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# Chemical risk assessment — A tool for disaster prevention

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**Abstract**

Accidents in chemical plants in the last few years have caused considerable public concern. It is generally accepted now that a comprehensive and objective assessment of risks from dangerous goods is required. One way to gain this comprehensive overview of risks from dangerous goods is to create a dangerous goods database, such as the one that has been introduced by the city of Winterthur in Switzerland. In the following, a general procedure for developing such a dangerous goods database and its use for risk assessment is outlined.

## Introduction

Chemicals and environmental risks, air and water pollution, etc. Are these phrases only used to stir up emotions, or do we really live in an apocalyptic world? There is certainly no doubt that the production, storage and transport of dangerous goods has increased enormously over the last decades. At the same time, however, large efforts have been made to reduce the risks to persons and the environment. For gaining insight in the risk for the inhabitants of a large city or an entire region and to be able to prescribe adequate safety measures, a chemical risk database is an indispensable tool. The main purpose of a chemical risk database is to register all dangerous goods that are processed or stored in the area of interest, to assess the risk they imply for the public and to develop safety measures for the most urgent cases.

## The chemical risk database

The development of a chemical risk database is a very complex and time consuming task. For such a project several hundred companies of different types with well over 1000 different dangerous products have to be analysed. In addition a systematic risk assessment has to be carried out. For the city of Winterthur a new procedure has been developed. It is based on a computerized

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database, which allows the processing of large amounts of data in a relatively short time.

*Data acquisition with questionnaire*

The project is divided, as shown in Fig. 1, in six main tasks. The layout of the questionnaire, trivial as this may seem, has an important influence on the success or failure of the project. The questionnaire has to be clear and complete and should at the same time be as short as possible. In developing the questionnaire for Winterthur, several companies located in the city area have been consulted. Their contribution has helped considerably.

In the questionnaire the dangerous goods had to be listed individually and not as categories; for instance, the amount of hydrochloric acid, sulphuric acid and acetic acid has been listed separately and not simply as the total amount of acid. Only small quantities have been summarized in specific categories. The effort required for this detailed compilation of data is high, yet warrants meaningful risk assessment. Furthermore it simplifies the work for updating the database at later stages.

*Damage potentials*

The kernel of the chemical risk database is the evaluation of the damage potential. A damage potential is defined as a measure for the danger a given product can pose. It is a measure of the ability to create damage. This parameter depends on both the amount and toxicity of the dangerous good, and not on the storage conditions or the safety measures. The damage potential of a certain amount of explosives, for instance, is always the same, whether it is stored in a city or in the desert. The risk, however, depends also on the actual environment.

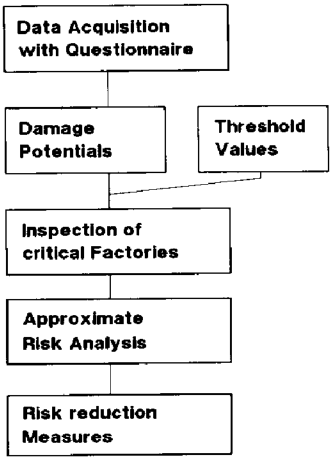


Fig. 1. Principal steps in developing a chemical risk database.

The damage potential *DP* is defined, as shown in Fig. 2, as $M\eta T$—the product of mass, activity and toxicity. Thus it is assumed that the possible damage is proportional to the participating mass (i.e. $M\eta$) and to the toxicity. It is obvious that such an assumption is an idealisation, but it is certainly sufficient for the purpose of the chemical risk database. The activity factor $\eta$ indicates which percentage of the stored material is most likely involved in an accident. Gaseous materials have an activity factor of 1.0, as participation of the entire stored material has to be expected. For liquid and solid materials smaller values are used, depending on the vapour pressure and the combustibility. The toxicity factor $T$ is derived from various technical, chemical and toxicological parameters.

An important aspect in the definition of the damage potential is the recognition of the various types of accident. The damage potential of a product cannot be characterized with one parameter only; a set of parameters is required to reflect the individual potentials for the six most important types of accidents, which are: (1) leakage of gaseous material or materials with a high vapour pressure; (2) fire (heat effects); (3) fire (toxic gas); (4) explosions; (5) leakage of liquids; (6) flooding. Therefore the damage potential is characterized by a set of six parameters as shown in Fig. 3. It is obvious that a damage potential assessment for an entire city is cumbersome and can only be carried out with the help of a computer. The computer program C-RISK has therefore been developed, which carries out the damage potential assessment automatically.

