ELSEVIER

Journal of Hazardous Materials 71 (2000) 59–84

Journal of Hazardous Materials

www.elsevier.nl/locate/jhazmat

Risk analysis and safety policy developments in the Netherlands

P.H. Bottelberghs *

Ministry of Housing, Physical Planning and Environment, Directorate for Chemicals, Safety, and Radiation (ipc 655), External Safety Division, P.O. Box 30945, 2500 GX the Hague, Netherlands

Abstract

In the Netherlands, external safety policy has been developed and implemented since the early eighties on the basis of a risk-based approach involving quantitative criteria for the tolerability of risk. Good experiences have been gained with the risk policy that applies to some 4000 establishments in the Netherlands where hazardous substances are present. On the basis of these experiences, legislation is now being prepared to give the risk tolerability criteria a full legal basis. This is aimed, in particular, to balance between risk control measures at the source through the licensing system, and spatial planning instruments to protect, e.g. residential areas against major hazards. The revision of the Seveso directive (96/82/EC) leads to the implementation of an integrated form of safety reporting, evaluation and inspection. Practical tools were developed for this implementation, e.g. for facilitating the selection of establishments and for assessing risks from major hazard establishments to surface water. In the past few years, the application of risk-based safety policy has been extended to other fields than establishments, e.g. for transport of hazardous chemicals and external safety of airports. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Risk policy; Risk assessment; Safety; External safety; Environmental risk

1. Introduction

The development of the external safety policy in its current form in the Netherlands originated in the beginning of the 1980s, when it became clear that the use of LPG would increase considerably. Extensive safety studies on LPG and related issues led to the development of an evaluation system that is based on quantitative assessment of risks and quantitative criteria for decisions on risk acceptability [1,2,12]. The occurrence

* Tel.: +31-70-339-4723; fax: +31-70-339-1314; e-mail: p.h.bottelbergs@dsvs.dgm.minvrom.nl

PII: S0304-3894(99)00072-2

of a number of major hazards — e.g. Flixborough, Beek, Mexico City, Los Alfaques, Seveso, Bhopal — has of course influenced thinking about the prevention of major accidents. Of great importance as well was the Seveso directive of 1982 [4]. In the Netherlands, in the period between 1982 and 1987, the LPG integral study and the so-called COVO study were conducted [3]. The LPG integral study resulted in a report (1984) of 24 volumes on all the safety aspects of the storage, transport and use of LPG and liquid automotive fuels. This study formed the basis for the LPG Integral Memorandum that was accepted by the Parliament in 1984 and which laid down essentially three important elements that have formed the basis for the Dutch external safety policy:

1. the use of quantitative risk assessment (QRA) to determine risks [1]
2. the adoption of two risk-determining parameters: *individual risk* and *societal risk*
3. acceptability criteria for both the individual risk and the societal risk.

In practical terms, the Memorandum stated the necessity to keep safety distances between LPG activities and vulnerable objects — like houses. The safety distances are based on QRA and on risk tolerability criteria. The risk assessment took account of the safety measures for LPG activities that are legally imposed. In both studies, quantitative assessment of risks was found to be the most effective instrument for dealing with the hazardous activities considered. It enabled to arrive at an effective policy to prevent and control major hazards with these activities [15,16,19,20,23,29].

In 1993, the use of acceptability criteria in the Netherlands has somewhat changed, due to discussions between the Minister for Environment (VROM) and the Parliament. The most important element of this change is that the concept of negligible risk that originally formed part of the policy, was abandoned. Along with that, the criterion for tolerability of societal risk was given a less strict character, in that exceeding the societal risk criterion can be tolerated by the authorities if sufficient arguments (e.g. economic) can be given for the specific situation involved.

In the development of safety policy after 1985, several groups of establishments have been consecutively dealt with. The first group of establishments was the LPG-related ones, filling stations and storage sites. Next the Seveso establishments were considered in detail. Following the Sandoz accident, the storage sites for pesticides and chemicals were dealt with. Then ammonia refrigeration units received the attention, while at about the same time, railroad marshalling yards, transport of hazardous chemicals, in general, and the external safety of airports received attention as well. The policies and regulations that have been developed for these fields are considered in separate paragraphs in this paper.

2. Legislation and regulations

In the Netherlands, the prevention of major hazards to protect the environment and to protect people who live in the vicinity of hazardous establishments, was until 1993

[1] In this paper, the terms *risk analysis* and *risk assessment* mean to indicate the same method, also referred to as QRA (quantitative risk assessment).

mainly provided for by the Nuisance Act. For ‘stationary’ hazardous activities, a license under the Nuisance Act was required. Such a license was granted if the competent authorities were of the opinion, that the activity does not pose undue risks or nuisance to its surrounding environment. Since March 1993, most of the environmental protection legislation is either replaced by, or integrated in a new law, the Environmental Protection Act [8]. An important principle of this new Act is that an establishment will obtain one single Environment Protection License which covers all types of environmental protection (air, water, soil, noise, risk, etc.; in the ‘old’ situation for each type of environment protection, a separate license was required). A license under the Environmental Protection Act covers measures to prevent major accidents. The Environmental Protection Act gives general requirements for companies that apply for a license. For companies that come under the Seveso criteria, an external safety report is to be submitted together with the license application. This safety report, including the safety measures described, forms an integral part of the license. The obligation to submit an external safety report is imposed by the Decree on Major Hazards (1988). The relationships between legislation, external safety reporting and risk acceptability criteria for Seveso establishments are presented schematically in Fig. 1. For other hazardous establishments, the same criteria and procedures apply, but a safety report is not required

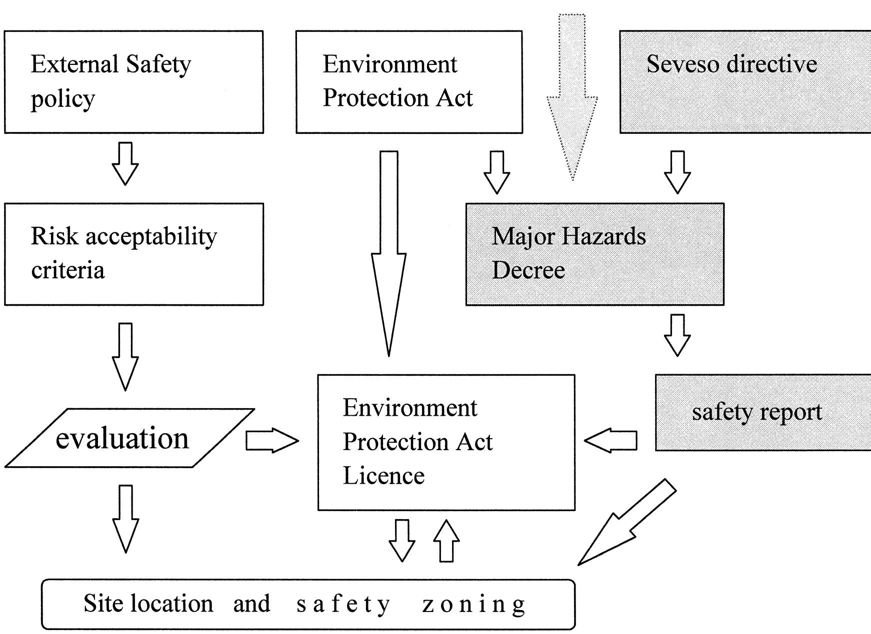

Fig. 1. Schematic overview of current Dutch external safety policy for Seveso establishments. The Major Hazards Decree 98 deals also with elements of internal safety (Labour safety act) and emergency planning (Disasters and major accidents act), which are in this scheme indicated by the dashed vertical arrow.

in those cases. A practical overview of the risk acceptability criteria as mentioned in this scheme is given in a manual which has been issued by the provinces and municipalities [27]. It describes how the external safety policy is to be applied in practical situations. The risk acceptability criteria are at present not yet legally binding, though in a majority of cases, they are being applied as if they were. There is a difference, however, in the degree of application in relation to licensing and to physical planning. For licensing purposes, the risk acceptability criteria are being met in most cases, but in physical planning, there are still shortcomings. In practice, this means that a strengthening of the formal status of the risk acceptability criteria for application in physical planning is of importance.

