduction of their self-cleaning abilities. Considering these facts, the need to monitor and to address environmental risks appears to be more urgent than ever.
**Keywords**: risk, risk identification, environmental risk, risk assessment

## 1. INTRODUCTION

Risk analysis represents the process of hazard identification and of risk assessment for individuals or for a group of people, for the objects of the surrounding environment and for other examined objects. Risk analysis identifies the probability and extent of consequences of a negative event resulting from a specific work activity or from other activities of equipment or of a system. Based on the identification of hazards it reveals the magnitude of risk [3, 5, 11]. There are many definitions of risk, but in the most common case risk is defined as the possibility that a certain fact may happen, which can subsequently cause undesirable consequences and also potential political, financial, moral and environmental damages or losses. A risk in terms of its structure can also be defined as a combination of a probability of occurrence of an event and of its consequences. [7] According to the Act № 261/2002 Coll., a risk is the probability of occurrence of a risk event and the extent (severity) of its possible consequences that may occur during a certain period of time or under certain circumstances [9, 10]. Each type of risk has characteristic sources and factors, with their classification shown in Table 1. We distinguish:

» external sources of risk (external factors) – e.g. economic, sociological, physical, technological, political, legal,
» internal sources of risk (internal factors) – e.g. information systems, management style, fellow workers, organization structure, capabilities of employees and the like.

**Table 1**. Types of risk

| Type of risk | Object of risk | Source of risk | Undesirable consequences |
|---|---|---|---|
| Individual | Man | Living conditions of man. | Disease, injury, disability, death. |
| Technological | Technological systems and facilities | Technological incapability, violation of the rules of operation of technological systems and of facilities. | Accident, explosion, disaster, fire, destruction. |
| Ecological | Ecological systems | Anthropogenic interference with natural environment, unusual technogenic situations. | Anthropogenic environmental disasters, natural disasters |
| Social | Social groups | Unusual situation, reduction of the quality of life. | Group trauma, diseases, death of people, and increase in mortality. |
| Economic | Material resources | Reduction of production safety or of the natural environment. | Increased costs on safety, damage resulting from insufficient protection. |

Risk occurs under conditions if:

» there exists a risk factor (a source of hazard),
» there exists a presence of a given risk factor at a certain level of exposure, dangerous (or harmful) for the objects,
» the object is susceptible (sensitive) to activities and factors giving rise to hazard.

The consequences of the impact of risk, of the so-called risk event, can be expressed in the form of a property damage (e.g. damage to the machine system, financial losses), of a non-property damage (in the personal sphere), of human losses and damages (the degree of damage to health, the degree of injury, the number of fatalities), of a negative impact on the environment (the degree of damage, financial losses), of impact on human health and safety, on the reputation of an organization and the like.

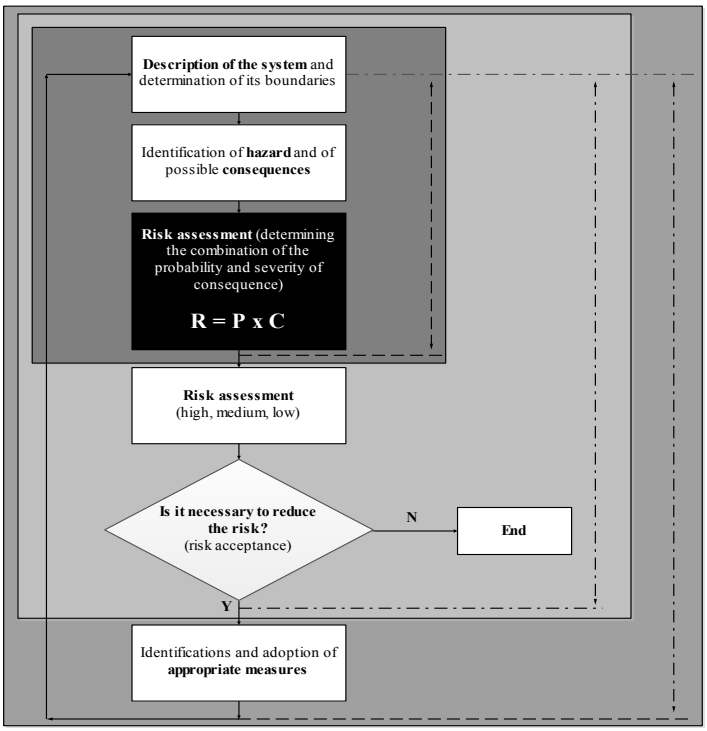


**Figure 1**. Algorithm of risk assessment and of risk management

## 2. ENVIRONMENTAL RISK

A risk can be considered to be an environmental risk if it is associated with a potential negative impact on the environment [7]. The risk represents a conditional probability of occurrence of specific environmental events associated with some of the consequences of these events.

