Incident repression hazardous materials/WVD

Guide to hazardous industrial activities

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Guide to hazardous industrial activities

Handbook for the cataloguing and selection of (industrial) activities for which an Emergency Management Plan ought to be drafted, compiled by J.M. Ham and Mrs. J.M. Blom-Bruggeman of the Netherlands Organisation for Applied Scientific Research (TNO).

Research by the TNO, carried out at the request of the Fire Service Directorate of the Ministry of Home Affairs and the Transport & Public Works Department of the Province of South Holland

The Hague, September 1988

Contents

Also to be used in conjunction with this Guide:
- enclosures A to S
- a set of forms

Summary

A methodology has been developed for the cataloguing of hazardous (industrial) activities and the evaluation of these activities as part of the process of formulating a emergency management plans. This 'Guide' will enable priorities to be set at local level (district, region) for the drafting of Emergency Management Plans.

Users will include: emergency management authorities or nuisance act departments at district level and district or regional fire officers. Users will be assumed to have a technical background.

The methodology is based on various categories of:
- dangerous activities (6 x)
- types of dangerous substances (11 x)
- system contents,

for which characteristic accident scenarios have been chosen and for which graphs can be used to determine the extent of the area in which people may be killed and in which people may suffer (reversible) injury. The potential number of casualties is calculated from demographic data.

Information is also generated in global terms about the frequency of occurrence of such accidents. At the same time information is gathered about the surrounding area and the emergency services that will be relevant to a response to emergency management.

On the basis of the information collected the relevant authority can be advised about the desirability of drafting an Emergency Management Plans certain hazardous situations.

1 Introduction

1.1 General notes

This 'Guide to hazardous industrial activities' is intended to be an aid in the selection of activities for which an Emergency Management Plan may have to be drawn up. One of the factors here is the potential damage arising out of an unwanted event, but the different ways of responding to the emergency (tackling the source, evacuation and so on) are important as well.

The following data and philosophies were considered in the development of the methodology:

□ There is no clear-cut definition (in numerical terms) of the term 'disaster'. Whether a particular accident will turn into a disaster (= serious damage to people and property, social disruption) depends very much on the area around the site of the accident (inhabited or uninhabited area) and the nature of the substance involved (flammable, explosive or toxic). Local conditions (presence of emergency services, availability of reception centres for casualties, infrastructure for moving casualties and evacuees away from the scene) will also be very significant in determining whether an accident escalates into a disaster.
Finally, local judgement, both political and administrative, can also determine what is experienced as a disaster.
This methodology concerns only (possible disaster caused by) accidents involving dangerous substances in industrial, storage and transport activities.
There are of course other events that can lead to a disaster situation: natural disasters, major fires in public buildings (hospitals, office complexes), terrorist attacks, etc. It is important to include accidents of this type in deliberations about the need for an Emergency Management Plan, but they fall outside the scope of this Guide.

□ The extent and the quality of the information about potentially dangerous activities in a certain place and region vary greatly. Some provinces already have a register, or are in the process of compiling one, district by district, of existing hazardous activities, of both the stationary type (processing plants and storage installations) and the mobile type (road, rail and water transport and pipelines). In other regions there is (as yet) no such systematic breakdown. The methodology includes a checklist for such a register with activities that might be relevant; but this list cannot possibly be exhaustive.

□ The number of potentially dangerous substances is very high. They can be broken down into the following categories by effect: flammable, explosive and toxic. And some in themselves harmless substances can emit toxic substances when burned.

A classification by physical state is also important: gaseous, liquid or solid. And the method of storage (under pressure, cooled, in tanks, in bulk, etc.) is also a factor. Given this multiplicity of parameters a list of substances cannot be exhaustive either.

□ Considerations of probability also have a part to play in the assessment of risks and the person assessing them will also want to be able to consider any risk aversion (a low risk of serious damage is worse than a high risk of minor damage).

The above considerations have led to a methodology as presented in this Guide that enables the user himself to determine a potential area of damage for a given activity, both on the basis of registered or yet to be registered data and by making use of graphs and standard values; priorities can be set for Emergency Management Plans on the basis of the predicted (maximum) damage.

Predicting the size of an area that would be affected by an incident in advance of that incident for each separate activity is impossible: the number of parameters for an accident scenario is too high, the different sizes of system too varied and the number of substances to be taken into account too great.

Using this methodology, it is relatively easy to classify and assess processes and substances that have yet to be developed or that do not appear in the lists.