In total, there are of the order of 4000 establishments in the Netherlands, that are within the scope of the external safety policy and regulations. These range from small LPG filling stations and ammonia cooling installations to the large chemical production establishments that are under the qualifying criteria of the Seveso directive. Each of these establishments is required to have an Environment Protection Act license, which describes the safety requirements for the establishment. In addition, safety distances are applicable for the situation around an establishment. These safety distances are based for the majority of situations on a generic risk modeling of the type of installation, in combination with the risk acceptability criteria. For large chemical establishments, this approach would not work, as the complexity of the site does not enable the determining of a generic safety distance. In these cases, the risk parameters for the establishment are being calculated specifically. The calculated risks then form the basis for licensing of the establishment and physical planning around the establishment.

Specific risk calculations (QRAs) for establishments are being carried out if there is no generic method to determine safety distances. For the majority of the so-called Seveso establishments in the Netherlands, this is the case. For each of these establishments, the company involved must submit a safety report that contains the necessary safety information, part of which is a topographic risk map of the establishment. In a licensing procedure for these establishments, the safety report forms part of the license application. When the license is granted, the risk maps contained in the application are part of the license and have to form the basis for physical planning around the establishment.

In addition to the Environmental Protection Act, specific regulations and guidelines impose requirements on safety management for hazardous activities:

1. administrative decrees, e.g. for LPG filling stations [5–7,9]
2. general circulars, e.g. on chemicals storage, railroad marshalling yards, pipeline transport [12–14]
3. CPR guidelines on activities, e.g. with hazardous bulk chemicals or pesticides
4. manuals on safety requirements, risk assessment techniques, etc. [18,21]

CPR guidelines are general guidelines on risk-reducing measures to be considered for producing, storing, handling or loading/unloading hazardous substances such as ammonia, chlorine, pesticides, etc. These guidelines are used in granting licences for individual establishments. The licences are granted either by the municipal or by the provincial authority, depending on criteria which are indirectly related to the size of the establishment.

3. Safety policy and risk management

External safety policy is in the Netherlands based on a risk management approach. Risk management can be characterized, in general, by a management cycle which comprises five steps:
1. identification of risks
2. assessment of the identified risks
3. evaluation of risks on the basis of acceptability criteria
4. imposing risk-reducing measures
5. monitoring and maintaining the acceptable risk.

In particular, when a new field of interest is being considered with respect to safety, it is helpful to consider each of these steps for the specific situation involved.

3.1. Identification of risks

Generally spoken, risks related with the presence of hazardous chemicals in establishments are identified by the nature of chemicals that are being produced, stored or used: chemical installations producing hazardous chemicals in large quantities, storage of gases under pressure or otherwise in large quantities, storage of pesticides or chemicals in warehouses, tank storage, trans-shipment activities, transport by pipeline, use of toxic gases in production or as a cooling medium, explosive substances, etc. are well known. Within this broad range of hazardous activities, the industrial activities that come under the Seveso directive criteria obviously get considerable attention. There are, however, many more activities that are being considered within the Dutch external safety policy:
- most LPG activities (e.g. filling stations)
- pipeline transport of natural gas
- pipeline transport of K1, K2, K3 liquids
- pipeline transport of other hazardous chemicals
- storage of pesticides in warehouses
- storage of chemicals in warehouses
- use of ammonia in cooling installations
- railroad marshalling yard activities involving hazardous chemicals
- storage of hazardous substances at stevedore companies
- transport of hazardous chemicals by road or by railroad cars
- transport of hazardous chemicals over inland waterways.

The way to control the risk of these activities is dependent upon the type of risk involved, although the criteria for acceptability are basically the same for all cases.

In addition to risks caused by the ‘stationary’ presence of hazardous chemicals at an establishment, other types of risks can be identified. One prominent type of risk that has been considered extensively over the past few years already, is the risk caused by the presence of a large civil airport in the vicinity of populated areas, even big cities. This risk is quite considerable in comparison with risks from, e.g. a chemical industry. Consequently, dedicated policies have been adopted for external risks from airports.

3.2. Assessment of the identified risks

The second step in a risk management cycle is the assessment of risks. This involves a quantification of the risks, i.e. the assessment of risks in terms of effects and probabilities in quantitative terms. Risk can be presented in the form of various parameters. (In this respect, it is important to consider exactly what is being calculated when comparisons are made.) In the Netherlands, two parameters are used to present risks and to evaluate risk acceptability for a hazardous activity:

1. the individual risk at a given location
2. the societal risk for an establishment.

When dealing with the risk of transport of hazardous chemicals, the societal risk is assessed — and its acceptability evaluated — for a defined length of the transport route. The calculation of these risk parameters is performed using QRA. This method is based on a combination of models that enable calculation of release scenarios and associated probabilities for the accidental release of hazardous chemicals, calculation of dispersion routes given various weather conditions, and calculation of adverse effects. Based on these combinations of models, the risk to a person to get killed outside the hazardous activity due to these effects given the probabilities, is calculated in the form of an individual risk at the given location. If the hazardous activity involves the presence of hazardous chemicals, this is analyzed with respect to all the containment systems which hold — or can hold — the hazardous substances. For each containment system, the possible release of these chemicals is modeled and the risk parameters are calculated.

The use of QRA is implied in the Dutch external safety policy. In this respect, it has led to generically calculated safety distances for several categories of establishments. Specific risk assessments are in the Netherlands required by law to establish risks for higher tier Seveso establishments. A QRA results in two quantitative parameters: individual risk and societal risk for an establishment:

Definitions

*The **individual risk** for a point-location around a hazardous activity is defined as the probability that an average unprotected person permanently present at that point location, would get killed due to an accident at the hazardous activity.*

*The **societal risk** for a hazardous activity is defined as the probability that a group of more than N persons would get killed due to an accident at the hazardous activity.* [2]

The individual risk is dependent on the geographic position and is displayed in the form of iso-risk contours on a geographic map of the establishment. The individual risk is thus not characteristic for any person, but only for the location — outside the establishment — for which it is calculated. Thus, the individual risk contour maps give

[2] The societal risk is given as a function of the group size in the form of a plot of frequency (F = probability per year) vs. group size N.

information on the risk of a location, regardless whether people are present at that location or not. An example of an individual risk contour map is given in Fig. 2.

The societal risk is in this sense not location-dependent, but rather is characteristic for the hazardous activity in combination with its populated surroundings and is displayed in the form of an F,N curve where the frequency (per year) is plotted against the group size for the group of people killed due to a major accident at the establishment. Thus, if no people are present around the hazardous activity, the societal risk is nil, whereas the individual risk may well be quite high.

Fig. 2. Individual iso-risk contours on a geographic map, indicating the risk situation at an industrial site (DSM Geleen, 1989).