The process of environmental risk management is based on several steps [2, 7]:

- risk identification,
- risk analysis and risk assessment,
- solution of risks, decision making of their solution and adopting measures,
- residual risks,
- monitoring and assessment of the risk management process.

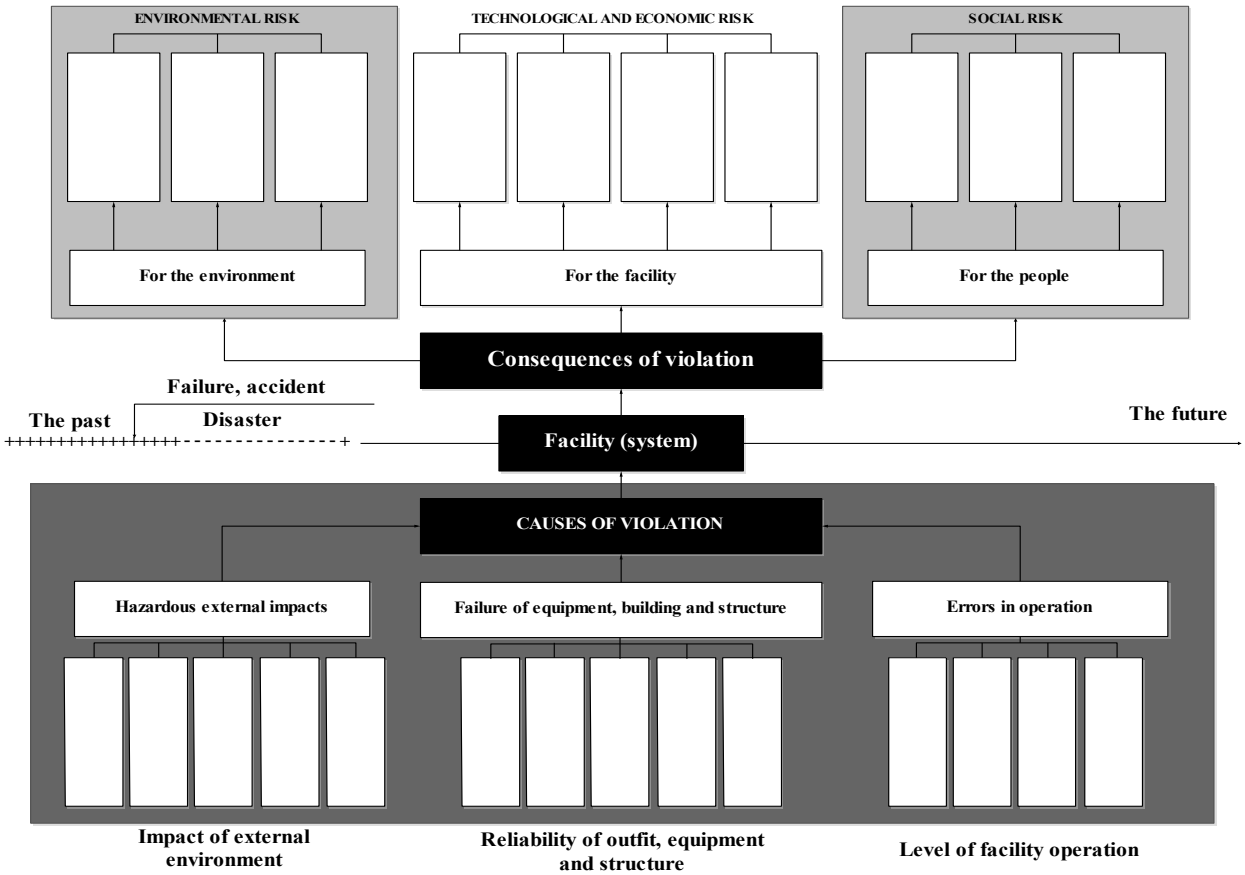


**Figure 2**. Model of risk development

The process of assessment and management of an environmental risk comprises the application of procedures, methods and practices, with the aim of managing and reducing the risk event, or of their reporting (Figs. 1, 2). [2]

### 2.1. Environmental Risk Identification

The main task of risk identification is the detection (on the basis of information about the given object, of the results of an expert examination and of experience from similar systems) and an accurate description of all the risks inherent in a given system. It is an important stage of the analysis, because if no environmental risks are detected at this stage, then their analysis is not elaborated and they are lost out of sight.