It is true that the analysis requires a certain amount of effort, but after a little practice this appears perfectly acceptable.

1.2 Responsibility for execution of the project

This Guide to hazardous industrial activities was produced by the Industrial Safety Department of the Division of Technology for Society of the TNO (MT-TNO) on behalf of two principals:
– the Fire Service Directorate of the Ministry of Home Affairs;
– the Transport and Public Works Department of the Province of South Holland.

Two consultative bodies were in existence while the project was under way:
□ *Project consultation:* representatives of the two principals and MT-TNO. Involved on the principals' side were:
– for the Ministry of Home Affairs: mr. J. Jeulink;
– for South Holland: D. van den Brand and C.J. van Zwieten.

□ *Supervisory committee,* consisting of representatives of the two principals, potential users and MT-TNO. Members of the Supervisory Committee/those present at its meetings were:
– A.M.M. van Leest, Ministry of Home Affairs (chairman)
– J. Jeulink, Ministry of Home Affairs
– D. van den Brand, Transport and Public Works Department of the Province of South Holland
– C.J. van Zwieten, Cabinet of the Royal Commissioner for South Holland (to January 1987)
– M.G. Blok, Cabinet of the Royal Commissioner for South Holland (from January 1987)
– L. Baljé, Gouda District Council
– J.H. Snijder, Central Twente Regional Fire Service
– G.A.J.M. van Strien, Central Brabant Regional Fire Service
– M.F.J. Flipsen, Directorate-General of Labour, Ministry of Social Affairs and Employment.

Four meetings of the Supervisory Committee were held during the course of the project. The Supervisory Committee expressed its approval of the result on 2 December 1987.

A draft version of the Guide was tested for practicability and convenience in two areas, viz.:
– the district of Papendrecht, in South Holland;
– the district of Delfzijl and surrounding area, in Groningen.

The experience gained from these trial runs played a significant part in the choice of the final form of this methodology.

The following were involved in the project on behalf of MT-TNO:
– C.M. Pietersen (project manager)
– J.M. Ham (project implementation and reporting)
– Mrs. J.M. Blom-Bruggeman (project implementation).

1.3 Responsibility with regard to the target group/users

While this Guide was being compiled there was thorough discussion of the desired depth of the methodology and the level it should be pitched at to suit the broad composition of the target group (the users).

As far as content was concerned, simplicity and ease of use were always at the forefront. Complicated calculations and difficult formulae had to be avoided.

A weighting and screening method for setting priorities was at the top of the list.

Nevertheless, the compilers took the view that some knowledge of the exact sciences and engineering was a requirement for evaluating this type of problem. Users were assumed to have knowledge of and ability to read graphs (logarithmically) and knowledge of basic physical concepts.

In addition, a certain pragmatism and ability to improvise are required of the user. It is impossible for the methodology to provide a ready-made answer to every situation that arises. It will be up to the user to try to make his input data suitable, in a comprehensible manner, for application in the methodology, sometimes by using 'common sense', sometimes with the help of expert opinions.

There is a very real possibility that the Guide will not be able to provide a (ready-made) answer to certain situations. In this case the following experts should be consulted:

- the provincial Environment and Safety office;
- district Fire Service Inspectorates;
- the Fire Service Directorate of the Ministry of Home Affairs.

There is also literature that can be consulted. A number of useful references can be found in section 5.

2 Methodological background

2.1 The constituent parts of the methodology

The axis around which the cataloguing and assessment methodology pivots is a number of forms. They can be found inserted at the back of this manual. More forms are available on request. We shall now give a brief explanation of the purpose and the content of the forms.

1st form 'Register of existing hazardous activities'
A record should be kept on this form of all the potentially dangerous activities in the area in question. Reference can be made to a (non-exhaustive) list of activities that appears in this Guide. In places where a record has already been made, completion of this form will require relatively little effort. In other cases, a record based on existing nuisance act files and using a local team of experts will be necessary.

2nd form 'Determination of damage and risk'
This double foolscap form is the main form for recording the information required for assessment, viz.:
– identification of the activity and the relevant dangerous substance;
– the potential damage, expressed as the number of persons in the 'fatalities' area of damage and in the 'wounded' area of damage. Account is taken here of the existence of special buildings in which large numbers of people may be present simultaneously;
– a global assessment of accident probability in relation to the scenario in question;
– a list of some specific factors (relating to the surrounding area) that (may be) are important in the formulation of an Emergency Management Plan;
– evaluation of the above elements, resulting in a recommendation regarding the necessity of an Emergency Management Plan.

