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Evaluation of the Use of the Prescribed Quantitative Risk Assessment Method for Land Use Planning in the Netherlands

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In the Netherlands, land use planning around establishments handling, processing or storing dangerous substances is based on a Quantitative Risk Assessment (QRA). The criteria for acceptance of a risk level are laid down in law: no houses are allowed in areas where the individual risk of mortality of 1×10^{-6} per year is exceeded. Since the criteria are very strictly, the QRA results must be transparent and robust. Therefore, it was decided in 2006 to lay down the risk assessment method in a detailed, stringent guideline and to prescribe the use of the software tool SAFETI-NL. A helpdesk was installed to address open issues and a model management organisation was initiated for maintenance and development of the method.
As the guideline and software have now been in use for five years, this is a good time to evaluate experiences and to weigh options for the future. Various evaluation studies have been carried out recently to determine whether the application of the QRA in land use planning fulfils the expectations and requirements. Topics of these studies include: (i) How does the simplified risk assessment method relate to the complexity of process plants? (ii) What is a good balance between stability of the method and incorporation of new (scientific) developments? (iii) Can new emerging risks be incorporated in the risk assessment method? and (iv) To what extent have the goals and objectives of 2006 been reached?
The results of the evaluation studies show that important objectives have been fulfilled The uniformity in risk calculations for land-use planning has increased substantially. Competent authorities can better assess the inputs and outputs of the risk analysis because one single guideline and software tool are in place. Additionally, there are side-effects, both positive and negative. The standard, structured approach has reduced the number of initiatives to make a site specific risk assessment. However, the remaining initiatives are justified in a more solid way. The easily accessible guideline and software tool has attracted a large new group of consultants to this market. This is good for competition but lack of experience may hinder the quality of the risk calculations. The largest remaining issue is the conflict between the desire for a stable method and the desire to incorporate new insights and new technologies. This issue requires further improvements to the model management organisation.

1. Introduction

In the Netherlands, Quantitative Risk Assessment (QRA) is already used for over twenty years in decisions on site permit granting of and land-use planning around sites with dangerous substances. Two different measures are used to assess the risk to which the public is exposed, the individual (or location-based) risk and the societal risk. The individual risk is defined as the probability that an (unprotected) person dies in one year as a consequence of an accident with dangerous substances and is expressed as a frequency (per year). Within the individual risk contour of 1.10^{-6} per year, the location of buildings for residents, such as houses and schools, is prohibited. For societal risk, there is no limit value defined, but the competent authorities have to include the societal risk in their decision process, balancing the benefits of the activity with the risk imposed by the activity. A more detailed description of the background of the Dutch legislative context is supplied in Bottelberghs et al., 2000.

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The limit value of 1.10^{-6} per year for the individual risk is laid down as an environmental quality requirement in the External Safety Decree for Establishments, which has the force of law. Therefore, any change in the individual risk calculation may have large financial consequences. A benchmark study clearly demonstrated that different consultants using a variety of QRA software tools resulted in significant different outcomes (Ale et al, 2001). To minimize the differences in QRA outcomes, it was therefore decided that a stringent guideline should be developed, the Reference Manual for Bevi Risk Assessments (RIVM, 2009). Furthermore, only one QRA software tool was allowed for the QRA calculations for land use purposes. The software package SAFETI-NL, a restricted version of the DNV software tool SAFETI (DNV, 2012), was selected in 2006 for this purpose and in 2008 prescribed in the legislation. RIVM is the organisation responsible for the availability of the Reference Manual and SAFETI-NL. A helpdesk was installed to address questions and a model management organisation was initiated for maintenance and development of the QRA method.

SAFETI-NL and the Reference Manual are now in use for over five years, and various evaluation studies were carried out (Hazardous Substance Council, 2010; Twijnstra Gudde, 2012). In this paper, we describe the evaluation of five years experience with the prescribed method. First, the use of the QRA method in practice is described (Section 2). Next, the prescribed QRA method is evaluated against a set of requirements and recommendations for improvement are given (Section 3). Finally, the most important conclusions are summarized (Section 4).

