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TRENDS IN RISK EVALUATION OF CHEMICAL PLANTS IN THE CZECH REPUBLIC

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Abstract

Risk evaluation has matured into a powerful analytical tool, which is focused to finding of applications in the field of precaution and regulation. However, the main focus of its development to date has been on the technical challenges of characterising and modelling the behaviour of chemicals. At the moment, a lot of anothers problematic areas are encountered during risk evaluation. In this contribution attention is paid to identification and selection of risk, analysis of human reliability and Modelling of accident consequences.

Key words: Quantitative risk analysis, safety in chemical industry, selection of risk sources, evaluation of human factor, modelling of consequences of serious accidents.

1. Introduction

The growth of new types of industrial accidents is accompanied by negative consequences for human life, property and environment. Simultaneously such accidents can provide new knowledge of chemical substances and their properties. These accidents and their analysis (mostly a complicated process the results of which are often not made available to the public) are important sources of information and highlight the dangers of lax safety in chemical companies.

At the moment, a lot of problematic areas are encountered during risk evaluation. In this contribution attention is paid to identification and selection of risk, analysis of human reliability and Modelling of accident consequences. These areas are illustrated in the following diagram:

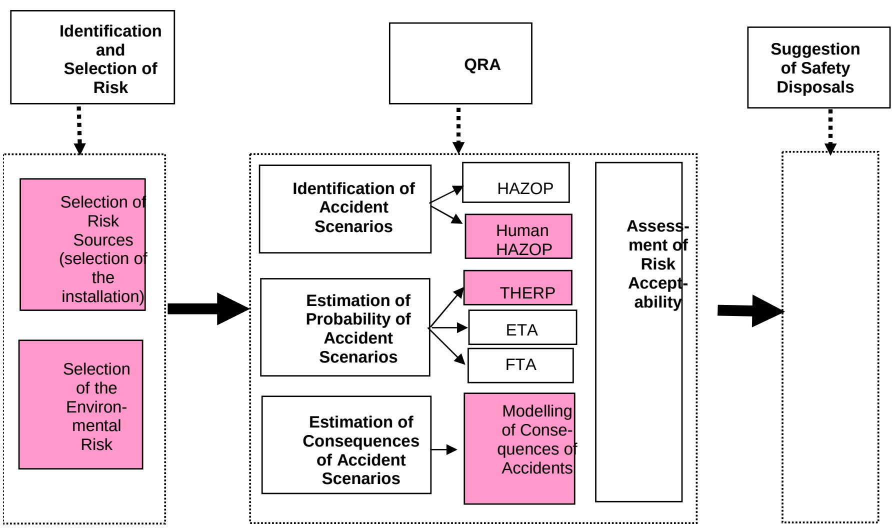

Figure 1 Quantitative risk analyses Diagram

2. Identification of Risk Sources

For a complex evaluation of social risk of large or small chemical plants, it is first necessary to objectively identify those risk sources which are most relevant to social risk. The process of identification of these risk sources in places where manipulation of toxic, combustible and explosive materials take place, requires objective assessment of all equipment and awareness of causes.

The oldest method of risk sources identification was the listing of apparatus and equipment; these were further selected by various screening and indexing methods. In practice, at present, we often meet with the application of this method, particularly with an incorrect interpretation of its results. Some of the major accidents in recent times serve as proof of this fact.

It is not possible to leave the identification of risk sources up to operators, technicians or maintenance staff; while on one hand, they have very valuable field experience, on the other hand, it is necessary to account for their *field blindness*, especially in identifying risk sources of serious accidents. Everyday contact with a source of risk, combined with a specific professional focus, can lessen the perceived seriousness of risk sources.

Identification of environmental risk sources is another problem.

2.1 Rational Selection of Risk Sources

A selection method has been developed for the purposes of sources of serious accidents with consequences beyond the boundaries of the premises. Such a method can evaluate objectively and compare different technologies and thus create a complex overview on risk sources in a particular building. The selection method can be used for a wide range of risk sources where various dangerous substances are present. In the initial phase this method demands more input information (there has to be good knowledge of technological apparatus and its division into individual units which can be quickly and effectively separated). There is also a need for cooperation with technologists and operations managers. Although this may be time-consuming and labour-intensive at the beginning, high-quality outputs for subsequent quantitative risk evaluation are obtained and in the end there are subsequent time and work savings. A relative simplicity of the application of the selection method is an advantage.

Advantages of the Selection Method

- When calculating the indication number expressing the danger of a unit, operational conditions (temperature, pressure at which the substance is present in installations), amount and physical state of the substance, installation type (processing or storage equipment), installation location (open area, indoor), local conditions of the installation, location of the assessed unit related to the installation boundary and inhabited area are taken into account, allowing to reach specific results for a given unit.
- The method can be used also in the stage of planning and designing of new installations due to the involvement of a safe distance from the boundary of the installation and surrounding inhabited area.
- Applying the selection method at the initial part of analysis, a basic overview of all units located on the premises of the assessed installation is obtained.