An example of a societal risk plot is given in Fig. 3.

To enable a reliable calculation of the risks caused by a hazardous activity, it is necessary to define standards for the risk modeling and the parameters used in these models. This standardization may, e.g. comprise the following aspects:

- selection of accident scenarios that are representative for the risks involved
- the physical modeling of outflow from the containment
- initial cloud formation and gas dispersion for given weather conditions
- consequence models for fire and explosion and for the effects of toxic gas clouds (so-called probit functions)
- parameter values to be used in these models.

For this standardisation, several regulations, guidelines and instruction manuals are used in the Netherlands. Part of this standardisation is institutionalised in the guidelines of Committee for the Prevention of Disasters (CPR, Commissie Preventie van Rampen, primary standards in the Dutch systems are the *Yellow Book* (CPR14E) and the *Green* (CPR16E) [10,11]. Currently, an overall standardisation manual for risk assessment referred to as the *Purple Book*, is being developed. This new manual will explain how the separate risk models should be combined to achieve a reliable assessment.

3.3. Evaluation of risks on the basis of acceptability criteria

The next step in the risk management cycle is the evaluation of assessed risks for an activity to determine whether the risks are acceptable. In our external safety policy, risk acceptability criteria have been developed and were adopted by the Parliament to support decisions that are to be made on the acceptability of risks in the field of external safety. The risk criteria are pertinent both for individual risk and for societal risk. Both types of criteria are of importance for decisions on Environment Protection Act licences

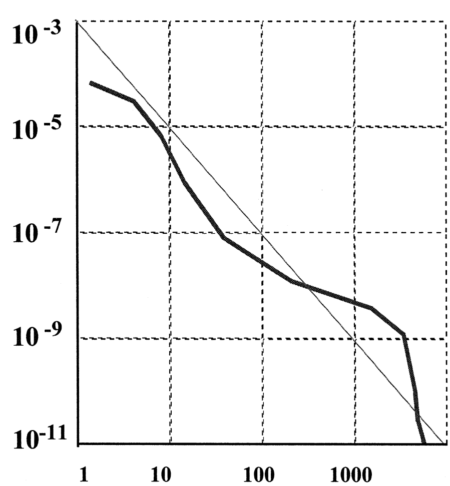

Fig. 3. Example of a societal risk curve plot (F, N plot). The numbers at the horizontal axis give the number of lethal victims; the vertical axis gives the probability per year for an accident at the hazardous activity that would cause more than this number of victims.

for hazardous activities and for physical planning around these activities. The subjects to be protected against the risks are the so-called ‘vulnerable objects’. As such are considered: housing areas, hospitals, schools and the like. Higher risks are tolerated for the ‘less vulnerable objects’: office buildings, hotels, restaurants, shops, recreation activities and the like.

Individual risk criteria state whether vulnerable objects or less vulnerable objects can be exposed to a risk above a certain level. For new housing, for instance, an individual risk above 10^{-6} is not considered acceptable. Therefore, new housing near hazardous activities should be built at a distance that is larger than the 10^{-6} distance. For generic categories of activities, this is given by the relevant safety distance for the activity, while in the case of a specific risk assessment, the housing cannot be built inside the 10^{-6} zone. If the housing is already present and a license application for a new hazardous activity is to be considered, it is evaluated whether existing housing and other vulnerable objects would come inside the 10^{-6} zone for the activity. If so, the license will not be granted until additional safety measures are taken that enable compliance with the risk criteria.

In any case, the ALARA principle (i.e. risk As Low As Reasonably Achievable = ALARA; all measures have to be taken that reduce the risk, as long as these measures are not unreasonable for reasons of costs or other aspects) is applicable to the hazardous activity: risk reduction ‘at the source’ must always be applied to the level that is still reasonably achievable. If safety measures would be extremely costly, this would not be considered reasonable in the sense of ALARA. As long as risk criteria are not exceeded, measures above ‘ALARA’ are not considered by the authorities. The same approach holds for less vulnerable objects like office buildings or restaurants that can be exposed to a higher individual risk level of 10^{-5} per year. (In Fig. 4, the individual risk criterion is presented schematically.)

Evaluation against the societal risk criterion is somewhat different. The societal risk is assessed taken into account the number of persons that are expected to be present in the objects classified as vulnerable or less vulnerable, even with a percentage of persons assumed to be present at the location of these objects, but being outside and therefore less protected. The distance range over which the calculation around the hazardous site is performed, is determined by the distance at which the conditional probability for lethalities is higher than 1%. The societal risk in the form of an F,N plot is then evaluated against the acceptability criterion. As in the case of individual risk, risk reduction ‘at the source’ should prevail according to ALARA. Next, it should be decided on the basis of the societal risk criterion whether a license can be granted for a new activity and/or whether new housing, offices or other objects around the establishment can be tolerated. The authorities can accept a situation that does not fulfill the group risk criterion, if it can be motivated that this is acceptable under the given circumstances. A precise instruction for this motivation has not yet been given at governmental level. It is considered the primary responsibility of the municipal authorities to establish the appropriate level of that motivation.

Thus, hazardous activities are evaluated with respect to their individual and societal risks basis of acceptability criteria. Till now, these criteria are as such not legally fixed, but are being used on the basis of the external safety policy that is developed. This has

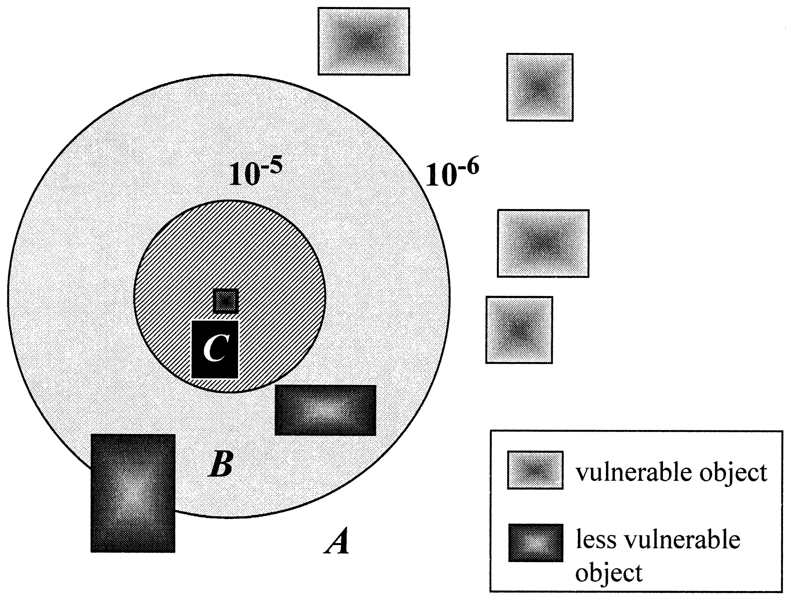

Fig. 4. Acceptability criteria for individual risk for new situations. For vulnerable objects (housing, schools, hospitals, etc.), the maximum value considered acceptable is 10^{-6} per year (area A). For less vulnerable objects (see text), the maximum acceptable value is 10^{-5} per year (area B). In area C, only less vulnerable objects are allowed that are exempted from the application of the criterion.

worked well over the past period to a certain extent, but in the field of spatial planning, there are still practical shortcomings. Due to this, the balancing of interests between industry and community asks for a more formal regulation (see Section 7.4).