2. The use of the prescribed QRA method

2.1 Users of SAFETI-NL

The RIVM is responsible for the distribution of SAFETI-NL in the Netherlands. If an organisation wants to use SAFETI-NL for a QRA in the Netherlands, an employee has to follow a dedicated training course of four days before getting a license. Up to 2010, in total 35 training courses were organised with an average of 10 participants per training course. The total number of organisations having a license is about 190 in 2010. The number of users is very high when compared to the number of organisations performing QRA calculations prior to the introduction of SAFETI-NL and compared to the number of 'competent consultants' for QRA calculations in Flanders, which is 23 persons in 12 companies (LNE, 2012). There are two reasons for the high number of users in the Netherlands.

- In the Netherlands, the local competent authorities have to approve the QRA in order to permit an activity with dangerous substances. Consequently, some competent authorities have also applied for a license in order to be able to verify the QRA.
- The threshold for obtaining a license for SAFETI-NL is low: only one person has to attend the four-day training course, and additional license costs are limited. As a consequence, a number of consultants working in the field of environmental protection added third-party risk and QRA calculations to their portfolio and applied for a license.

The number of QRAs carried out is limited, in the order of 250 per year (Twynstra Gudde, 2012). A minor part of the SAFETI-NL users is therefore frequently involved in QRA calculations. The knowledge and experience of the remaining part of the users is minimal. This is reflected in the strongly fluctuating quality of the QRAs performed. The inexperience of the users and the varying quality of the QRAs is therefore a major area for improvement.

As an important step towards improvement, the competent authorities decided to bring together their knowledge and experience in a few expert groups in 2013. The approval of QRAs will then be done by a smaller group of experts. In this way, the quality of the accepted QRA should be improved considerably.

2.2 Support of SAFETI-NL

The RIVM operates a helpdesk to support the users and to address open issues. An overview of the number of questions to the helpdesk in one year is shown in Table 1.

The questions concerning content, i.e. related to the Reference Manual and the QRA-modelling with SAFETI-NL, appear to require a large amount of support time, over 500 h/y. The large amount of support hours partly reflects the large number of users and the inexperience of part of the user group.

Table 1: Help desk requests for support in 2010

Type of questions	Number of requests	Relative
Training and license requests	153	31 %
QRA method and models	137	28 %
General questions	115	23 %
Computer problems	56	11 %
Administration	32	7 %
	493	**100 %**

3. Requirements for QRA methods

3.1 Introduction

A risk assessment method to be used for land use planning should meet a number of requirements. Requirements are often stated in terms of transparency, robustness or validity. However, the meaning of these terms may differ between different references. We evaluate the prescribed risk assessment method for land use planning with the following requirements, which are based on Hazardous Substances Council (2010), Christou et al. (2006) and Gooijer et al. (2010).

3.2 Transparency

The term 'transparency' means that the risk assessment method is well described, understandable and unambiguous. If the method is transparent, each expert carrying out the assessment should come to the same conclusions for the same situation.

Users score the prescribed QRA method very high on transparency due to the unambiguous set of scenarios, frequencies and consequence calculation. This is considered as the major advantage of the prescribed QRA method: there is an increased stability in de decision process due to less discussion between the competent authority and the risk analyst. Furthermore, since the competent authorities have the same software tool at their disposal and the input files are submitted together with the QRA report, the inspector can now easily verify the correctness of the calculations. Experience shows that the data described in the QRA report differ sometimes from the actual data used in the input files, often due to errors in copying scenarios in the software tool and/or in the report descriptions.

3.3 Proportionality

The term 'proportionality' means that the effort put into the risk assessment should be in balance with the risk level. For rather simple situations it is therefore decided to use as much as possible simple reference tables with fixed distances and to limit the use of the QRA method to complex situations only. Table 2 gives an overview of the establishments for which either fixed distances are used or QRA calculations should be carried out.

Table 2: Land use planning method for different types of establishments

Type of establishment	Land use planning method
Seveso II	QRA calculations
LPG filling stations	Reference tables
Refrigerators, less than 10 tonnes of ammonia	Reference tables
Refrigerators, more than 10 tonnes of ammonia	QRA calculations
Warehouse with dangerous substances with storage areas less than 2500 m^2	Reference tables
Warehouse with dangerous substances with a storage area exceeding 2500 m^2	QRA calculations
Storage of fertilisers containing ammonium nitrate compounds	Reference tables
Shunting yards	QRA calculations

the QRA method is standardized and therefore easy to carry out, especially for simple installations. The effort will increase with the complexity of the installation. We therefore conclude that the prescribed risk method in the Netherlands scores good on proportionality.