### *Threshold values for the damage potential*

The damage potential is an ideal parameter for the *relative* assessment of the potential danger in a factory. As soon as the damage potential for a suffi-

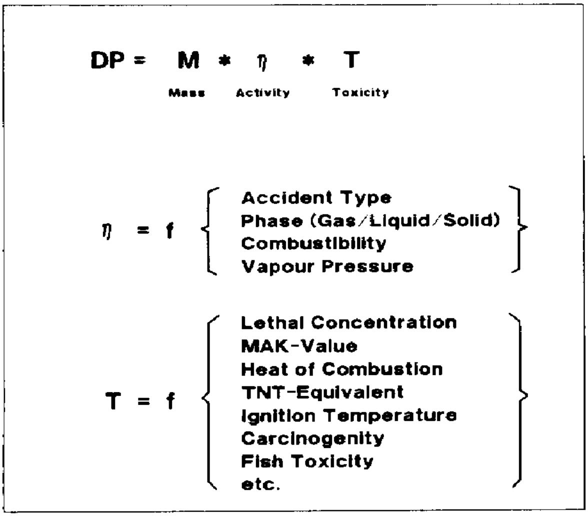


Fig. 2. Definition of damage potential.

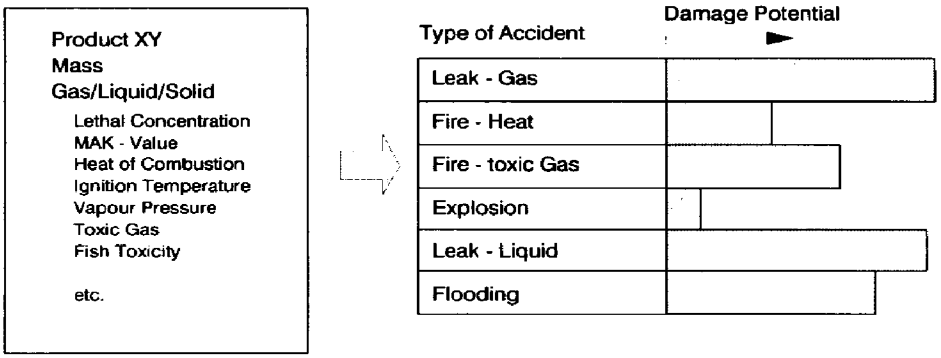


Fig. 3. Representation of the damage potential by a set of six parameters.

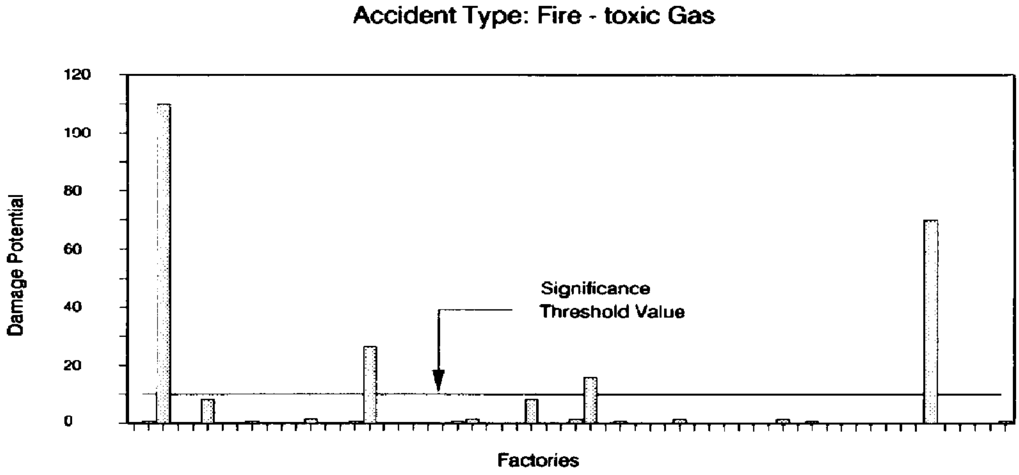


Fig. 4. Typical example of the damage potentials in a city, where hundred companies have been investigated.

cient number of factories has been determined, it is easy to recognize, (see Fig. 4) which factories do not need any further investigation. However, to obtain an *absolute* assessment of the damage potential of a factory or storage house, significance threshold values have to be determined; i.e., from which damage potential value upwards is damage to persons, environment or buildings outside of the factory to be expected?

