THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 3 - 2016, ISSN 1453 – 083X

ENVIRONMENTAL RISKS ASSESSMENT BY QUALITATIVE AND QUANTITATIVE METHODS

Tamara RADU
"Dunarea de Jos" University of Galati, Romania
e-mail: tradu@ugal.ro

ABSTRACT

The paper presents qualitative and quantitative methods, applicable on environmental risks, and conditions of application. The principles of the two classes of risk assessment methods and the advantages and disadvantages of their application in environmental risk assessment are presented. For both methods, there is a wide range of techniques and tools with applicability more or less specific to certain types of risks. The risk matrix method with its many application forms and examples are presented. Also, it analysed the environmental risk associated thermal plants by risk matrix method.

KEYWORDS: environmental risk, qualitative and quantitative methods, risk matrix

1. Introduction

Globalization of environmental problems raise increasing concerns internationally. Production processes require natural resources which, integrated into an appropriate technology [1-3], lead to useful or recyclable products [4, 5], and also to unusable products which return to the environment and contaminate it [6, 7]. Environmental risk arises from such interactions between human activities and the environment. This risk has begun to occupy an increasingly important place in the environmental management of an organization. Environmental policies of organizations with significant environmental impact include more and more commitments to environmental risk.

The scope of the environmental risk assessment may however be much broader, including environmental risks (such as those relating to biodiversity, species extinction, etc.), risks of environmental factors (e.g. depletion of water resources, desertification, ozone depletion, global warming, etc.) or the occurrence of environmental hazards (risk of floods, earthquakes, storms, etc.).

2. Characteristics of qualitative and quantitative methods

Environmental risk assessment is relevant whenever installations or technological operations can interact with the environment and there is the possibility of adverse effects.

For this purpose, two main classes of methods may be used: qualitative methods and quantitative methods.

2.1. Qualitative risk analysis

Qualitative risk analysis involves using qualitative criteria, in order to both appreciate the consequences of a hazard and to determine the frequency of its occurrence. Also, qualitative decisions are taken based on the expertise in the field, for risk classification [8].

Hazard identification is based on various qualitative methods such as check lists, inspections of installations, preliminary hazard analysis, analysis of human errors, method "but if", analysis of the properties of hazardous substances, HAZOP (Hazard and Operability Study) studies, environmental audits, etc. [9]. After rigorously identifying the hazards, it is proceeded to determine the gravity of the consequences and the occurrence probability of that risk by establishing classes of suggestive names (e.g. small, medium, large) to which numbers may be assigned, or not (e.g. 1 - low, 2 - medium, 3 - large) and the risk is to be calculated, in the latter case, numerically. Qualitative methods are valuable mainly for the assessment of risk in complex systems such as the environment.

The *benefits* of applying qualitative methods [10]:

- are easy to apply;
- are effective;
- can be tailored to the situation subject to risk assessment (simplified or enriched);
- can be applied by non-specialists as well;
- are inexpensive;
- do not require complicated databases;
- have a general nature hence broad applicability.

As major *disadvantages*, we can mention:

- are subjective, depending much on the interpretation of the person who applies the method;
- can have a high degree of ambiguity;
- have a high probability of "lost" risk (unidentified);
- are less useful in characterizing the magnitude of risk.

Because of these restrictions, these methods will not be used to exclude dangers from further consideration, but only for their ranking purpose.

The literature presents various qualitative methods for assessing environmental risk such as: risk matrix, events tree, error tree, analysis of source-path-receiver, model of pollutants conveyance etc.

2.2. Quantitative risk analysis

Quantitative risk analysis is an expensive specialized method requiring background data and analysis and may also include formal mathematical modeling. Quantitative analysis means to assess the number of variables, parameters and states of the system subject to risk assessment and provides quantitative results. This approach is more objective and accurate. Quantitative quantifying of the environmental risk is made especially for extremely rarely occurring events, very severe with possible catastrophic consequences [9]. It should be noted that the quantitative results can be greatly affected by the accuracy and validity of the input parameters. Uncertain, complex and variable data affect and make considerably difficult the analysis and adversely affect its outcome. For this reason, quantitative results in risk analysis should not be considered as exact numbers, but estimated on a variable scale depending on the quality of the data used in the calculations.

Where possible, a detailed and quantified analysis made by competent persons provides a better understanding of risk and its management opportunities, as compared to a purely qualitative analysis. The strength of the quantified approach is not its accuracy, but the benefits of a more rigorous analysis [8]. A trap of the quantitative analysis may be unjustified confidence in the accuracy of numerical results. These are not absolute, because the results of the analysis may be based on inaccurate information and usually require generalization and simplification of assumptions [8].