2.2 Application of Selection Method in Practice

Selection method has been applied in various industrial enterprises (plants of different character, such as chemical factories, gasworks, mines etc.) as well as in various industrial installations, a wide spectrum of chemical substances, different operational conditions, and complex pipeline systems. The assessed installations differed mainly in the number of individually considered units and the age of the installations.

According to the number of units, enterprises are divided into:

- Small enterprises – up to 50 individual units which can be taken into consideration,
- Medium-sized enterprises – 50-100 individual units which can be taken into consideration,
- Large enterprises – more than 100 individual units which can be taken into consideration (it can reach up to about 1 000 units in the largest enterprises).

The following data were found at the statistical evaluation of the selection method:

- As for small enterprises, about 2% of units (out of the total number of assessed units) would affect the area beyond the premises of the assessed installation and a subsequent analysis is required.
- As for medium sized enterprises, about 2 - 5% of individual units (out of the total number of assessed units) would seriously affect the area beyond the premises of the assessed

installation and a subsequent analysis is required.

- As for large enterprises, about 5 - 10% of individual units (out of the total number of assessed units) would seriously affect the area beyond the premises of the assessed installation and a subsequent analysis is required.

2.3 Selection of the Environmental Risk Sources

Environmental risk, where the risk source may be the leak of a substance hazardous to the environment, is understood as the risk of damaging components of the environment (e.g. water, soil, atmosphere, bio-systems).

Basic procedure of classifying environmental risk includes:

- Risk identification (determination of substance hazard-level),
- risk estimation (analysis of dose - reaction relationship, exposure time),
- risk characterization, determination of risk acceptability.

At present, neither a unified approach to the evaluation of environmental risk nor a unified methodologically secured approach to the evaluation of this risk are clearly determined.

The qualification of social risks (also called health risks) is achieved through a process similar to that used with environmental risk.

Complex assessment of environmental risks with regard to the transport of contaminants is a difficult, multidisciplinary task. The transport of contaminants in the environment from their source to their final recipient involves many stages, the description of which can require the input of a large quantity of data.

3. Human Error Analysis

It is generally accepted accidents do not happen in isolation. Rather, they are the result of a chain of events often culminating with the unsafe acts of operators. The most of accidents causations has been at least partially caused by human error.

Howbeit the company management brings about organizational influences, which often lead to instances of unsafe supervision which in turn lead to preconditions for unsafe acts and ultimately the unsafe acts of operators. The order of analysis of unsafe acts of operators is focused at the bottom.

The purpose of the human error analysis is to evaluate the relevant consequences to the system of the human errors identified. To get error probabilities of the human actions, we must take two steps in judging human reliability: in the first step, we collect the qualitative data about the situation to be judged. In the second step, we quantitatively evaluate the situation with the help of an HRA. A large number of techniques exist to quantify the probability of human failures. However, a small number of these techniques have actually been applied in practical human error analysis.

3.1 Task description model

First of all, it is necessary to build up a description model. It must be generally valid and it must be applicable to all observable events. Furthermore, the model must be able to collect all information items on human errors from the events in such a form as is necessary for an analysis because the purpose of a task analysis is to collect information on a human activity in such a way that this information can be used in a human reliability analysis. A detailed task analysis is required for most of the human error identification techniques and human reliability analysis techniques.

Task analysis describes the demands made on the operator in the tasks he or she has to perform, and examines the resources required and available to enable the operator to meet those demands. A demand is a requirement for the operator to meet some goal which is a partial requirement for achieving a higher goal.

The most significant benefit is, that model can provide knowledge of the tasks that the user wishes to perform. Thus, it is a reference against which the value of the system functions and features can be tested. Description Model Method or Hierarchical Task Analysis is the most used analysis.

3.2 Human HAZOP

HAZOP, or Hazard and Operability Study is the risk assessment technique used for new projects and process modifications. The technique makes detailed examination of the process and engineering intention of new or existing facilities to assess the hazard potential of operation outside the design intention, or malfunction of individual items of equipment and their consequential effects on the facility as a whole. Human HAZOP is the extension of the technique to the field of procedures performed by humans.

The key benefits of Human HAZOP are comprehensiveness, systematicness and effectiveness. Human HAZOP ensures that potential deviations from intended task procedure are identified and corrected, process hazards are revealed and actions for necessary process or instrumentation improvements can be planned.

3.3 HRA event tree

If there is required a quantitative human reliability analysis a Human reliability event tree must be done.

Event trees must be constructed to represent the errors that could occur in the execution of each task. The HRA event tree represents a combination of necessary subtasks of personnel which were determined by means of a task analysis. This order is able to give error probabilities and success probabilities for sub-tasks.