The significance threshold values for accidental gas release, for instance, has been calculated by applying atmospheric dispersion models.

Development of a database that can list the damage potential of the various factories and storage houses, and can provide comparisons with the significance threshold values, creates an objective selection tool to determine the "dangerous" companies. The procedure developed here allows not only potentially dangerous companies to be identified, but shows in which respect these companies are dangerous and which product is responsible for the high damage potential.

*Inspection of critical factories*

The next step was the inspection of the 15 companies with the highest damage potential. It was a very positive experience to see that during these visits many safety measures could be developed in cooperation with the management responsible for safety affairs in the individual companies. Generally there is a preparedness in the companies to introduce new safety measures if it can be proved that they are needed, and if there is evidence that these measures will reduce the risk.

*Approximate risk analysis*

Based on the information gained during the inspections of the 15 factories and combined with the data from the damage potential assessment, an approximate risk analysis has been carried out. Therein the type of construction, type of containment, the safety devices and the environmental characteristics

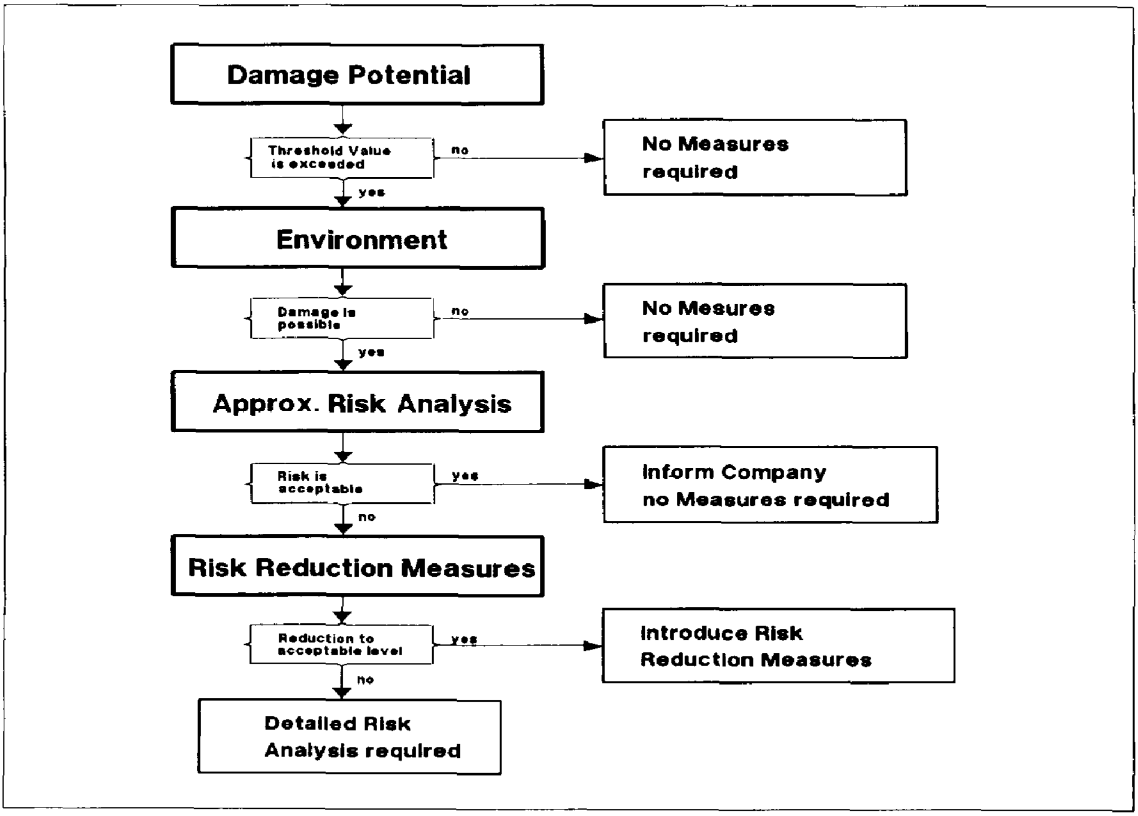


Fig. 5. Step-by-step procedure for an approximate risk analysis.

(location, population density, ground water table, etc.) has been taken into account. In Fig. 5 the different steps in this procedure are shown. It is a multiple screening process, which allows the determination of those cases that are most serious. If the approximate risk analysis shows that the risk is above the acceptable level, but no risk reduction measures can be agreed upon, a more detailed risk analysis is required.