Quantitative analysis benefits from special techniques such as modern statistical and probabilistic methods or simulation method. Among the well-known methods, we may include: DOW method, Monte Carlo method, errors tree, events tree, Mond Index etc. The quantitative methods are generally complex, their application requiring specialists with relevant expertise.

2.3. The application of qualitative and quantitative methods in environmental risk

For both quantitative and qualitative approaches, there is a wide range of techniques and tools applicable more or less specifically to certain types of risks. Also, tools and techniques of risk assessment are developed continuously. Most experts in the field of risk are for an initially qualitative analysis followed, if the situation requires, by a quantitative analysis, as shown in Figure 2 [11]. Qualitative risk assessment techniques are used when risks cannot be quantified or when insufficiently reliable information is available for the quantitative assessment, or when collection of data is not efficient in terms of time required for study or costs. Quantitative assessment techniques are usually used in more complex activities to supplement qualitative techniques.

As it can be seen from the diagrams shown in Figure 1, the two types of analyzes aim, in different terms, at dimensioning the two factors which determine the risk, i.e. the likelihood and the consequences of a danger.

Determining the probability of an event in environmental risk assessment can be a very simple or very difficult approach. There may be many situations where the probability of an event is 1 (so it will happen for sure). For example, once it was decided to build a bridge and the necessary resources were allocated, the construction will be done for sure and with all environmental consequences (loss of habitats, landscape elements and structures in the area). In this case, the important parameters to be considered are: the *likelihood* and *magnitude of the consequences* to the *likelihood of the event* (building) itself. There are as many situations, especially those caused by accidents, when the probability of the trigger event becomes very important. These events usually have a probability of less than 1 and it will be necessary to determine it. For example, in certain situations of malfunction or accident, the planned release of pollutants into the air from various industrial activities can exceed the allowed limits with significant consequences on the environment [6].

In this case, it is necessary to establish the likelihood of the triggering event through various techniques and methods available.

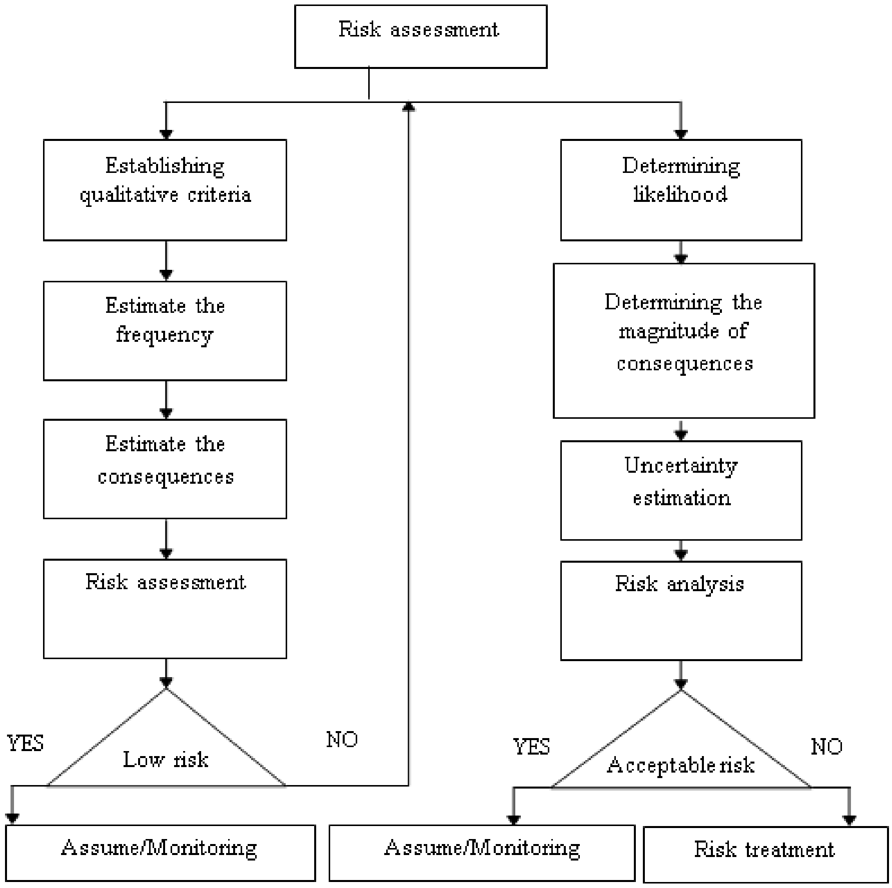

Fig. 1. *The application of qualitative and quantitative methods to assess environmental risk* [11]