HRA event tree begins with any suitable point in a system procedure works forward in time. The level of detail depends on the purpose of the analysis. The top-down procedure enables to analyze what leads to what. It follows the same sequence in time as the underlying task analysis and facilitates showing in graphic form those parts of the task analysis relevant to the HRA.

3.4 Human failure data – THERP

Initially, it may be necessary to use expert judgments as a source of the probability estimates. But keeping the criticisms of HRA in mind, it is crucial that the expert judgments are calibrated as well as possible. Meanwhile, every effort should be made to collect sufficient empirical data. Note, however, that empirical data should not be sought for separate actions but for types of actions. When the observations are made, in real life or in simulators, both actions and context should be recorded, and a statistical analysis should be used to disentangle them.

Collection of human failure data is contained in THERP method [8]. THERP (the technique for human error rate prediction) was developed by Alan Swain at Sandia National Laboratories as a quality control method for estimating errors in the assembly of nuclear warheads.

The tabled error rates used by THERP have evolved over a 30 year period based on a combination of statistical data and expert judgment and are presumed to be accurate within an order of magnitude.

4. Modelling of Consequences of Serious Accidents

One of the consequences of serious accidents involving chemical apparatus can be the leaking of toxic substances. The properties of the substance leaked, the type of leak, and the meteorological conditions all determine the nature of the toxic cloud which is formed, its development, migration and dispersal. The process of describing the behaviour of this toxic cloud in the air is known as Modelling the Dispersion of Toxic Substances.

In practice, a wide range of computer programmes is used when modelling the dispersion of toxic substances. The results obtained through these programmes often conflict with each other. In emergency planning, safety planning and project design, it is important to choose those programmes which can objectively predict the size and concentration of toxic clouds.

4.1 ALOHA [9]

For some time, the Czech Republic has been modelling leaks of toxic substances into the atmosphere; mainly with the **ALOHA** modelling programme (Areal Locations of Hazardous Atmospheres). This programme is already out-of-date compared to those used in other countries.

Typically, the ALOHA programme produces results which are out-of-proportion in comparison with other software. As a consequence, the predicted size and concentration of toxic clouds can be disproportionate.

4.2 EFFECTS Programme

EFFECTS is a programme developed by Dutch company **TNO** Environment, Energy and Process Innovation Department of Industrial Safety. This programme allows users to judge the physical effects of the accidental leak of toxic and combustible chemical substances.

EFFECTS includes several modules which allow detailed modelling and quantitative assessment.

4.3 SAFETI 6.42.

SAFETI programme was developed by the international organization **DNV** Det Norske Veritas, established in 1864 in Norway. SAFETI 6.42 allows not only the modelling of the physical effects of accidental toxic leaks, but also allows the automatic calculation of a full QRA (Quantitative Risk Analysis).

4.4 Comparison of Computer Programmes

The **EFFECTS** and **SAFETI** computer programmes are modern tools which, unlike ALOHA, allow the simulation of a wide range of possible scenarios. For this reason, their use is not limited to modelling only the leaks of toxic substances. A further characteristic of both programmes is that, as already mentioned, they are continuously updated and improved - thus, the results obtained through the programmes are increasingly accurate and exact. However, the greater complication of these programmes means that greater training is required to operate them, and that users must have knowledge of both physical chemistry and construction of chemical equipment.

Basic differences between the two programmes are in their use; EFFECT is used mainly for judging the physical effects of an accidental leak of toxic or combustible chemical substance, while SAFETI allows for a complete QRA (Quantitative Risk Analysis).

EFFECTS is made up of a number of modules, each of which allow detailed modelling of a single phenomenon. In order to model a specific scenario, it is necessary to choose the correct modules, and place them in an appropriate sequence. With SAFETI, however, the programme itself determines this choice, based on user input. Both programmes require the user to have extensive knowledge of the subject.

As already mentioned, the disadvantage of the EFFECTS programme when compared with SAFETI is that users must select modules manually, and that it offers no QRA. The benefits, however, are that its results are comparable with those of SAFETI, and that it is much cheaper.

5. Conclusion

A detailed analysis of all apparatus with dangerous substances in big plants (technological complexes) is not possible. It is thus necessary to deal only with such risk sources the consequences of which go beyond the boundaries of the plant in question. The results of the selection of risk sources thus have to be transparent and have to provide an overview on the safety of all apparatus.

Human Reliability Analysis is a serious problem of safety engineers and risk assessment analysts. The main reason for that is the subjectivity and vagueness of the methods used to evaluate human reliability and the uncertainty of the data concerning human factors, together with the complexity of the human behaviour. Human reliability analysis techniques can model and quantify only some types of failures. Any other event that is not covered by a human reliability analysis can be quantified using subjective judgment.

The selection of a suitable modelling tool and its appropriate use is important for the determination of the impact range of the toxic substance. In practice many outdated modelling programmes as well as incorrect interpretations of the results can be encountered. This fact can result in an incorrect determination of risk acceptability.

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