At the time when the chemical risk analysis for the city of Winterthur was carried out (1988), no legal provisions existed as to how to assess significance thresholds or risk acceptability. In 1989 the draft version of the "Verordnung über den Schutz vor Störfällen" (Standard for prevention of large industrial accidents) [1] appeared, which contains also quantity limits, indicating from which quantity upwards a risk analysis is required.

*Risk reduction measures*

Based on the approximate risk analysis, the risk situation for an entire city can be depicted by means of a risk matrix, as shown in Fig. 6. Each block in Fig. 6 corresponds to a potential accident; the location in the matrix indicates the probability of occurrence and the degree of damage. It is important to note

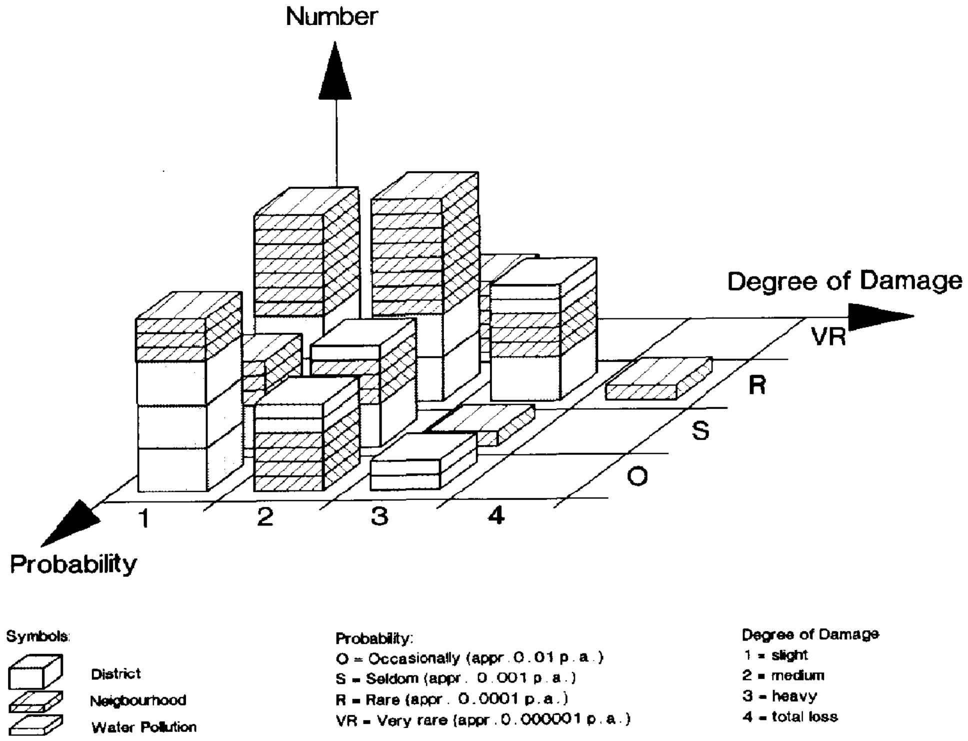


Fig. 6. Representation of the risk situation in a city by means of a risk matrix.

that the bounds for the degree-of-damage classes have to be specified as accurate as possible for effects on mankind, on environment and on buildings, in order to render a diagram as shown in Fig. 6 meaningful. From this presentation of risk it is evident where safety measures are most urgently needed. In a first step, risk reduction measures have to be introduced for those cases which belong to probability class "occasionally", and to the degree-of-damage class 2,3 or 4. In a second phase, the risks with probability class "seldom" have to be dealt with.

## Conclusions

Certainly specific probabilities of accidents with dangerous goods cannot be predicted with the procedure presented in this paper. Nevertheless this procedure is a valuable tool to obtain an overview of the existing damage potentials; and it enables assignment of safety measures where they are needed most urgently.

Last, but not least, a chemical risk database is of great value for the government, especially the environmental departments. Furthermore, it is a valuable contribution to the information system of the fire brigades, as they can retrieve data on both the locations and the amounts of dangerous goods.

## Acknowledgements

The procedure described herein has been applied successfully in the project "Chemie-Risikokataster für die Stadt Winterthur". The author has carried out this project as subcontractor for GSS Zürich. The computer program C-RISK is a data base oriented program to develop and evaluate chemical risk data base. It is continually updated and expanded.

## References

1 Verordnung über den Schutz vor Störfällen (Störfallverordnung, StFV), Entwurf, April 1989, Eidgenössisches Department des Innern, Bern.