3.4. Risk-reducing measures

If an activity is evaluated, and it is concluded that the risks are not acceptable, risk-reduction measures must be applied. The first question of course, is whether there are possibilities for risk reduction. These possibilities can be determined by means of a study which quantifies the influence of possible safety measures. Such studies can analyze the total risk for the whole of the activity in order to determine whether the most cost-efficient risk-reducing measures have been applied. A differential scheme of risk-reduction possibilities vs. cost of safety measures can be helpful in selecting optimal risk-reduction strategies. [3] Finally, risk-reduction measures — safety measures — have to be set as a requirement in the license under the Environment Protection Act.

[3] Though we have experience in the Netherlands in developing such risk reduction strategies, a detailed consideration of that work is outside the scope of this paper.

3.5. Maintaining the acceptable risk

The risk situation that is considered to be tolerable, could change without being noticed when the owner of a establishment identified as hazardous, would modify his way of operating the installations in the establishment, the nature or quantities of the chemicals present in the establishment, or e.g. the maintenance or inspection procedures for parts of the establishments. A good inspection scheme used by the authorities will avoid that this could be unnoticed. (The assessment of these influences in a quantitative way, is not yet really established, however, which implies that in this field, mainly semi-quantitative considerations are used.) In case there are important changes in the activities, the risk assessment should be updated and re-evaluated.

4. Criteria for the acceptability of risk

The quantitative risks that are assessed generically for a type of activity or for a specific situation, are evaluated against acceptability criteria, both for the individual risk and for the societal risk. For several categories of activities mentioned above, this has led to the determination of safety distances, which are subsequently regulated or used within the safety policy framework. For specific situations where risks have to be assessed for an individual establishment, the assessment results in individual risk contours on a topographic map and a societal risk curve plot. This risk information, e.g., forms part of the safety report that is required for higher tier Seveso establishments and has to be evaluated against the risk criteria.

The individual risk criterion protects each individual against hazards involving hazardous chemicals; it does not distinguish between the size of accidents that may occur. The societal risk criterion, on the other hand, protects society against the occurrence of major accidents, in particular. This latter criterion is based on the consideration that even if the individual risk criterion is met, in the conceivable case of a high population density which is located near the safety distance for a hazardous activity, it is still possible that a major accident occurs which would cause a large number of victims. Though this cannot be avoided completely, the policy is that the probability for such large accidents must be sufficiently low. This is implied in the societal risk criterion.

The basis for the calculation of the individual risk and the societal risk is also somewhat different. The individual risk is calculated regardless of any actual vulnerable objects will be present around the activity. The results are, in principle, the same, whether there is a densely populated area or an nonpopulated area. Also, it assumes no protection for individuals present at any location. This is different for societal risk: in the calculation of societal risk, the actual (averaged) presence of persons is taken as the basis for the calculation, and a difference is made in the assessment between persons inside a building or in the open air with respect to their vulnerability. Such corrections are not made for calculation of the individual risk, as this parameter gives a risk value that is characteristic for a point-location regardless of the actual presence of persons.

In Figs. 4 and 5, the risk acceptability criteria are displayed. These graphs represent the modifications in the acceptability criteria adopted after discussions between the Minister of Environment (VROM) and the Parliament in 1993–1994. It was concluded that the level of negligible risk used before 1993 should be abandoned as a separate criterion. Thus, only the 'maximum acceptable risk' is used as a criterion, while it is assumed implicitly that ALARA is always required via the safety measures in the license. The level of this maximum acceptable risk differs for various categories of objects — which are considered different in their vulnerability. In addition, there is a difference in the criterion for new and existing situations, since new situations cannot always be brought to the safety level for a new situation. A new situation in this context means either a new license given an existing spatial planning situation — e.g. housing actually present — or a new spatial planning given an existing establishment which has a license that implies acceptation of the risks caused by the establishment, or it can mean a coincidence of both. The individual risk criterion displayed schematically in Fig. 4 is used in the evaluation of new situations. If the establishment belongs to a 'standard category' for which the individual risk levels have been translated to safety distances, the actual distances between the establishment and the vulnerable or less vulnerable object are compared with the safety distance. If the object comes within the safety distance, there may be in certain cases still a solution possible. For certain categories of establishments for which generic safety distances are available, specific risk assessments are still accepted. If it can be shown for the specific situation that the actual risk is lower than assumed in the generic calculation, the specific risk assessment can be used in the evaluation, rather than the generic distance. In particular, this may be the case when additional safety measures have been taken in the establishment in order to decrease the risks. This procedure is allowed only for certain generic types of establishments.

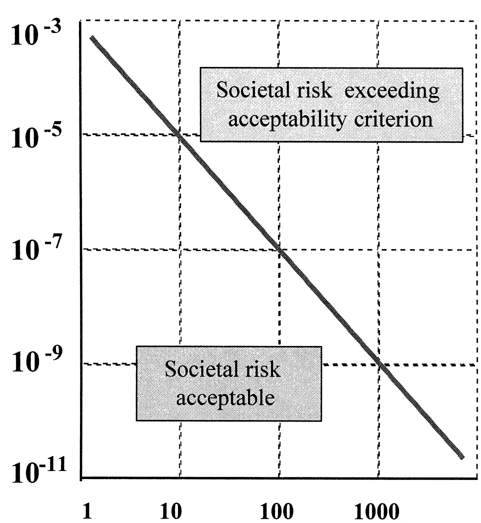

Fig. 5. Acceptability criterion for societal risk. The societal risk criterion can be written in the form: $10^{-3}/N^2$ per year, which is the maximum probability per year that would be acceptable for any accident at an establishment that would cause more than N lethal victims outside the establishment.

For some existing situations, a risk above the criterion for new situations cannot always be avoided. In such cases, there will be a discussion between the authorities and owner of the hazardous establishment, to analyse whether additional safety measures can decrease the risk, provided there is not a binding safety distance as described above.

Risk reduction at the source, i.e. the establishment based on ALARA always has priority. Subsequently, land use planning is of importance, to ensure that safety measures will not become ineffective due to the fact that housing or other vulnerable objects are built at a location where the individual risk would exceed the risk acceptability criterion. For non-Seveso companies, a similar consideration holds, be it that a specific risk analysis is not requested, as safety distances are applicable.

5. Risk-based safety zoning

Industrial activities involving hazardous activities can involve residual risks, even when special safety measures have been taken to prevent accidents. It is also conceivable that safety measures suitable to further reduce the residual risk are extremely costly. In order to prevent that large-scale industrial accidents become major accidents with possibly large numbers of victims, it is necessary to protect persons outside the establishment by keeping distance between hazardous activities and populated areas. For any hazardous establishment, it is possible to ensure an acceptable risk level by adopting a zone from which vulnerable objects — such as housing — are excluded. This is a general principle in safety policy and it has become an important element in the revision of the Seveso directive. The Seveso II directive sets requirements with respect to this element in article 12. In the Netherlands, keeping distance between so-called vulnerable objects — housing and other objects — has long been an element in the evaluation of license applications for hazardous activities. However, a good method of evaluation was first introduced by the risk-based policy. This enabled to determine safety distances and safety zones, that take the various risk elements into account. QRA in combination with risk tolerability criteria results in safety distances and safety zones that are practicable and that can have a uniform base for all the hazardous activities considered. Basically, two approaches have been followed in the Netherlands over the past two decades.