With regard to this final point, it should be noted that the methodology does not provide any general rule about when an Emergency Management Plan is necessary and when it is not. This will depend very much on the local circumstances and whether or not there are other dangerous activities. Priority setting and/or combination in the emergency management plans may be desirable.

3rd form 'Determination of damage by category of substance'
This is a set of 11 forms, one for each separate substance category. One of these 11 forms will be completed according to the substance identified on the main form. The extent of the 'fatalities' and 'wounded' areas of damage can be calculated from tables, standard values and graphs.

For the best possible assessment information needs to be collected about:
– the nature and the state of the substance(s) in question;
– the nature of the activity (storage, transport, etc.).
This Guide gives standard characteristic values for a number of these aspects, which will generally provide a sufficiently accurate approximation. However, local information will sometimes be required.

2.2 Accuracy and use of the results

When using this Guide it will be useful to be aware of a number of aspects regarding the quantitative starting points.

The approach of accident scenarios and models of effects in risk studies is often a pessimistic one. In certain respects this is true of this Guide as well. But in others a more average situation is considered.

In addition, with a view to increasing simplicity and ease of use, categories are used wherever possible, for classifying the characteristics of substances, for example. This has of course to be at the expense of 'accuracy' or discernment.

The user must be aware of the following starting points:

– A pessimistic assumption has been made about the intensity of the source, in the event of an accident; it is generally assumed that maximum source intensity occurs, the entire system content being involved.

– The weather class used for the dispersion of the vapours of dangerous substances is neutral weather (class D) with a wind speed of 5 m/s. This is more of an average rather than a pessimistic situation. With extremely stable weather and low wind speeds (night-time conditions) the extent of the area of damage may be considerably greater (factor 5 to 10).

– A pessimistic starting point has been used in the selection of the categories of substances, especially the toxic substances. The damage distances given are generally based on the 80th to 90th percentile of the substances within a particular category. This means that 80 to 90% of the substances within that category are less toxic than the criterion chosen.

– The size of areas damaged by toxic substances is based on exposure lasting 30 minutes. There will generally be effective countermeasures (source reduction, alerting the surrounding area) (well) within this period of time. Under certain circumstances, however, it might take longer than this for effective protection to be put into place. The methodology may well underestimate the actual damage for these situations, especially as casualties will generally be weaker as a result of the exposure and less able to flee. The damage distances will then be greater.

– As far as the most important damage from the major incident viewpoint, namely the number of wounded, is concerned, the results tend towards the pessimistic side. For example, for damage caused by fire and explosions the 1% fatality criterion is used for the prediction of 100% wounded. For toxic damage the 50% reversible injury area is regarded as 100% wounded. It may be concluded from the above that the accuracy, in absolute terms, with which consequences are calculated is limited. The final conclusion about damage must therefore be translated into terms such as 'a few deaths' or 'several dozen wounded'. These results will generally be perfectly adequate as selection and priority criteria for the purposes of drafting an Emergency Management Plan. This is especially true of the discernment (mutual balancing) between various activities.

3 Guide to completing the forms

3.1 Register of existing hazardous activities

You must record all potentially dangerous activities in your district/ region on this first form. Use existing register material and information from environmental permits and so on. Use the list given in Enclosure A as a checklist.

Some types of activity will occur several times in your region, filling stations, for example. While exhaustive assessment of each of them may be unnecessary, inclusion of them all on this first form is advisable.

The form has been designed as a table consisting of six columns.
It should be completed as directed below.

a Activity
Enter here the identified activity as clearly as possible, for instance:
– Smith filling station
– transport of dangerous substances along the motorway
– storage of pesticides by a horticultural cooperative.
Give each activity identified a serial number.

b Address
This section is self-explanatory for stationary installations.
For transport enter a road number, a street name or a route indicator (from ... to ...).

c Category
Enter here the nature of the activity as one of the following:
– road transport
– rail transport
– inland waterway transport
– pipeline transport
– storage installation
– processing plant

d Information available
Indicate here whether quantitative information is available about the activity in question: if so, state on what it is based. For example: nuisance act permit, fire brigade plan of attack, traffic intensity, etc.

e Relevant substances
Enter here (some of) the most relevant substances involved in the activity in question. Where necessary, use group descriptions, for example:
– petrols + LPG
– fuels, solid chemicals
– various insecticides and agricultural poisons

f Initialling
Initial here either if an evaluation using the following forms has taken place for this activity or if a more detailed evaluation is not considered necessary.