The aim of risk identification is to determine, to what extent an undesirable event can occur. In the course of identification we are looking for an answer to the questions: **"What can occur? Why and when can it occur?"**

The basic tools for the identification of environmental risk include:

- SWOT analysis,
- sensitivity analysis,
- simulation procedures,
- decision trees,
- professional assessment of a risk event
- Risk Diagnosis Methodology and others.

### 2.2. Environmental Risk Assessment

The assessment of the impacts on individual components of the environment is very exacting due to the magnitude and diversity of anthropogenic impacts on the environment and due to the complexity of natural systems.

There are a number of suitable methods, which are used in risk assessment (Table 2). One of the subdivisions discerns:

- quantitative methods, which use numerical assessment of risks by expressing their probability (frequency, credibility) and the consequence of the undesirable phenomenon (the value in monetary units, the degree of damage to health, etc.),
- qualitative methods, which use verbal expression for describing probability and consequences,
- semi-quantitative methods, which use qualitatively described scales by means of assigned numeric values (the so-called point method of assessment), whose combination is used for determining the numerical value of the risk.

**Table 2**. Some additional methods of risk assessment [2, 8]

| Method | Description |
|---|---|
| FTA Method (Fault Tree Analysis) | A deductive method based on a considered risk event, the outputs of which are a number of critical paths leading to it. |
| Delphi Method | The basis of the method is forecasting, in the course of which ideas are generated. It uses an explicit estimate of experts for assessing the probability of each risk event. |
| MOSAR Method | The method comprises a systematic risk analysis. The system is divided into subsystems, which are gradually identifying hazards, the adequacy of measures and their interdependence. Safety measures are arranged into a logical tree and residual risks are analysed on the basis of an agreement. |

Other instruments for assessment of risk significance can also include Pareto analysis and the so-called UMRA (Universal Matrix of Risk Analysis) Method. In our paper we will address the semi-quantitative method for environmental risk assessment, namely by creating the so-called risk matrix. The probability (frequency) of occurrence and severity of the impact of a risk event on the environment (or its components: soil, water, air) is most often expressed by using a three-degree or a five-degree scale. A five-degree system for risk assessment is shown in Tables 3 and 4 [6].

**Table 3**. Probability / frequency of occurrence of an environmental risk event

| Probability | Denotation | Value | Probability of risk occurrence |
|---|---|---|---|
| Rare | A | 1 | It is almost inconceivable that a risk event could occur. |
| Possible | B | 2 | Very unlikely (its occurrence is not known). |
| Probable | C | 3 | Unlikely, but possible occurrence (it occurs rarely). |
| Highly probable | D | 4 | Probability of occasional occurrence (it occurs irregularly). |
| Almost certain, frequent | E | 5 | Probability of a very frequent occurrence (it occurs regularly). |

**Table 4**. Severity / consequence of the impact of an environmental risk event on the environment

| Severity level | Denotation | Value | Severity of risk occurrence |
|---|---|---|---|
| Negligible, insignificant | I | 1 | Minimum, almost no impact of the risk event on the environment, or on its components. |
| Minor | II | 2 | Small extent of the impact of the risk event on the environment, or on its components. |
| Major, moderate | III | 3 | Medium extent of the impact of the risk event, less severe impact on the environment, or on its components. |
| Significant | IV | 4 | Extensive, serious impact of the risk event on the environment, or on its components. |
| Severe, disastrous | V | 5 | Disastrous impact of the risk event on the environment (environmental disaster), or on its components. |

The assessment of environmental risks is used for making decisions on the severity of risks and for deciding whether a given risk is acceptable or whether actions should be taken to address it. It makes use of methods and procedures used by ecology, chemistry, toxicology, ecotoxilogy, hydrology, and other sciences for determining the probability of occurrence of adverse events and of the severity of their impact on the environment. According to [2, 4, 12, 13, 15], the value of the risk is expressed by the functional dependence of at least two parameters, i.e.

$$R = f\left(P, C_E\right), \qquad R = \sum_{i}^{n} P_i \times \sum_{j}^{m} C_{Ej} \tag{1}$$

where P represents the probability of occurrence of a risk event (hazard) and $C_E$ is the degree of damage, the consequences (or severity) in the case of occurrence of a risk event having an impact on the environment, or on its basic components.

Inclusion of a given consequence of the risk into a respective degree of the scale is then dependent on the selected criteria and on the method of assessment of negative consequences. Personal experience, intuition, sufficient amount and easy access to information also play an important role.