(1) A generic approach for categories of hazardous establishments which have very similar characteristics and size. A standardised QRA modeling is applied for the pertinent category of establishments. Depending on size and other characteristics of the establishment, e.g. lay-out and safety measures applied, a safety distance table is calculated in a concerted effort between the parties involved. The table has its basis in the risk modeling, on the one hand, and the risk tolerability criteria, on the other hand. The safety distance table then forms the basis for determining appropriate safety distances for specific cases. The safety distance table can either be incorporated in regulations, or it can be a incorporated in a ministerial circular.

(2) A specific approach for large establishments and establishments where the generic approach could not be used. This implies a specific QRA for the case under consideration, which is, in principle, based on the Environment protection act license where the plant lay-out, processes operated, quantities of hazardous substances that may be

Table 1
Overview of safety zoning rules for hazardous activities in the Netherlands for new situations
The risk tolerability criteria for the Seveso establishments are considered for the regulation that is now drafted; currently lower IR values are considered acceptable for these establishments.

Hazardous activity	No vulnerable objects within:	No less vulnerable objects within:
Seveso establishments	10^{-6} IR contour	10^{-5} IR contour
Railroad marshalling yards	10^{-6} IR contour	10^{-5} IR contour
Stevedore companies	10^{-6} IR contour	10^{-5} IR contour
LPG tank filling stations	80 m from filling point	20 m from filling point
Pesticides storage	20–235 m[a]	20–145 m[a]
Chemicals storage	20–235 m[a]	20–145 m[a]
High pressure natural gas pipelines	5–20 m[b]	5–20 m[b]
Hydrocarbon pipelines	5–16 m[b]	5–16 m[b]

[a] The actual safety distance depends on the size of the storage and on the fire protection system of the storage.
[b] The actual safety distance depends on the pipeline diameter and on the hydrocarbon type.

present, and safety measures imposed, are described. Thus, the QRA has a formal basis which enables enforcement of the safety measures and the other elements that determine the risk of the establishment. The QRA results in a geographic map with individual risk contours, and a societal risk plot.

The objects that are protected against risks from industrial establishments, pesticides storage or other hazardous activities, are grouped into two categories of vulnerability. The distinction in vulnerability between objects has been introduced since the start of the risk-based external safety policy.

As *vulnerable objects* are classified:

- houses, apartment buildings and other residential objects
- hospitals and other institutions for medical care
- schools and other education facilities
- objects of a high strategic value.

As *less vulnerable objects* are classified:

- shops, department stores and similar objects
- hotels, restaurants, cafes
- commercial and industrial buildings
- office buildings
- recreational facilities.

This distinction is of importance for evaluating the risks in a new situation in the first place. For existing situations, the same distinction is applied, though the evaluation criteria for risk acceptability are different. In Table 1, an overview of safety distances and safety zones used in relation with various hazardous activities is given.

6. Current situation for establishments and spatial planning

An inventory of the risk situation [24] around hazardous establishments in the Netherlands was made in 1997, covering LPG filling stations, ammonia cooling installations, storage of pesticides and chemicals, Seveso establishments and railroad marshalling yards. The inventory study resulted in indicative numbers found by extrapolation of actual data and does not give a full list of all establishments. The results of the study are summarised in Table 2. The results show that only in a very limited number of cases on a total of some 4000 hazardous establishments, vulnerable objects are exposed to an individual risk level above 10^{-5} per year. The establishments where vulnerable objects are exposed to an individual risk above 10^{-6} per year, the value deemed tolerable for new situations, is also reasonably limited. A relatively high number of cases is found for the category of ammonia cooling installations and for the lower tier Seveso (I) establishments. The reason for these categories to give increased individual risk levels at vulnerable objects is that these establishments are often situated near inhabited areas, whereas the upper tier Seveso establishments are mostly situated in industrial areas, far from inhabited areas. Exceeding the tolerability level for the societal risk occurs in less than 10% of all the cases.

Mainly the LPG filling stations contribute to the risk situation for establishments with respect to this risk parameter. LPG activities are effectively regulated by several pertinent Decrees. A national enforcement action in 1991 has shown that the majority of LPG tank filling stations meet the legal requirements. A number of LPG filling stations were closed since they could not meet the legal requirements. For a number of railroad marshalling yards, the societal risk is high as well and may remain high also in the future in a limited number of cases, even after all possible measures have been taken.

Table 2
Overview of the risk situation (1995) [24] around hazardous establishments in the Netherlands

Category of establishments	Number of establishments				
	Total	Having vulnerable objects within 10^{-5}	Having vulnerable objects within 10^{-6}	Having vulnerable objects within 10^{-5}	Not cf. societal risk criterion
Seveso I higher tier	122	0	4	1	9
Seveso I lower tier	100–150	< 2	10	14	2
LPG filling stations	2200–2700	0	0		(150) indicative
Ammonia cooling installations	300–500	< 4	71		0
Pesticides and chemical storage warehouses	500–700	< 9	< 20		0
Railroad yards with hazardous chemicals	80		6 (1993)		13 (1993)

Values 10^{-5} and 10^{-6} per year refer to the individual risk criterion. The number of situations is indicated where the risk tolerability criterion (individual risk or societal risk) would not be met if this would involve a new situation.

The situation for less vulnerable objects within the 10^{-5} (per year) individual risk contour is not completely known from the study that was conducted. It is expected, that this problem will occur only in a relatively low number of cases, due to the limited distance of the contour. In the Rijnmond area, 30 Stevedore companies have been identified in addition to the very large companies that were previously identified as meeting the Seveso criteria. A risk study performed several years ago for companies of this type has indicated that neither individual risks nor societal risks for these companies Rijnmond area are likely to exceed MTR levels, due to sufficiently large distances to populated areas.

A more recent study [25] considered the implementation of the external safety policy in practice. A distinction was made between the practical application in licensing procedures and in spatial planning. The study was performed for five categories of establishments in four provinces. In total, 87 establishments were investigated:

- 32 LPG filling stations
- 7 ammonia cooling installations
- 20 storage warehouses for pesticides and/or chemicals
- 19 Seveso upper tier establishments
- 9 Seveso lower tier establishments.

From this study, the following conclusions were drawn.

(1) For LPG filling stations, it was found that the authorities have evaluated the existing stations (built before 1985) and that the safety measures from the pertinent circular are imposed. For the majority of cases, the external safety policy is effectively applied for existing LPG filling stations.

(2) For ammonia cooling installations, the authorities make use of the CPR-13 guidance to grant new licenses. In some cases, the authorities have requested to submit a QRA to evaluate whether distances to vulnerable objects are sufficient.

(3) For storage of chemicals and pesticides (CPR-15 establishments), it was found that in siting and licensing new establishments, required safety distances are in many cases not explicitly evaluated. License applications are global in nature and do not give details on quantities of chemicals present. All the establishments found are, however, sited in an industrial area, so that distances to vulnerable objects can be expected to be sufficient.

(4) For Seveso upper tier establishments, license applications are evaluated on the basis of the risk parameters presented in the safety report. Both the individual risk and the societal risk are considered. In one situation, a license application was taken into procedure, though the safety report was not submitted. This apparently was an administrative error. In virtually all cases, it was found from the license and the related documents, that the individual risk criterion was being met. For Seveso upper tier establishments, the external safety policy works in practice very well.

(5) For Seveso lower tier establishments, the competent authorities are aware of the fact that pertinent regulations are applicable. In many of those cases, a QRA is asked from the establishment owner. For a limited number of lower tier establishments, the authorities are not sufficiently aware of the regulations.

