Nanomaterials and Risk Assessment

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The definition of risk

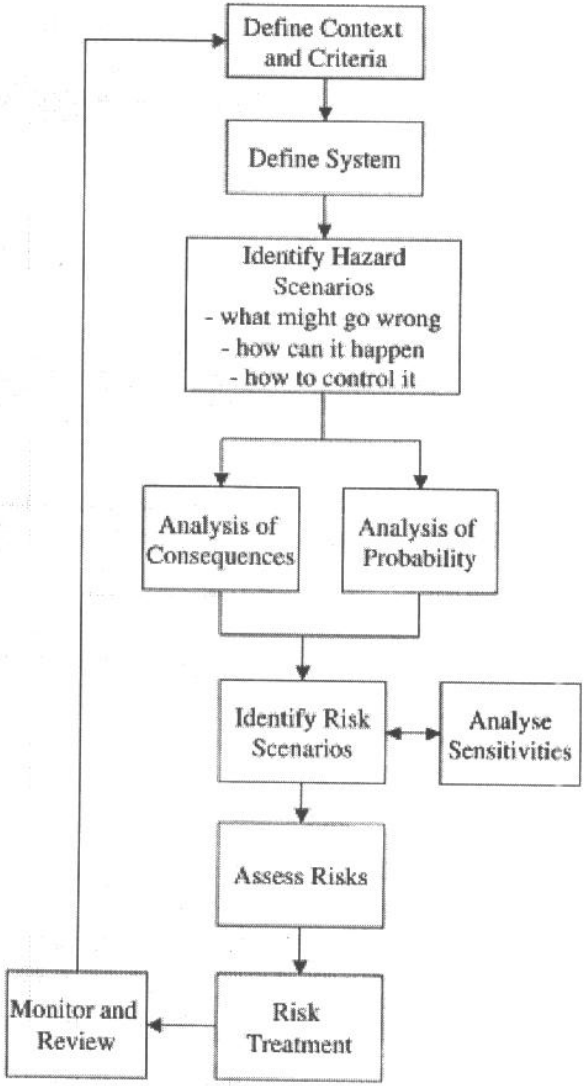
Risk is rather commonly used notion and is used interchangeably with words like chance, likelihood and probability to indicate that we are uncertain about the state of item, issue or activity under discussion.

Technical risk is defined as the expected consequences associated with a given activity. Considering an activity with only one event with potential consequences risk $\boldsymbol{R}$ is thus the probability that this event will occur $\boldsymbol{P}$ multiplied with the consequences given the event occurs $\boldsymbol{C}$, i.e.

$$\boldsymbol{R} = \boldsymbol{P} \times \boldsymbol{C} \qquad (1)$$

The practical implementation of risk analysis

Risk analysis may be represented in a generic format, which is independent from the application or whether the risk analysis is performed in order to document that the risk associated with a given activity are acceptable or is performed to serve as basis for a management, decision. Fig.1 shows a generic representation of a risk analysis. We see that risk analysis is not a “one-off” process, but one that may well require regular monitoring and review due to changes in system needs, increased operating experience, accidents and other new information relevant to system performance.


Define Context and Criteria
Define System
Identify Hazard Scenarios
- what might go wrong
- how can it happen
- how to control it
Analysis of Consequences
Analysis of Probability
Identify Risk Scenarios
Analyse Sensitivities
Assess Risks
Risk Treatment
Monitor and Review

Hazard identification. One of the first tasks in risk analysis of civil engineering facilities is to identify the potential hazards, i.e. the sources of risk. If all the relevant hazards are not identified then the risk analysis will result in biased decision-making, which in general will be cost inefficient and ultimately could lead to unacceptably high risks to people and the environment. Different techniques for hazard identification have developed from various engineering application areas such as chemical, nuclear power etc. A complementary approach is that hazards may also be identified on the basis of past experience as reported incidents data banks containing a systematic documentation of events leading to system failure.

A large proportion of failures of civil engineering facilities are due to human error (impact) yet hazard scenarios for many civil engineering facilities ignore the influence of human impact, in design, construction, use or maintenance.

Logic tree analysis. Having identified the different sources of risk for an engineering system and analyzed these in respect to their chronological components, logic tree may be formulated and used for the further analysis of the overall risk as well as for assessment of the risk contribution from the individual components. The analysis of logic trees provides the tools for assessing the various branching probabilities in the event decision trees as well as the corresponding consequences.

Uncertainty modeling. Risk analysis are typically made on the basis of information which at least party is subject to uncertainty or just incomplete. The sources of uncertainty, even for the same facility, are very dependent on the purpose of the risk analysis. For example, for design of a new facility the uncertainties may be based on analysis of historical data (i.e. past experience) covering a range of existing facilities. However, these predicted uncertainties may fail to capture the actual uncertainties of this new ‘as built’ facility (e.g. the quality of concrete or the operating environment might be different from that predicted). This a posterior risk analysis will provide for more accurate results.