3.2 Determination of damage and risk

The (double-sided) main form will, on completion, contain the most relevant information for a decision about drafting an Emergency Management Plan. In principle, one of these forms should be completed for each of the activities identified above. However, if a certain type of activity has been encountered a number of times, a filling station, for example, then you would do best to begin by evaluating just one such situation. Select the one that appears, at first sight, to present the greatest risk.

Possible criteria in this respect would include: location close to concentrations of population, very high intensity of use (high turnover or a measure of this kind) or location close to a relatively dangerous place. If the evaluation shows that you do not expect this 'dangerous' representative to give rise to a 'major incident', than there is no need to evaluate the others. If, on the other hand, you do foresee serious consequences, then you must carry out the same exercise for the other representatives as well.

We shall now move on to step-by-step instructions for completing the form.

I Identification

The first section of this part of the form can be completed by referring to the first form. Under 'subject' generally enter the container of the dangerous substance in question. For example: pipeline, railway tank wagon, warehouse, cooled storage tank, etc., where possible with a code.

Under type of substance enter as specifically as possible the (chemical) name of the substance, for example, LPG; acetone; chlorine; acrolein. This will not always be possible, for instance, with wholesalers' warehouses and such like. Then it is best to use collective terms, such as various flammable solvents and paints; various forms of fireworks; various pesticides; etc. (see also 4.4).

Then decide to which of the eleven categories of substance the identified substance belongs. Consult the codings in the 'List of substances' in Enclosure B.In the case of a 'gas' (both flammable and toxic) state under what conditions this gas is kept in its container (liquefied by compression, liquefied by cooling or gas under pressure). Colour the appropriate box black.

Then complete the appropriate substance category form, as directed in 3.3. Where there are several dangerous substances in each subject that do not all come into the same category, a separate form must be completed for each substance.

II Determination of consequences

Calculate the dimensions of the areas of damage for fatal injury and reversible injury by completing one of the substance category forms, which from now on must be kept with this main form. Enter the main results in II as well.
It is important to make a clear distinction between circular and rectangular areas of damage.
You must now determine the potential damage (this is the possible number of persons present in the respective areas) using topographical and demographic data. You would do best to use the following for this:

- ☐ Topographical maps of the surrounding area; depending on the size of the area of damage, to a scale of 1:10,000 (area of damage <2 km) or of 1:25,000 (area of damage >2 km). For smaller areas of damage (say: <250 m) local street plans will be perfectly adequate.
- ☐ Sheet of transparent paper (or plastic) on which you can draw the shape and the dimensions of the area of damage.

The areas of damage are shown schematically in Enclosures F to Q. Place the transparent sheet, with the two areas of damage drawn on it, over the map; make sure that the mid-point coincides with the site of the accident.

This 'site' is not so easy to lay down in the case of a road, for example. What we actually have here is a band running either side of and parallel to the road. It may be possible to opt for a site that is particularly hazardous, such as a dangerous crossing; but more important is the orientation in respect of the environment.

Now lay the transparent sheet over the map so that the outline drawn lies over the most densely populated area. Remember the possible presence of large concentrations of people in special buildings, such as a school, a hospital, an old people's home, sports accommodation, etc. Where necessary, refer to Enclosure E1 for help in the selection of this area.

Then decide how many people there might be in the respective areas of damage. Such information is often known locally, especially for the special buildings. For other residential buildings a figure of three persons per household can be used. Where necessary, use can be made of the standard densities of population, as shown in Enclosure C.

Enter the data used in II (for example, number of homes, name of the school with number of persons, etc.) and then enter the potential number of casualties on the form.

NB: When calculating the number of persons affected, make sure that you make allowance for a reduction of surface area in the 'wounded' area, namely for the 'fatalities' area. In other words, when using the standard densities of population the following applies:
– number of dead = A1 x density of population (A1: surface area of 'fatalities' area),
– number of wounded = (A2 - A1) x density of population (A2: surface area of 'wounded' area).

Finally, make a (provisional) choice regarding the desirability of an Emergency Management Plan on the basis of numbers of casualties by placing a cross in the appropriate box.
If your conclusion is 'absolutely unnecessary', there is no need to complete the rest of the exercise (determination of probability, information concerning the surrounding area).
Just complete part V, in so far as the relevant parts have been evaluated or calculated.