With respect to the physical planning (spatial planning), the situation found was somewhat more troublesome. For most of the situations investigated, a spatial plan was actually in place. However, most of these plans were of old date and had not been updated. In one-third of the recent spatial plans investigated, insufficient account was taken of the external risks of hazardous establishments. This has the formal consequence that building of new vulnerable objects (housing etc.) near these establishments cannot be prohibited. In one-third of the establishments investigated, the necessary safety distances do not follow clearly from the licenses granted. In virtually none of the spatial plans, the requirements that follow from external risks of hazardous establishments are mentioned. This does not necessarily mean that the actual situation is not in agreement with external safety requirements, but this is not explicitly considered in the spatial plans. It appears that in one-third of the cases, authorities are not sufficiently aware that external safety has to be considered at the location.

7. Implementation of the Seveso II directive

The original Seveso (I) directive, 82/501/EC that was implemented in the member states before July 1989 had a considerable influence on dealing with safety problems around the establishments where major hazards were to be considered. In the Netherlands, there was — at that time already — some experience in dealing with external safety matters on the basis of quantitative risk management. Therefore, implementation of the directive in our country took advantage of the available methods and regulatory procedures based on the risk management approach. In other words, QRA is an element in the evaluation of a license application for a Seveso establishment. Obviously, this has become a standard element in the external safety policy in the Netherlands and will remain so in the implementation of the revision of the Seveso directive. The Seveso I directive was implemented in the Netherlands in 1989 with respect to the information requirements, i.e. safety reporting to the authorities in the Brzo (Major Hazards Decree). As far as the safety measures were concerned, this was already a requirement for the establishments involved, as each of these is required to have a license under the Environment protection act. For the safety reporting, two types of reports were obligatory for the companies involved: an internal safety report (occupational safety) and an external safety report. The experiences with external safety reporting were very positive. In 1992 an evaluation was made of 66 safety reports (Bottelberghs, [17]). From the evaluation, it became clear that standardisation in the way of safety reporting and in the risk assessments made, is very important, both for the quality of the documents and for the efficient evaluation of each report. This experience has led to the adoption of a standard manual on safety reporting [18]. In view of the 5-year update, most of the Seveso companies have submitted a first and a second version of the external safety report.

The new Seveso II directive (96/82/EC) [22] that has come into force in February 1997, contains several important elements in comparison with the original directive (82/501/EC):

- emphasis on establishments rather than on installations
- companies are qualified by modified qualifying criteria, where the emphasis is on the harmful properties of chemicals, and in addition, a limited list of named substances

- a prevention policy on major accidents and a safety management system
- identification of groups of establishments where domino-effects can occur
- an inspection system under control of the authorities
- land use planning around Seveso establishments.

Over the past 2 years, the implementation of the Seveso II directive in the Netherlands has been prepared with respect to the various elements involved. The formal implementation will occur in agreement with the directive. In addition, the practical implementation is facilitated through the availability of practical instruments that have been developed. Finally, instruction courses on safety reporting and on other aspects of the directive are planned for 1999. The following are the various elements of the implementation in the Netherlands.

7.1. Modifications in legislation

The Environment Protection Act, the Labour safety Act, and the Act on disasters and major hazards had to be modified to incorporate the necessary requirements for implementing the Seveso II directive. This legislative step can be completed by November 1998.

7.2. Major Hazards Decree 1999

Implementation of the directive requires a complete revision of the Major Hazards Decree. Given this fact, it was decided that the revision should also establish the requirement to submit integrated safety reports to the authorities, different from the requirements under the (first) Major Hazards Decree, which imposed the submission of separate reports for external safety and for internal safety of the establishment.

7.3. Ministerial regulations

The Ministerial regulations under the Major Hazards Decree give details on the legal requirements laid down in the Decree. As well as the Decree, these regulations are legally binding. Under the modification of the Decree, the Ministerial regulations will be modified as well, in order to give details on new articles and on revised articles in the Decree. The regulations will deal with essential elements of safety reporting and on other elements of the Decree.

7.4. RIB (Report on information requirements for the Major Hazards Decree, Brzo 1999)

The legislation implementing the directive establishes the formal requirements in agreement with the directive. The application in practice, however, may still require explanation on specific details, in particular, for those who are not very familiar with these types of establishments or with the technical requirements of safety reporting and risk assessment. In the formal regulations, there is no room for such explanations. This report (RIB) was therefore written as a guidance document to help amongst other the establishment owners in writing the safety report, and to help the authorities in its evaluation and in various aspects of the notification and reporting procedures as required by the Decree.

7.5. Manual on co-ordination management for single-counter reporting

As the authorities that are competent for various parts of the directive can be different and may operate under the jurisdiction of different Acts and regulations, implementation of an integrated system of reporting, evaluation and inspection requires a good coordination of the authorities' tasks. It was decided that the authority that is competent under the Environment protection act will be responsible for the overall co-ordination of these tasks regarding Seveso II establishments. To facilitate the co-ordination, a manual was developed for the pertinent authorities. This manual is called BLS (acronym for Bestuurlijke Leidraad Seveso = authority guidance on Seveso implementation). The manual will become available early 1999.

7.6. Summation rule instrument Safety and Environment Risk Database (SERIDA)

The instrument comes as an add-on to a database which holds relevant data for over 250 chemicals, including physical–chemical properties, toxicity, environmental toxicity and classification into various systems such as the EU labelling system (R-sentences). The computer program developed is called SERIDA. It gives access to the database and holds the routine for making the summation calculation. (At a later stage, it can be extended with the domino instrument for implementing the directive.) The efficiency of using this tool lies in the fact that the user does not have to find the classification of a substance into any of the categories relevant for Seveso, neither does the user have to find the relevant threshold value for the classification of the substance, as the program does this automatically. Finally, the program prints a full report on the results and the reasons for qualifying an establishment for articles 6, 7 or 9 of the directive. A beta version of the software instrument is being tested as from September 1998. It is expected that the consolidated version of the program will be available early 1999. It can then be made available both for authorities and for industrial companies that may want to check whether the quantities of hazardous substances in the establishment qualify the establishment under the Seveso II directive.

7.7. Domino effects instrument

An instrument that deals with the identification of groups of Seveso II establishments where a domino effect may occur has not yet been developed in the Netherlands. A first consideration on what this instrument could be based on, was however already indicated

[26]. The development of the instrument will start early 1999. A conceivable structure for the instrument could be as follows.

1. Seveso II establishments are first selected on the basis of an indicative distance, e.g. between 500 and 1000 m (the distance criterion is still to be determined).
2. A list of the establishments is made, and their mutual distances are placed in a table together with data on the hazardous substances present in the establishment.
3. A risk-based calculation is performed for any combination of establishments and substances present in the table, so as to determine for each case whether a domino effect between the pairs of establishments, can occur.
4. Each pair of establishments so identified is registered and reported as relevant.

These calculations are preferably automated using a computer program. The Ministry of environment — together with RIVM — currently investigates possibilities for such a computer program.

7.8. Safety reporting instruction courses

A series of instruction courses is planned for 1999 to deal with the legal and practical requirements under the implementation of the Seveso II directive. These courses are aimed at the authorities involved, at regional environment protection services, safety inspectors and fire brigades. The courses will deal with all the important aspects of the implementation, the pertinent legislation, the manuals and guidance documents and the facilitating instruments.