Evaluation of risk. The simplest form of risk analysis is the prior-analysis. In the prior-analysis the risk is evaluated on the basis of statistical information and probabilistic modeling available prior to any decision and/or activity. In practice, this typically occurs for the design of new facilities. A simple decision tree in fig.2 illustrates the prior analysis. In prior analysis the risk (expected utility) for each possible activity/option is evaluated as

$$R = E[U] = \sum_{i=1}^{n} P_i C_i \tag{2}$$

Where *U* is the utility, *Pi* is the branching probability and *Ci* is the consequence of the event of branch *i*.

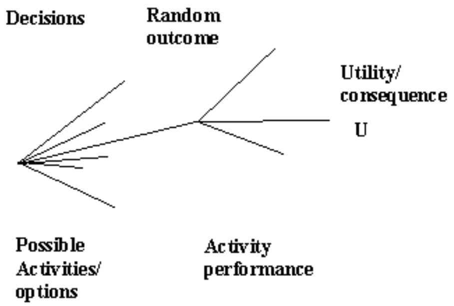


Fig.2

A posterior analysis is of the same form. However, changes in the branching probabilities and/or the consequence in the decision tree reflect that the considered problem has been changed as an effect of risk reducing measures, risk mitigating measures and/or collection of additional information.

Analysis of consequences. The consequences of a failure event are measured in terms that directly affect people and their environment such as loss of life or injury and economic losses. Consequences of most contention are those that tend to result from catastrophic low probability/high consequence events. A major difficulty in estimating consequences is how to compare direct economic losses (building damage, production losses), indirect losses (user delay or inconvenience, impact on economic growth, unemployment) and non-monetary losses resulting from loss of life or injury, damage to the environment, social disruption etc.

Analysis of probabilities. Classical reliability theory was developed for systems consisting of a large number of components of similar type under loading and all practical matters statistical independent. This has found wide application in various industries. The theoretical basis for reliability analysis is thus the theory of probability and statistics developed for disciplines such as operations research, system engineering and quality control. The probability of failure of such components can be interpreted in terms of relative failure frequencies observed from operational experience. The main focus is directed towards the formulation of probabilistic models for the estimation of the statistical characteristics of the time until component failure. Having formulated these models the observed relative failure frequencies can be applied as the basis for their calibration.

Reliability analysis. For reliability analysis it is thus necessary to established probabilistic models for loads and resistances including all available information about the statistical characteristics of the parameters influencing these. For structural component for which the uncertain resistance R and load S are modeled by random variables with probability density functions *FR*(*r*) and *fS*(s), respectively. In general, the resistance and the load cannot be described by only two random variables but rather by functions of random variables. Hence, a general formulation for the probability of failure may be determined through the following *n*-dimensional integral

$$P_F = \int_{g(x)} f_x(x) dx$$

Where *fx*(*x*) is the joint probability density function for the vector of basic random variables X and the integration is performed over the failure domain.

Optimality and risk acceptance criteria. The development and implementation of risk acceptance criteria involves:

- Perception of risk: ensure that level of system risk is acceptable (or tolerable);
- Formal decision analysis: analytical techniques to balance or compare risks against benefits (e.g. risk-cost-benefit analysis, life-cycle cost analysis);
- Regulatory safety goals: legislative and statutory framework for the development and enforcement of risk acceptance criteria.

The risk acceptance criteria generally adopted by various regulatory authorities is that risks and hazards should be “As low as reasonably possible” or “As low as reasonably attainable”.

The risk assessment of nanomaterials

The unique properties and extremely small size of nanomaterials are such that even determining the full extent of the risks to human health and environment is currently beyond the means of existing risk assessment frameworks.

Given that nanomaterials can be more toxic than their conventional equivalents, it is clear that the risks associated with nanomaterials cannot be inferred from the relative risk or safety of their bulk equivalents. That is, although some nanomaterials are made of substances that have long been used in other forms, their very different physical and chemical properties mean they may pose different risks than conventional materials. The toxicity of a nanomaterial cannot be assumed by comparison with another nanomaterial since toxicological properties arise from a variety of features, such as their surface characteristics, size, shape, overall composition and chemical reactivity. There are in essence several independent and interdependent variables that dictate toxicity.

For example, the European Commission’s *Scientific Committee On Emerging and Newly Identified Health Risks* has suggested that any determination of the critical dose of nanomaterials must also take into account the number of particles and total surface area, rather than just the exposure mass of a substance, which is the current practice. In addition, the effects of surface characteristics and coatings, their size and shape, physical composition and chemical reactivity, and the potential for aggregation (clumping) all need to also be specifically tested to develop a comprehensive assessment of the risks of nanomaterials.