In all other cases proceed with determination of probability.

III Determination of probability
There are two important factors to consider when determining the probability of the incidence of the number of casualties calculated in II on an annual basis:
– the initial accident frequency; this is the probability in any one year that the described accident scenario will occur;
– the probability that the number of persons calculated will be affected.

Generic figures for the initial frequencies of the different scenarios can be found in Enclosure D. A distinction is made here, specifically for transport activities, between traffic intensity (number of traffic movements) and the safety of certain situations. A differentiated approach has sometimes been applied in the case of storage installations as well. The use of these data is described in the explanation under D.

Enter in III after f(acc) the value of the accident frequency (or rather: the probability of the physical effect) taken from Enclosure D. At the same time make a note on the form of the parameters used (activity, intensity, etc.).
A correction must be made for the probability that the calculated maximum number of persons present will actually be victims of the supposed accident.
This can be affected by:
☐ The probability that the selected most densely populated area will be affected.
If the density of population of the area surrounding the site of the accident varies a great deal, a correction will be required for 'homogeneity'.
The procedure for determining the correction factor in this respect is described in Enclosure E1. Enter the value found in III, after p(hom).
☐ The probability that the number of persons calculated to be present in/at a given location are actually there (for example, on the beach, in a football stadium, and so on). In this case determine the correction factor using the method described in Enclosure E2 and enter it in III, after p(loc).

Then calculate the resulting frequency by multiplying f(acc), p(loc) and p(hom).
Enter this figure after F.
In the summary at the end of III mark a cross in the box corresponding to the total frequency calculated. Enter the qualitative probability indication found (for instance, 'significant') on the appropriate line in V.

IV Specific factors relating to the surrounding area
In deciding whether an Emergency Management Plan is desirable it is important to collect information about some of the features of the area of the dangerous activity. These will also be important matters when it comes to drafting such a plan. While for the most part immeasurable in quantitative terms, the following elements will certainly have to be considered:
☐ The degree of difficulty of any evacuation, for example, old people's flats compared with low-rise buildings with mostly young households.
☐ The possibility of substantially reducing the effects by fighting the source and the extent to which the emergency services are prepared for specific situations.

□ The facilities that exist for the transportation and reception of the wounded after a serious accident. Take account of the medical treatment capacity of the hospitals in the region and also the distance from the scene of the accident to the hospital. The sections of part IV to be completed speak for themselves. Enter the result in part V (evaluation) using key words.

V Evaluation
Part V is largely based on the results of parts I to IV. This is here a recommendation can finally be made about whether or not an Emergency Management Plan should be drawn up.

The result of part II is often crucial for this. Nevertheless, the conclusions of parts III and IV are likely to affect the priority setting. Enter your recommendation on the last line of part V.

A number of factors may be important in this recommendation. As has already been stated in the Introduction (section 1.1), it is impossible to give a clear-cut numerical gauge for this. The terminology used in the definition of a 'disaster' in the disaster Relief Act also points to the lack of such a measure.

The following points can be considered, however:
□ Is the number of potential casualties so great that this will generally be felt to be a 'disaster', taking account also of local feelings?
□ Will the consequences of the accident lead to a (more or less long-term) disruption of social life?
□ Will (more or less comprehensive) coordination of the activities of several emergency services be necessary?
□ Are there any major bottlenecks to be expected with regard to the potential number of wounded in terms of rescue, transport and medical treatment/care of the wounded? A basis for this would, for example, be the medical treatment capacity of hospitals within a certain driving time, say half an hour.
□ Is the accident in question reasonably 'foreseeable' (see: probabilities)?
□ Can prevention of escalation of the accident be reasonably guaranteed by solely repressive action?

These and other considerations must come into the deliberations surrounding the drafting of emergency management plans. It is by no means impossible that there will be differences in the decisions taken by different districts or regions. This is unavoidable with this method of priority setting.

It is generally fair to say that an Emergency Management Plan is useless if the major incident does not develop (fatalities only, no one wounded) or if there is no question of any efficiency of effort.

3.3 Substance category forms for determining damage
There is a separate form for each of the eleven defined categories of substances, on which you should enter the information required as specifically as possible. Each of the categories of substances has its own set of tables with characteristic values and graphs with damage distances as a function of the system content.