Estimating the extent and probability of consequences. In some cases, especially in the environmental risk assessment, there will be a high level of uncertainty in estimating the magnitude of the consequences. Ecosystems are often complex, with many food chains or other interdependencies between species that require costly or lengthy investigations to establish the extent of the consequences of a hazard. In such cases, measures of optimal cost / efficiency ratios will be taken, even in the presence of uncertainty regarding the magnitude of the consequences in order to avoid serious or irreversible damages. However, in most cases it is possible to quantify the magnitude of the consequences and even conversion into a monetary value that will facilitate the socio-economic analysis. For example, there are well-developed techniques to estimate the probability that a chemical product released into the environment adversely affect organisms. This assessment is based on a comparison of a known concentration at which side effects occur and a concentration predicted or measured in the environment. If no data are available on the consequences of a hazard or the risk assessment uncertainty is unacceptable, use may be made of various models, assumptions, extrapolation techniques, etc. For example, to assess the dispersion and concentration of a substance accidentally released into the environment, its physico-chemical properties and details of the amounts released can be analyzed.

3. Risk matrix method- case study

Most commonly, a qualitative analysis refers to a matrix approach. Risk matrix presents columns for frequency and lines for the consequences extent. The analyst or group of specialists classifies the identified hazard depending on the effect size and frequency, setting its appropriate place into the matrix. The literature shows different types of matrices from the simplest, with three levels on each axis, to various combinations: three to four, four to four, four to five, five to five, etc. Experience suggests that five classes for each axis should be minimal because analysts find it difficult to take decisions to establish rank risk with a smaller number of options [9]. A larger number than five levels may be useful in some complex systems for which other analytical tools are not available, but may induce the false sense of precision of such a risk analysis. The magnitude of risk can be dotted inside the risk matrix also by suggestive colors such as green - low risk, yellow - medium risk, and red - for high risk.

The best, however, matrices are those of five classes for consequences, five classes for risk frequency and five levels of risk: Table 1 [8, 9, 12].

Table 1. *Risk Matrix with five classes for each axis*

		Severity of the consequences				
Frequency		Insignificant	Minor	Moderate	High	Very high
	Very low	Very low	Very low	Very low	Very low	Low
	Low	Very low	Low	Low	Low	Medium
	Medium	Very low	Low	Low	Medium	High
	High	Very low	Low	Medium	High	Very high
	Very high	Low	Medium	High	Very high	Very high

In literature are presented the models detailing the five levels of risk and probability and severity expressed only in suggestive words [13,14,15]. Much more advantageous are the methods using risk matrices whose severity and probability classes are accompanied by specifications to guide assessors to a more accurate risk assessment [9, 12].

Let us consider the major environmental hazards caused by specific processes and operations of a thermal plant using coal and natural gas as fuel [16], namely:

h1 - the emission, transport and dispersion of SO_2 in the air over the accepted norms;

h2 - the emergence of acid rain caused by SO_2 and SO_3 by reaction with rainwater;

h3 - CO_2 emissions with major influence on climate change;

h4 - NO_x emissions over the accepted norms;

h5 - formation, due to NO_2, of the nitric acid and the ammonium nitrate aerosols;

h6 - formation of the ozone; having as precursor of NO_2;

h7 - emissions diffuse / fugitive of CO;

h8 - emissions diffuse / fugitive of dioxins and furans;

h9 - soil pollution in the slag dump;

h10 - soil pollution by coal dust in the storage of raw materials;

h11 - soil pollution by oil products;

h12 - pollution of groundwater;

h13 - pollution by wastewater;

h14 - fly ash;

h15 - slag and ash particles shattered of the air currents;

h16 - radioactive slag and ash;

h17 - transfer and dispersion of pollutants in aquatic environments;

h18 - noise pollution;

h19 - production of the fires;

h20 - production of the explosions.

These hazards, depending on the frequency and probability evaluated, we will place a risk matrix, shown above, to determine for each hazard the level of risk - Table 2.

Table 2. *Environmental Risk Matrix for hazards specific of a thermal plant**

		Severity of the consequences				
Frequency		Insignificant	Minor	Moderate	High	Very high
	Very low	-	-	Very low risk h4	Very low risk h5	Low risk h6, h7, h16, h20
	Low	-	-	-	Low risk h2	Moderate risk h8, h19
	Medium	-	-	-	Moderate risk h1	High risk h12, h13, h17
	High	-	-	Moderate risk h10, h11	High risk h3, h14	Very high risk h15
	Very high	-	-	High risk h18	Very high risk, h9	-

* The matrix presented is in the first place an example of the method without claiming a well-documented assessment as required by such an approach.