8. Integrated safety reporting

As mentioned in Section 7, the second ‘round’ of safety reports under the Seveso I directive have profited from the manual on safety reporting. Still, to the opinion of the parties involved in the safety reporting and in its evaluation, the double reporting for external safety and for internal safety that followed separate procedures, was not optimal from a point of view of efficiency. An integration of both reporting systems is considered necessary to improve reporting efficiency. This is combined with the so-called one-counter approach in which only one authority receives the report, communicates this to the other authorities and co-ordinates the evaluation of the report between the authorities. A complication in this context was, that different authorities are responsible for the three main fields: external safety and environment protection, labour safety and emergency planning and control. To facilitate the necessary co-ordination, a manual on the pertinent procedures and on co-ordination models is being developed [30]. Integrated safety reporting forms part of the implementation of the Seveso II directive in the Netherlands. The legal requirements for safety reporting are laid down in the Major Hazards Decree 1999 and in the Ministerial regulation for the application of this Decree. In addition, there will be a manual on safety reporting, the so-called RIB-manual (report on information requirements in the Brzo 1999).

Apart from essential administrative information on the owner of the establishment, the safety report must contain at least the following information. (This is not the literal text of the Dutch legislation and is neither a fully comprehensive list.)

- a description of the establishment and its environment
- the location of the establishment and relevant weather data
- information on the safety management system and the organisational structure
- maximum number of persons present at the establishment
- a description of installations and other activities in the establishment that may cause a major accident
- a description of the zones that can be affected by a major accident in so far as is relevant for internal safety, external safety or emergency planning
- a description of the activities and products that are relevant for the safety situation
- a description of the processes operated in the establishments
- a description of possible major accidents in the establishment that can cause a danger outside the establishment; a list of the measures taken to prevent these accidents or limit their consequences
- a description of the chemicals present in the establishment as well as their quantities present and information on the properties of these chemicals
- for each installation, a detailed description of the scenarios for major accidents that may occur as well as the relevant circumstances and events that can lead to these major accidents
- a description of the scenarios for major accidents in the establishment that are of importance for the internal emergency plan and for the planning of equipment for the company fire brigade; a description of the company fire brigade facilities
- an evaluation of the size and severity of the consequences of identified major accidents
- a quantitative assessment of the risk to persons outside the establishment in terms of Individual Risk and Societal Risk
- an assessment of the risk for the environment

The QRA of the establishment involving hazardous activities must result in a geographic map of the establishment, at a scale of 1:10 000 where individual iso-risk contours are displayed (see, e.g. Fig. 2) and a societal risk (F,N) plot of the type CCDF (cumulative complementary frequency distribution) where the absolute probability F for an accident with more than N lethal victims is plotted against group size N (as in Fig. 3).

9. Environmental risks

In addition to the above-mentioned requirements, more emphasis is put on the aspect of environmental risks since the modification of the Seveso directive after the Sandoz incident Airborne pollution is not considered separately, as the safety report to be submitted for Seveso II article 9 establishments contains a QRA largely based on dispersion and further consequences of gaseous releases. Even though this assessment deals with persons, the results of these risk assessments are expected to be quite indicative for any airborne environmental risks as well. As far as soil contamination is concerned, this has not received primary interest either, as it is expected that regular soil protection measures in establishments should provide for protection in case of a major hazard as well, and furthermore, measures that limit the consequences of spills can, in general, be activated following a major accident that can give soil pollution. It was therefore concluded in the Netherlands, that risk assessment aimed at protecting the environment against major accidents should deal with surface water in the first place. This can be of guidance in finding preventative measures and can result in environmental risk management in the most effective way. In the period from 1992 till 1996, both the Ministry of Environment and the Ministry of Transport and public works have developed approaches for risk assessment of establishments with respect to surface water risks. Since 1996, these developments are being merged in a concerted effort together with the Ministry of the Interior and the National Institute for Public Health and the Environment RIVM Bilthoven) to find even better tools for managing surface water risks [27]. Recently, this has resulted in a new computer program, PROTEUS, which enables quantitative assessment of surface water risks from an establishment. It makes use of the different strong points and elements that were present in the earlier computer programs (VERIS and RISAM). The PROTEUS program, after being inputted with the proper data, generates a full risk assessment report automatically. It makes use of standard pollution relevant data available in the SERIDA database. The use of the new computer program will be tested in the field and will later be strongly recommended to the competent authorities as it represents the state of the art in environmental risk assessment in the Netherlands. The program will be available in English.

The following are the most important elements of the PROTEUS program.

- The program allows to select between a defined set of risk units (process, storage, etc.) catchment systems (sewerage, treatment, . . .) and surface water types (river, lake, etc.).
- The physical structure of the establishment is input to the program in a graphical form.
- The aquatoxic substances (i.e., substances that are toxic of aquatic organisms, e.g. toxic for fish, algae or daphnia) present in the risk units can be selected from the chemicals list and the quantities are input to the program.
- A safety management oriented questionnaire is scored for the establishment.
- The program generates accident scenarios automatically and calculates the environmental risk in the form of a pollution vs. probability curve.
- The program generates a full report automatically.

Use of this program will be recommended for the safety reporting under the Seveso II implementation, though equivalent assessments can be accepted.

10. Regulating risk acceptability

The risk acceptability/risk tolerability criteria used in the Dutch external safety policy are not as such legally binding. Nevertheless, they are being taken into account in many situations as if they were. This is the case, in particular, in licensing procedures, where it is required by the authorities that the risk tolerability criteria are met. In spatial planning, however, taking account of the risk criteria receives less attention. In certain cases, this can lead to unwanted situations, in particular, when there is an economic pressure to maximise land use near hazardous establishments. Another important element is the aim to practice the same risk tolerability criteria in all situations involving hazardous activities. These are not confined to the major hazard establishments under the Seveso directive, but involve some 4000 hazardous establishments in the Netherlands. Till now, the various regulations and circulars use slightly different definitions for vulnerable and less vulnerable objects. It is now considered that these differences cannot be reasoned and therefore the systems should be harmonised.

The environment protection act enables the establishment of absolute limit values for environment quality parameters. Thus, risk tolerability can be regulated by legally establishing a limit value for individual risk. In practice, it will not be practical for many smaller hazardous installations to check its risk tolerability at a risk limit. It is preferred that for these smaller establishments, appropriate safety distances — or safety distance tables — are set in the law. These safety distances are based — as they are in current safety policy — on generic risk models in combination with the aimed risk limits. For the larger establishments such as the Seveso establishments, a dedicated risk assessment (QRA) for the individual establishment will in many cases be necessary. The risks that are established are then to be evaluated by the authorities against the risk criteria. The evaluation then forms the basis for decisions on granting a license, siting an establishment or zoning around the establishment. In these cases, it is necessary that the risk assessment is reliable since these decisions depend on the outcome of the QRA. This is achieved through standardisation of the risk assessment modeling. Draft legislation establishing the risk tolerability criteria is expected to be available early 2000.

11. Transport of dangerous chemicals and airport related risks

An activity that occurs on a large scale in the Netherlands is the transport of dangerous chemicals. These chemicals are transported in large quantities over the road, by railroad, pipeline and over inland waterways. Important chemicals in this respect are LPG, chlorine, ammonia, ethylene oxide and acrylonitrile. In the first place, the legal requirements for the transport of dangerous chemicals are aimed at a high level of safety. Nevertheless, traffic accidents may involve transport units carrying dangerous chemicals. Over the period between 1978 and 1992, around 300 accidents occurred involving road transport of dangerous chemicals. In 138 out of these 300 cases, dangerous chemicals were released. In most cases, there were no lethal victims due to these releases; however, it is conceivable that such an accident can lead to lethal victims. In order to control the risk of these transport activities, the risk management system involving QRA adopted for stationary installations, has been further developed for transport risks. Within this management system, risk acceptability criteria play an important role.