The information for the completion of these forms can be found in Enclosures F to Q, as follows:
F Flammable liquid
G Flammable gas, liquefied by compression
H Flammable gas, liquefied by cooling
J Flammable gas, gas under pressure
K Explosives
L Toxic liquid
M Toxic gas, liquefied by compression
N Toxic gas, liquefied by cooling
O Toxic gas, gas under pressure
P Toxic solid
Q Toxic combustion product

Complete the appropriate form.

4 Additional instructions for 'special' situations

In a practical test of the suitability of the methodology it became apparent that a number of circumstances and situations that occur in practice cannot readily be solved with it.
Evaluation of these situations showed that it is impossible to take account of all these circumstances within the framework of a simple methodology.
In general terms the Guide is an aid that must be used with a certain amount of common sense interpretation on the part of the user.

Below you will find general recommendations to help you find your way through some of the more frequently occurring problems.

4.1 Processes at elevated temperatures

The basis of the calculations of the effects underlying the damage distance graphs in this Guide has been a storage or processing temperature of 20°C.
Clearly, at higher temperatures the intensity of the source will generally be greater: liquids will evaporate more quickly.

It is recommended that the following rule of thumb be used:
for every 10°C rise in temperature above 20°C the damage distance is a factor 1.3 greater.
This is a practicable approximation for the purposes of this Guide.

For example: a liquid is stored at t=50°C.
This is 3 x 10°C higher than the base value of 20°C higher than the base value of 20°C.
The calculated damage distance from the graph is multiplied by $(1.3)^3 = 2.2$.

4.2 Several containers of the same kind

If several identical containers are involved in an activity (for instance, ten 700 l drums of chlorine instead of one 7m^3 tank), the methodology should generally speaking be carried out for each container (drum of chlorine). With regard to probability, account can be taken of the occurrence of several identical containers.
This recommendation applies to compartmentalised storage in general.

If, however, it is clear that the accident scenario in question will not be confined to just one container, enlargement of the system content to be considered will be necessary. The same applies to the storage of liquids in tanks in a tank pit; in this case he surface area of the tank pit is crucial, even when it contains more than one tank. Once again, the reasonableness of the approach is left to the user.

4.3 Casualties almost exclusively indoors

In some situations the physical effects of an accident will be of an extremely local nature or will not even disperse outside the building. Think, for example, of a fire in a chemist's shop or excessive chlorine generation in a swimming pool.
Accidents of this kind cannot usually be calculated with this Guide, although the potential number of casualties may be considerable and it may be possible to speak of a 'major incident'. It is important that the emergency services are aware of the existence and the potential danger of these kinds of activities and, where necessary, formulate procedures to deal with them.

But they fall outside the scope of this Guide.

4.4 Storage of a variety of substances

In customs sheds and wholesaler's warehouses in particular the composition of the products in store is likely to be extremely varied. It will therefore be impractical to classify all these substances using the lists of substances. Furthermore, the chemical composition will often be completely unknown, so that it does not appear in the list of substances.

In such situations it is recommended that a group approach be applied and that the distance graph that is the most suitable for this group be used.
For example:
– for solvents, etc.: special boiling point spirits
– for various chemicals, liquid: toxic liquid, medium.

4.5 Chemical solutions (acids, etc.)

The 'active' constituents of a number of chemical solutions, such as hydrochloric acid, sulphuric acid, chlorine bleaching lye, can be found in the list of toxic gases. The liquids are often not included as such in the lists.

Given the selection criteria used in the preparation of the lists of substances it may be assumed that these substances will not cause extensive areas of damage as liquids. This can occur, however, in the case of chemical reactions (for example, the formation of chlorine gas when hydrochloric acid and bleaching lye mix, as happens in cleaning activities). But reactions of this type are not considered within the scope of this Guide.

4.6 Record of traffic flows

The effort involved in mapping the routes and traffic intensities of the transport of dangerous substances can be fairly great. It is advisable to set up some form of (provincial?) coordination with regard to neighbouring districts. This is because the destination of much of the traffic is further on and therefore the traffic must be regarded as passing by several districts.

4.7 Spills on water

When there is an escape of a dangerous substance on water, it is important to take account of the physical behaviour of that substance in water: does the substance dissolve? Is its density greater than that of water so that it will sink?

Only by estimation will it be possible to determine the effects on the source intensity and the damage distances.