For the implementation of the step of the risk assessment by using the semi-quantitative method it is necessary to construct the risk matrix. In general, the matrix is created by the combination of the two basic parameters P and $C_E$.

**Table 5**. Risk matrix

| Probability | Severity of the impact of a risk event (Consequence, Impact) | | | | |
|---|---|---|---|---|---|
| | Negligible (I) | Minor (II) | Major (III) | Significant (IV) | Severe (V) |
| Almost certain (E) | I-E | II-E | III-E | IV-E | V-E |
| Highly probable (D) | I-D | II-D | III-D | IV-D | V-D |
| Probable (C) | I-C | II-C | III-C | IV-C | V-C |
| Possible (B) | I-B | II-B | III-B | IV-B | V-B |
| Rare (A) | I-A | II-A | III-A | IV-A | V-A |

**Table 6**. The level of environmental risk assessment

| Probability | Severity of the impact of a risk event (Consequence, Impact) | | | | |
|---|---|---|---|---|---|
| | Negligible | Minor | Major | Significant | Severe |
| Almost certain | 5<br>Medium | 10<br>Medium | 15<br>High | 20<br>Extreme | 25<br>Extreme |
| Highly probable | 4<br>Medium | 8<br>Medium | 12<br>High | 16<br>High | 20<br>Extreme |
| Probable | 3<br>Low | 6<br>Medium | 9<br>Medium | 12<br>High | 15<br>Extreme |
| Possible | 2<br>Low | 4<br>Medium | 6<br>Medium | 8<br>Medium | 10<br>High |
| Rare | 1<br>Low | 2<br>Low | 3<br>Medium | 4<br>Medium | 5<br>High |
| Low | Very low, negligible level of environmental risk | | | | |
| Medium | Low level of environmental risk | | | | |
| High | High level of environmental risk | | | | |
| Extreme | Very high level of environmental risk | | | | |

An important step in the environmental risk assessment is to determine the degree of significance of the risk and at the same time to determine the level of its acceptability. The degree of significance of the risk is in the simplest case the product of the point rating of the probability of occurrence and of the severity of impact of the risk, i.e. R = P x D

According to [7], when using a five-degree risk assessment, the numerical value of 15 expresses an unacceptable risk. Table 6 shows a proposed scale for numerical assessment of the significance of the environmental risk.

### 2.3. Decision on Addressing Environmental Risks

The decision is the final result of the risk management stage. The decision on the acceptability or non-acceptability of an environmental risk is based on two levels of risk [7]:

- A negligible level of risk represents a socially acceptable level of risk, at which the probability of occurrence of an undesirable consequence is so small, the effects of the risk impact are so mild and the benefit of the situation is so substantial that persons, groups, an organization or the society as a whole are willing to undergo this risk. This level does not require any control measures for reducing the environmental risk.
- An unacceptable level of risk requires immediate adoption of control measures for reducing the risk.

According to the Health and Safety Executive (HSE), there are three basic levels of risk acceptability (Fig. 3).

**The intermediate level** is defined as the level, where the so-called ALARP (As Low as Reasonably Practicable) philosophy is applied, i.e. this is an area where the reduction of risk value is managed by the approach "to invest so far as to keep the risk value so low as it may be reasonable and practical". At **an unacceptable level**, it is necessary to take immediate measures, which ensure the reduction of its value to an acceptable level. In the case **of a negligible level of risk** this is a condition, when risk is monitored (or regularly checked), but it does not require any measures for its reduction [1, 2, 14].

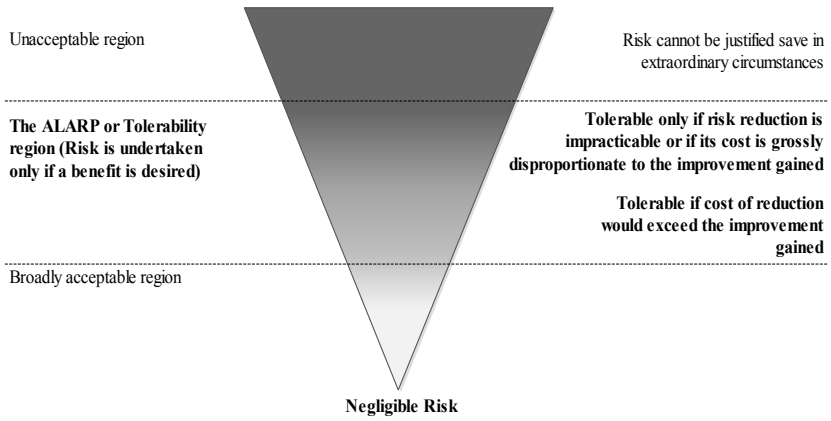


**Figure 3**. Levels of risk acceptability according to HSE

The occurrence and the degree of severity of an environmental risk can be influenced by reducing the probability of the occurrence of a risk event or by reducing the severity of the consequence of the risk. Many environmental risks can be eliminated or their level can be reduced by appropriate regulatory measures. When reducing the level of risk by introducing corrective measures these should be based on the basic parameters of the risk. Environmental risk can be reduced by reducing the probability of the occurrence of a risk event or by reducing the consequences of this event.