However, the user group considers the prescribed QRA method still as complex (Twynstra Gudde, 2012). This may be explained by the fact that the introduction of the prescribed QRA method in the Netherlands had a strong emphasis on transparency and reproducibility. This, in combination with the availability of SAFETI-NL for a large community of consultants, may have introduced the idea that the QRA method is simple as well, even for complex installations. However, expert knowledge is still necessary to perform a valid QRA calculation for a complex industrial site.

3.4 Consistency

The term 'consistency' means that a risk analyst will obtain similar outcomes for situations that are roughly the same. The risk assessment method may therefore not be very sensitive to small changes in the input parameters.

The prescribed QRA method uses a very limited set of scenarios. As an example, only three scenarios are used to model the third party risk of a storage tank, i.e. instantaneous release, outflow of the tank content in 10 min and outflow from a small hole (10 mm). For pipelines, often only one scenario is relevant, a full bore rupture. Since only a few scenarios are used, the variation in individual risk with distance to the source can be small over a distance of hundreds of m. Consequently, a small variation in e.g. the failure frequency may result in a small change in risk level at a specific location, but simultaneously may lead to a large change in distance to the risk contour. Since the acceptability criterion for the individual risk, a mortality risk of 1.10^{-6} per year, is used as a black-and-white criterion, a small change in input data may have large consequences for land-use planning. We conclude therefore that the QRA method needs improvement in consistency.

3.5 Verifiability

The term 'verifiability' means that the risk assessment method is well documented. It should be possible to determine the models and data used, to trace back the models and data to the original sources and to determine the arguments used to select certain models or input parameters. If the method is verifiable, the basis of the method is known and open for discussion.

The prescribed QRA method is, in theory, very well verifiable. The models in SAFETI-NL are very well documented. The scenario and frequency data in the Reference Manual are mostly collected in the 80's. The original data date back to the 60's, and the origin of the data and choices made are not always very good documented (Beerens et al, 2006). In order to improve the verifiability of the Reference Manual, a procedure is developed for revisions, specifically addressing the sources of data used, the method to derive the failure frequency and the reasoning of choices made (Laheij et al, 2012).

3.6 Robustness

The term 'robustness' means that the risk assessment method follows a realistically safe (or conservative) approach in case of uncertainty. If there is large uncertainty, estimates should be conservative. If more information becomes available, the estimate will be closer to the realistic value.

The prescribed QRA method is intended to be conservative. However, historic choices in the QRA method have not always been conservative. The current intention is to be safe when uncertainties are high. In the derivation of failure frequencies, both the 0.5 and 0.95 confidence limits are reported, and the latter are used when possible (Kooi et al, 2012).

3.7 Validity (correctness)

The term 'validity' means that the risk assessment gives realistic outcomes. Aspects that play a role are the completeness of the method, the scientific basis of the models and their validation, and whether all crucial features of the system under consideration are included in the method, such as safety measures.

The scenarios and failure frequencies in the Reference Manual are based on limited set of data. Due to the low probability of failure, actual data do not to derive specific scenarios and failure frequencies. Therefore, either generic data are used, e.g. one failure frequency for all types of pressure vessels, or expert judgement is used. The validity of the scenarios and frequencies is therefore limited.

SAFETI-NL is a restricted version of the SAFETI software tool and a state-of-the-art tool for QRA calculations (DNV, 2012). The validity is therefore good. However, it is recognised that in exceptional cases the generic modelling of SAFETI-NL may not be adequate, and site-specific characteristics have to be taken into account. For this purpose, the legislation allows to use an alternative model than the ones included in SAFETI-NL, provided the following requirements are met:

- the difference between SAFETI-NL and the model proposed should be *relevant* for the land use planning decision;
- the model proposed should be *better* than the SAFETI-NL model for the specific case; this is to be demonstrated by model validation;
- the model proposed should be well *documented*, and the results should be *reproducible;*

- the model should be *available* for other users.

The last requirement is included to have a 'level playing field' between competing companies: other companies should be able to use the same model if they have the same site-specific characteristics.