Environmental risk analysis for the heat plant shows mainly large and very large severity of the consequences. Risk occurrence frequency covers all classes. The risk levels of the hazards are concentrated on moderately large and very large risk.

4. Conclusions

Environmental risk assessment can be a very simple or very difficult approach depending on the complexity of the issue being analyzed and the available data. When the environmental hazards cannot be quantified or are not available sufficiently reliable information necessary for quantitative assessment, or collection of data is not efficient in terms of time required for study or costs, qualitative assessment techniques will be applied. A widely-applied method for this purpose is the risk matrix method. The best matrices are those with at least five classes for serious consequences, five classes of frequency and five levels of risk. Most experts in the field of risk are in favor of an initial qualitative analysis followed, if necessary, by a quantitative analysis. Quantitative assessment techniques are expensive and complex but wherever possible, a detailed and quantified analysis made by competent persons provides a better understanding of risk and its management opportunities as compared to a purely qualitative analysis. Both methods have established methods and techniques that can be applied to environmental risk assessment. Environmental risk analysis for thermal power plant shows mainly large and very large severity of the consequences. Risk occurrence frequency covers all classes.

References

[1]. Vlad M., Radu T., Mitoseru O., Potecasu F., *Environment Quality Improvement at Hot-dip Galvanisation and the Recycling of Zinc By-products*, Journal of Environmental Protection and Ecology 12, no. 3A, p. 1415-1423, 2011.

[2]. Radu T., Ciocan A., Balint S., DraganV., *Environmental friendly solution for the hot dip galvanized coatings*, SGEM2011 Conference Proceedings, June 20-25, vol. 3, p. 53-60, 2011.

[3]. Balint L., Istrate G. G., Balint S., Radu T., *Composite coatings with nickel matrix and silicon by clean technology*, SGEM 2011, Conference Proceedings, June 20-25, vol. 3, p.27-34, 2011.

[4]. Ciocan A., Radu T., Balint L., Balint S. I., *Recovery of precious and special metals from cell phone waste by pyrometallurgical processing of printed circuit boards*, SGEM2013 Conference Proceedings, June 16-22, p.749-756, 2013.

[5]. Vlad M., Movileanu G., Radu T., Balint L., *Recycling of zinc by products*, SGEM 2011, Conference Proceedings, June 20-25, 2011, vol. 3, p. 875-882, 2011.

[6]. Radu T., Ciocan A., Balint S. I., Balint L., *Dioxins and furans emissions in the primary steel sector*, SGEM2013 Conference Proceedings, June 16-22, p. 609-616, 2013.

[7]. Ciocan Anisoara, Florentina Potecasu, Veiga Joao Pedro, *Characteristics of the blast furnace dust in accordance with the conditions imposed by the valorization solution*, Metalurgia International, vol. 15, issue 10, p. 85-90, 2010.

[8]. Dryden P., Beer T., Lambert I., s. a., *Environmental risk management*, ISBN 0642546304, Australia, 1999.

[9]. Ozunu A., Anghel C. I., *Evaluarea riscului tehnologic şi securitatea mediului*, Ed. Accent, Cluj-Napoca, 2007.

[10]. Tamara Radu, Maria Vlad, Marius Bodor, Gelu Movileanu, *Managementul riscului de mediu*, Galati University Press, Colectia Stiinte Ingineresti, 2015.

[11]. ***, http://www.scribd.com/doc/31130364/Slide-Riscuri.

[12]. Radu T., Ciocan A., Vlad M., Balint S. I., Dragan V., *Environmental risk assessment in the galvanizing of steel sheets*, SGEM 2012, 12th International Multidisciplinary Scientific GeoConference Proceedings, vol. 5, p. 391-397, 2012.

[13]. ***, *Environmental Risk Assessment*, Environment, Health and Safety Committee [EHSC] of the Royal Society of Chemistry. Environment, Health and Safety Committee, www.rsc.org, 2008.

[14]. Green E., Short S., Taylor March M., *Guidelines for Environmental Risk Assessment and Management*, ISBN 0 11 753551 6, 1998.

[15]. ***, *Environmental Risk*, ACE European risk briefing, http://www.acegroup.com.

[16]. Radu T., *Environmental Risk Assessment for Thermal Power Plants*, The Annals of "Dunarea de jos" University of Galati, Fascicle IX. Metallurgy and Materials Science, no. 4, p. 38-42, 2015.