## 3. COMPREHENSIVE ASSESSMENT OF THE IMPACT OF RISK ON THE ENVIRONMENT AND HUMAN HEALTH

In addition to the impact on the environment, also severity of the impact on human health is often monitored.

**Table 7**. Severity / consequence of the impact of an environmental risk event on human health

| Severity level | Level | Value | Severity of the risk event |
|---|---|---|---|
| Negligible | $\alpha$ | 1 | Without impact on human health |
| Minor | $\beta$ | 2 | Minor influence on health |
| Major | $\gamma$ | 3 | Significant damage to health |
| Significant | $\delta$ | 4 | Serious damage to the environment |
| Severe, catastrophic | $\varepsilon$ | 5 | Catastrophic consequences (death) |

For a comprehensive assessment of mutual relations between probabilities of risk, consequences for the environment and impacts on human health, a cubic diagram can be used (Fig. 4). This type of diagram allows building of an interrelationship between all three parameters at the same time [6].

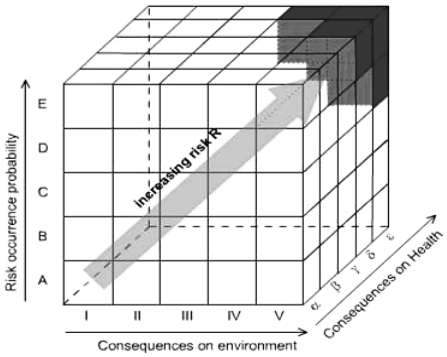


**Figure 4**. Cubic risk matrix diagram

The degree of significance of risk, R, is in this case determined by the product of the point rating of the probability (frequency) of occurrence of risk, P, of the consequence of impact on environment, $C_E$ (environmental risk), and of the consequence of impact on human health, H (risk to human health). It is expressed by the formula:

$$R = P \times C_E \times H$$

The value of the degree of significance of risk, R, can range from 1 to 125. It should be noted, however, that this value can take only certain discrete values. Also in this case the resulting numerical assessment of risk and determination of its degrees is influenced by subjective opinions, where values in the range from 70 to 125 can be regarded as an unacceptable risk.

**Table 8**. Determination of the range of the resulting risk

| Risk | Range of point rating | Impact on environment and human health | Remedial measures |
|---|---|---|---|
| Insignificant, negligible risk | 1 – 4 | The system is safe, negligible impact on human health and environment. | Routine procedures, it is not necessary to take any measures. |
| Acceptable, minor risk | 5 – 10 | Acceptable risk with increased attention, first aid needed. | Opportunity to achieve improvement, corrective plans. |
| Undesirable risk | 11 – 50 | The risk cannot be accepted without protective measures, medical treatment inevitable. | It is necessary to take safety precautions. |
| Significant risk | 51 – 100 | The system is dangerous, high possibility of a major emergency event, and/or extensive injury, loss of ability to work. | It is necessary to take immediate corrective actions with a short deadline. |
| Unacceptable risk | 101 – 125 | The system is unacceptable, permanent threat of a risk event, death. | Immediate application of safety measures, system shutdown |

## 4. CONCLUSIONS

Environment influences the life of all of us. It consists of the space around us. Just as the environment affects us, people also affect it in various ways. For decades, warning messages have been appearing in the media reminding us of the gradually degrading state of the environment. Soil, water and air are polluted, endemic species, but also other certainly not less important species of plants and animals are threatened with extinction, mineral resources and drinking water supplies are irretrievably consumed.

Risk assessment is a process, which is in most cases going on individually, but it cannot be understood in isolation. Risk assessment is a part of risk management and it represents a process, currently requiring heavy demands for its implementation and use.

Risk analysis and environmental risk management are focused on elimination of risks, even if we have to realize that their complete removal is not possible. It is important to reduce risk to an acceptable level. This level reflects the residual risk, which is acceptable for an individual, for an organization and for the society. The results of the analysis of environmental risk are of great importance for the adoption of reasonable and preventive solutions, which are very important for protection of health and safety of humans and for protection of the environment.

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