In the last five years, two requests for the use of an alternative model were administrated, of which one request could be rejected immediately due to lack of information. In the other request, an alternative jet fire model for hydrocarbons was proposed for use at a natural gas processing facility. The alternative model results in a reduced flame length and a reduced risk contour. Following an extensive investigation in the documentation and validation, it was concluded that the alternative model was relevant and documented; it was also validated with a larger set of experimental data (Kooi and Uijt de Haag, 2012). Provided that the alternative model is made available for other users, it can be accepted in the QRA calculation.

The use of an up-to-date software package in combination with the possibility to use alternative models supports the validity of the QRA method. However, the validity of the prescribed QRA method may erode over time:

- The prescribed QRA method was introduced because different QRA tools gave different results. The use of the prescribed QRA method minimizes the spread in results. As a consequence, users may consider the risk outcomes as accurate and valid, ignoring the uncertainty in the results. This is strengthened by the decision process on the acceptability of the risk, where a change in a few metres in the contour of an individual mortality risk of 1.10^{-6} per year may change an acceptable situation into an unacceptable situation or vice versa.
- The introduction of a prescribed QRA method in legislation makes it more difficult to introduce new scientific knowledge since any update of the software tool requires modification of the legislation. For any modification of the models, an extensive survey of possible consequences in the land use planning is required, and the financial consequences may hamper the introduction of new knowledge. The current SAFETI-NL model (version 6.54) is, apart from small modifications, already in use for more than five years and now starts lagging behind the international developments in SAFETI (version 6.7).
- The use of the prescribed QRA method leads sometimes to simplifications because the QRA calculations are sometimes seen as a blanks exercise. Although the more complex behaviour of the outflow of material in a process plant can be modelled in SAFETI-NL, QRA calculations are sometimes done using the default values and thus ignoring the outflow from connecting pipework. The newly drafted guideline for onshore natural gas production and processing facilities therefore take the outflow of connecting pipework explicitly into account (see e.g. Kooi et al., 2012).
- Preventive safety measures are difficult to value in the prescribed QRA-method since fixed failure frequencies are used, and modifications of the failure frequency should be well substantiated (Laheij et al, 2012). Users consider this as an important drawback of the QRA method, especially in cases where there is a problem in land use planning and safety measures are proposed to solve the problem.

Table 3: Pre-analysis for emerging risks

Factor	Description
Substance	Substance and substance properties (related to operating conditions): - are the substances new (have the substances not been used before)? - are the amounts of substance within installations larger than currently used amounts? - are the proposed operating conditions new for these substances? The substance properties include physical properties, chemical properties and biological factors (e.g. toxicity).
Process	Process and Equipment (related to substance and operating conditions): - is the process new or are the process conditions new? - is the equipment (equipment type, materials used and the like) new for these substances and process conditions?
Operation	Operation and Risk Management: - is the environment of the operation different from current operations? - is the operation of the process different from current operation (e.g. automation of manual tasks, change in inspection regime)?
Scale	What is the time scale and spatial scale of a potential impact of the activity?
Impact	What is the impact of the activity on the environment (including human beings)?
Up to date	Are the latest understandings of the hazards of the activity known and applied?

3.8 Emerging risks

A risk assessment method should be able to evaluate the emerging risks of new technologies. Emerging risks are not always covered adequately by the prescribed QRA method. Since the method is prescribed, there is a tendency to keep the QRA method as close as possible to the prescribed QRA method. In the iNTeg-Risk project, we investigated how the method should be modified to include emerging risks (iNTeg-Risk, 2011). It is concluded that for an emerging risk of a new process, activity or technology, a pre-analysis should be done, using the elements covered in Table 3. Depending on the result of the pre-analysis, the prescribed QRA method should be modified and a more thorough investigation is needed.

4. Conclusions

The prescribed QRA method fulfils the most important goal: QRAs are now transparent and verifiable, and discussions between the competent authorities and the operators are reduced. Furthermore, there are less ad hoc solutions that cannot be justified properly. However, there are also drawbacks. The introduction of new scientific knowledge to keep the QRA method valid may be hampered in future by the (financial) consequences in land use planning. Alternative, better models can be applied, but the stringent requirements make this a cumbersome procedure. Furthermore, there is a large SAFETI-NL user community with only limited experience, resulting in a strongly fluctuating quality of the QRAs performed. This may be balanced in future by the introduction of expert groups for the competent authorities.

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