4.8 Non-continuous activities

Certain types of activity only take place during the day and on working days. This has an effect on the distribution of people over the area of damage and the probability of their being affected.

As far as possible account must be taken of this; for example, schools and catering establishments that will be busy during the day and churches and large sport complexes that will almost certainly be empty at this time.

4.9 The situation in the surrounding area for which the evaluation must be made

In general, the methodology must be applied to the existing situation. However, if there is any question of a change to or preparation of a zoning plan, it is advisable to take this into account as well. The same applies to procedures undertaken for the routing of dangerous goods.

Alternatively, the results of this evaluation may have an effect on the decisions made with regard to zoning plans or routing.

5 Literature to be consulted

This section contains a number of (Dutch) sources that may be consulted by users of this Guide if they require additional background information on any particular subject. The sources given were also consulted in the compilation of this Guide.

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[9] The storage of explosives and detonators.
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State Publishers, The Hague.
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Appendix I Injury criteria

This Guide catalogues the possible injuries resulting from an accident with a dangerous substance, within the framework of a response to a major incident. Two types of injury have been distinguished for the purposes of fixing and defining the areas of damage:

- Fatality: it is assumed that 100% of those present in the area defined as such will be killed.
- Wounded: it is assumed that 100% of those present in the area defined as such will suffer 'reversible' (= curable) injury; this is taken to mean an injury requiring life-saving and medical care.

This division is fairly arbitrary, but perfectly acceptable for the purposes of this Guide. It provides a sufficiently accurate basis for an estimate of the numbers of casualties and (consequently) the extent of the emergency service required.
The division is adequate for the weighting and ranking purposes of priority setting.

The injury criteria used for the fatality and wounded types of injury are determined by the nature of the accident and the associated physical effect. The criteria chosen will now be explained by type of physical exposure.

a Heat radiation (pool fire, BLEVE)
Fatality: This injury is assumed for 100% of persons exposing to direct flame contact. In other words they are within the area of the fire, or in the path of the column of fire or fireball, or in the flare.

Wounded: This degree of injury is used for an exposure to heat radiation that produces (at least) second degree burns on unprotected parts of the human body.
It is assumed where the heat radiation is $\geqslant 7$ kW/m^2 for 30 seconds.
This intensity of radiation has been chosen as the limit value for the wounded area of damage.

b Explosion (gas cloud explosion, explosive)
The description of the injury criteria for this effect depends on the kind of substance that causes the explosion.

Fatality: In the event of a gas cloud explosion, 100% dead is assumed for those within the explosive area of the gas cloud.
The cause of death is then direct flame contact and/or asphyxiation through lack of oxygen or fumes.

In the event of explosions caused by explosives, it is assumed that 100% of those in the immediate vicinity of the centre of detonation (10-100 m, depending on the amount of substance involved) will be killed by the very strong blast wave and/or by debris and airborne fragments.

Wounded: It is assumed that everyone inside an area in which the peak overpressure is $\geqslant 0.1$ bar will be wounded by mechanical damage.
For the gas cloud explosion this will be inside a circle with the middle of the gas cloud as its centre.
For explosives the centre of detonation is the mid-point of this circle of damage.
The assumption that everyone inside this area will be wounded will probably lead to an overestimate of the numbers wounded.

c Toxic exposure (toxic gas cloud)
Generally speaking very little is known about the acute toxic effects of substances on human beings. What we do know mostly comes from tests on animals. So all we know about these substances in general is what constitutes a lethal concentration for a certain animal for a certain exposure time.

Conversion models [3] have been developed for the appraisal of lethal toxic doses of substances for humans, in which corrections are made for the type of animal tested and for the exposure time. A calculated lethal concentration has been determined for the exposure doses in this Guide for (50% of the) persons exposed for a period of 30 minutes: LC50-human (½ hour).

In addition, standards have been formulated in what are known as STEL values for the exposure of humans to environmentally harmful substances. For these concentrations a minimum degree of irritation is assumed.

Duiser [5] has proposed that the following levels be defined for the injury criteria for toxic substances:
- slight irritation
- serious irritation
- reversible injury (no permanent aftereffects)
- irreversible injury (permanent aftereffects)
- fatality (dead).

Duiser assumes a geometric progression in the successive dose values of these levels. This means that a fixed factor is assumed between two consecutive exposure concentrations.

The above LC50-human (½ hour) concentration derived from tests on animals has been defined for the 'fatality' criterion. In addition to this only the minimum injury level, slight irritation, has been defined via the STEL value.