The risk assessment of nanomaterials is further complicated by a lack of established standardized indicators for nanotoxicity. And so, without a coherent testing regime within which the risks of nanomaterials can be appropriately assessed, it is currently impossible to make informed decisions regarding their handling and use. Not only is there not enough information about the actual hazards of nanomaterials currently in use to effectively manage these risks, but there are no established risk assessment regimes capable of considering the unique characteristics and properties of these new materials.

Simulation of risk assessment of nanomaterials

The analysis of nanomaterials manufacture shows, what even at normal functioning, the influence of such objects on an environment is connected both to social - psychological influence on people, and with the potential danger of pollution of an atmosphere and territory dangerous substances. Therefore, the model of risk should reflect all essential factors on which functioning system to the greatest degree depends should be taken into account.

Output parameters of mathematical model of risk determine a mathematical expectation of amount of the affected people living in area of industrial object. We shall consider possible analytical approaches to the decision of a problem. The mathematical expectation (risk *R*) of amounts of affected people can be determined dependence

$$R = \int_{\varphi=0}^{2\pi} \int_{l=0}^{\infty} r(\varphi,l) \cdot P(\varphi,l) d\varphi \cdot dl$$

Where: $r(\varphi,l)$ is a distance from a plant up to the person in polar coordinates (the beginning of coordinates is superposed with plant); $P(\varphi,l)$ is a probability of affection of the person in a point with (φ,l) coordinates.

The probability of affection $P(\varphi,l)$ is defined as follows:

$$P(\varphi,l) = P0(\varphi)\cdot Pl(l,\varphi0),$$

Where: $P0(\varphi)$ is a probability of that at the moment of emission the direction of wind $\varphi = \varphi0$ will be realized; $Pl(l,\varphi0)$ is a probability of affection on distance l from a place of emission in direction $\varphi0$.

As a pollution is equiprobable at any moment then $P0(\varphi)$ should be defined on the basis of a wind rose in the given zone or region. If to neglect differences in characteristics of an underlying surface on each of directions of possible distribution of harmful emission and to enter concept of the average characteristic it is possible to simplify essentially a problem, having divided variables:

$$R = \int_{l=0}^{l=\infty} P(l) \int_{\varphi=0}^{\varphi=2\pi} r(\varphi,l)\cdot P(\varphi)d\varphi\cdot dl$$

This approach to calculation of risk criterion is one of possible variants of an analytical method of assessment. In practice of risk assessment the following approaches to mathematical modelling risk are considered by us.

Modelling of individual risk. Individual risk is probability of the person affection in the course of year from the certain reasons in the certain point of space. Results of the analysis of individual risk are displayed on a map of the plant as the closed lines of equal values (isolines).

The construction of isolines of individual risk is carried out under the formula

$$R_i(x, y) = \sum_{m \in M} \sum_{l \in L} P_{Q(x,y)} F(A_m)$$

Where: *PQ(x,y)* is a probability of influence on the person in a point with coordinates *(x, y)* of the damaging factor *Q* with the intensity corresponding to affection of the person (healthy man of 40 years) under condition of realization of *Am* event (pollution); *F (Am)* is frequency of occurrence of *Am* event per year; *M* is a set of indexes which corresponds to considered events; *L* is a set of indexes which correspond to the list of all damaging factors arising at considered events.

We have carried out researches at a plant of polymeric nanomaterials (and nanomaterials). Isolines of equal risk and zones of individual risk are resulted on fig. 3 for this factory.

We can see from fig.3, that near of plant (zone 1) the individual risk of person affection is high, *R*=10-4. In zone 2 *R*=10-5 (the individual risk of person affection is acceptable). At last, in zone 3 *R*=10-6, i.e. the individual risk of person affection is low.

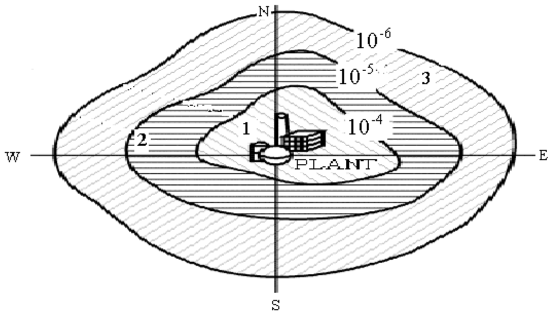


Fig.3

Modelling of social risk. The social risk is a dependence of occurrence frequency of the events causing affection of people, on this number of people. Social risk *R - F (N)* characterizes scale of possible extreme situations. The social risk can be designed under the formula

$$R_s(N)=\sum_{m\in M}\sum_{l\in L}P\left(\frac{N}{Q_m}\right)P\left(\frac{Q_m}{A_l}\right)F(A_l)$$

Here: $P\left(\frac{N}{Q_m}\right)$ is a probability of N people affection from the damaging factor *Qm*; $P\left(\frac{Q_m}{A_l}\right)$ is a probability of occurrence the damaging factor *Qm* at realization events *Al*.

THANK YOU

Təşəkkür edirəm