The following risk acceptability criteria have been developed for transport risks: The maximum tolerable individual risk for transport of dangerous chemicals is 10^{-6} per year which is equal to the risk criterion for stationary activities. This is the level considered in the evaluation of the activity per se, so cumulation of risks from various activities is not considered unless the activities belong to one establishment for which a license is requested. There is no combined evaluation of ‘stationary’ risks from establishments and, e.g., transport risks. For existing situations, where a higher risk could occur, a policy will yet be developed. The risk criterion formulated does not withstand that in special cases, an integral balancing of interests may lead to acceptance of an individual risk which is higher than 10^{-6}. For societal risk, an acceptability criterion was developed as well, similar to the societal risk criterion for establishments. It implies a value of 10^{-4} per year for the frequency to cause an accident with 10 or more lethal victims, 10^{-6} per year for the frequency to cause an accident with 100 or more lethal victims, etc. per kilometre of transport route. This criterion is to be a less strict, however, than the individual risk criterion. Its nature is that the local authorities should use it as a criterion, but that they can allow the risk to exceed this value if this can be properly motivated. An easy-to-use calculation tool for assessing the risk of transport of dangerous substances has been developed. In addition, a manual has been published on how to deal with these transport risks [28].

The policy system that was introduced, has been evaluated with respect to its consequences in practice. This was done by making an inventory of the number of possible geographic locations where the risk acceptability criteria may not be met. In total, over 3000 geographic locations have been investigated. On the basis of these global inventories, it is expected that in less than 5% of the geographic locations exceed the MTR. For those locations, additional risk mitigating measures will be investigated. In addition, the possibility of zoning could be considered for such locations.

The Dutch national airport, Schiphol (Amsterdam) has in the past few years been the object of extensive external safety studies in the framework of the ongoing growth in number of flight-movements at the airport and plans for further expansion. In 1994, a core planning decision (PKB) for the situation around Schiphol has been adopted by the Parliament [31]. Within the 10^{-5} risk zone, new construction of housing as well as other dwellings is prohibited. Within the 5×10^{-5} risk zone, existing housing will even be ‘closed down’ on the longer term. Within the 10^{-6} contour, an overall risk policy is adopted, aimed at a stand-still in the development of the risk contour area. In an even larger area, the construction of dwellings is restricted to a certain extent. This also involves a policy with respect to societal risk. As from 1999, the external safety situation around Schiphol airport will be re-evaluated every 5 years.

12. Conclusions

The Dutch external safety policy is based on the risk management approach, involving quantitative assessment of risks and evaluation against quantitative tolerability criteria. The experience in harmonizing the policies for the various activities involving dangerous substances, is very positive from a viewpoint of efficiency and transparency. To facilitate the application of risk-based safety policy for medium-size installations like, e.g., tank filling stations and ammonia cooling units, practical instruments like standard safety measures and safety distance tables can be effectively applied. Similar instruments developed for the management of risks from the transport of dangerous substances are being applied very effectively as well.

Acknowledgements

The author acknowledges Mr G.C.M. Lommers for reading the manuscript.

References

[1] LPG Integral, TNO Apeldoorn, Netherlands, 1983.
[2] LPG Integral Memorandum, Netherlands, Staatsuitgeverij Den Haag, 1984.
[3] Report on the COVO study to the Rijnmond Authority, Reidel Publ., Netherlands, 1970.
[4] Council Directive 82/501/EC on the major-accident hazards of certain industrial activities, Commission of the European Communities, 1982.
[5] Besluit LPG tankstations, Staatsblad 95, 1988.
[6] Besluit propaanopslag, Staatsblad 472, 1987.
[7] Besluit opslag propaan in de bouw, Staatsblad 506, 1988.
[8] Wet milieubeheer, Staatsblad 80 (1994) (Environmental Protection Act, Netherlands).
[9] Besluit Risico's Zware ongevallen, Staatsblad 291 (1992) (Major hazards decree, Netherlands).
[10] Methods for the calculation of physical effects, report CPR14E from the Committee for the Prevention of Disasters, 2nd Edn. (1992), issued by Ministry of Social Affairs, the Hague.
[11] Methods for the determination of possible damage, report CPR16E fro Committee for the Prevention of Disasters, 1st Edn. (1992), issued by Ministry of Social affairs, the Hague.
[12] Circulaire LPG Integraal nota (21 March 1984), DGMH/B 2724055.
[13] Circulaire veiligheidsafstanden voor buisleidingen met K1, K2, K3 vloeistoffen, Ministry of Environment, Netherlands.
[14] Circulaire veilighedsafstanden voor hoge druk aardgasleidingen, Ministry of Environment, Netherlands.
[15] B.J.M. Ale, Dealing with risk of fixed installations in the Netherlands, Cryogenics 8 (1993) 762–766.
[16] C.J. van Kuijen, La quantification du risque, Preventique 28 (1992) 23–29.
[17] P.H. Bottelberghs, Evaluatie van de externe veiligheidsrapportage (1992), Ministerie van Volkshuisvesting, Ruimtelijke ordening en Milieubeheer (VROM), report SVS 1992/1993.
[18] Handleiding voor het opstellen en beoordelen van een extern veiligheidsrapport, IPO A73, Den Haag, 1994.
[19] P.H. Bottelberghs, QRA in the Netherlands, IBC Safety Cases Conference, London, February 1995.
[20] M.J. Pikaar, M.A. Seaman, A review of risk control, Ministerie van Volkshuisvesting, Ruimtelijke ordering en Milieubeheer, rapport SVS 1994/27, 1994.
[21] Handreiking externe veiligheid, IPO, Den Haag, 1996.
[22] Council Directive 96/82/EC on the major-accident hazards involving dangerous substances, Commission of the European Communities, 1997.
[23] C.M. Plug, PSA for environmental impact, ESREL'96 International Conference on Probabilistic Safety Assessment and Management (June 1996) Crete, Greece.
[24] AVIV report, Landelijke inventarisatie van risico's, Ministry of Environment, Netherlands, VROM/SVS 1997.

[25] DHV report, Doorwerking externe veiligheidsbeleid in vergunningen en ruimtelijke ordening, Ministry of Environment, Netherlands, VROM/SVS 1998.
[26] P.H. Bottelberghs, B.J.M. Ale, Consideration of domino effects in the implementation of the Seveso II directive in the Netherlands, European seminar on domino effects, Leuven (September 1996), Ministry of Employment and Labour, Brussels, Belgium.
[27] G.J. Stam, P.H. Bottelberghs, J.G. Post, Environmental risk: towards an integrated assessment of industrial activities, J. Hazard. Mater. 61 (1998) 371–374.
[28] Handreiking externe veiligheid vervoer gevaarlijke stoffen, VNG publishers, the Hague, 1998.
[29] G.C.M. Lommers, A.J. Muyselaar, External safety policy and land use planning in the Netherlands, report to EU DG-XI (1997) Ministry of Housing, Physical Planning and Environment, Netherlands.
[30] BLS manual, Ministry of Environment, Netherlands, in draft.
[31] Planologische kernbeslissing Schiphol en omgeving, Tweede Kamer (1994–1995) 23552.