For the purposes of a response to a major incident the reversible injury level has been chosen for the 'wounded' criterion. This type of injury will most probably require medical attention.
The concentration for reversible injury for half-an-hour's exposure can be calculated using the arithmetic relationship between the highest and the lowest level of injury.

Calculating this relationship for the 110 or so toxic liquids and gases included in the lists of substances (enclosures B, L, M, N and O) the mean ratio of the lethal concentration to the concentration for reversible injury comes to a factor of 40. In other words:

$$\frac{C_{lethal}}{C_{reversible}} = 40$$

While this factor appears to vary between the different substances, application of the factor 40 seems to produce an injury criterion between 'serious irritation' and 'irreversible injury' for nearly all substances. This injury span is considered since 'wounded' is defined as 'needing medical help', practicable for the wounded criterion. It is therefore assumed for all calculations that:

$$C_{wounded}\text{-human (½ hour)} = \frac{\text{LC50-humnan (½ hour)}}{40}$$

To summarise for the areas of damage:

Fatality: This injury is assumed for 100% of the people who are exposed for more than 30 minutes to a concentration of a substance ⩾LC50-human (½ hour).

Wounded: This injury is assumed for 100% of the people who are exposed for more than 30 minutes to a concentration of a substance ⩾one fortieth of LC50-human (½ hour).

The criteria are based on the injury concentrations for toxic liquids and gases. It is assumed that the calculated relationship also holds true for toxic combustion products and toxic powders.

A Flammable substances

Flammable substances are divided into two categories, viz.:
- flammable liquids
- flammable gases.

When stored, flammable gases can occur in three forms, namely: liquefied by compression, liquefied by cooling and gas under pressure. For both liquids and gases the danger of fire and/ or explosion is determined by their volatility or boiling point.

A1 Flammable liquids

For the purposes of this Guide the flammable liquids have been subdivided into two categories on the basis of the potential physical effect:
- flammable liquids where only the POOL FIRE effect is important (nearly 100 substances);
- flammable liquids where both the POOL FIRE effect and the GAS CLOUD EXPLOSION effect are important (approx. 15 substances).

The distinction has been made on the basis of the maximum vapour pressure (Pv) at 20°C; it is assumed that substances with $P_m > 0.3$ bar can form an explosive gas cloud.

The substances can be found in Enclosure F.

A2 Flammable gases

The flammable gases liquefied by compression have been subdivided into two volatility classes on the basis of boiling point.

In addition to the properties of a substance, its physical state is also important for the determination of risk: gas liquefied by compression, gas liquefied by cooling, or gas under pressure.
These considerations are irrelevant for the classification in this framework. Account is taken of them in the distance graphs.

The table below shows the criteria for the classification of the flammable gases liquefied by compression:

Class	Boiling point (K)	Examples
3	>265	butane, acetaldehyde, butene, ethyl chloride
4	<265	natural gas, LPG, propane, ethane, propene, hydrogen

Enclosure G gives a summary of some 20 flammable gases with their boiling points and class numbers for use with the Guide. The list has been compiled for the 'gases liquefied by compression' category.

The classification does not appear to be important for the flammable gases liquefied by cooling.

B Explosives

The explosives category is subdivided into three main categories, their respective explosive effect per kg of substance applying as the criterion for classification. A distinction is made between the following, in order of declining strength:
1 explosive organic peroxides;

2 explosives (dynamite, TNT);
3 fireworks: firecrackers, bangers, and so on.
For the purposes of this Guide each category is converted to kg of TNT, according to the following rules:
– 1 kg of 'organic peroxides' = 10 kg of TNT
– 1 kg of 'explosives and ammunition' = 1 kg of TNT
– 1 kg of 'fireworks' = 0.1 kg of TNT.

For example: In this methodology a stockpile of 2000 kg of fireworks is treated as 200 kg of TNT. At the same time 20 kg of organic peroxides also corresponds to 200 kg of TNT.

Enclosure K gives a list of about 30 organic peroxides. Each substance is followed by a percentage, usually 70 to 80%. Above this limit the substance is to be regarded as explosive (capable of being detonated); below it there is no such danger. In principle itemisation of them is unnecessary for the purposes of this Guide. The user need only enter the total amount of explosive organic peroxides. To express this quantity in kg of TNT, multiply it by 10.

Enclosure K also contains a number of substances from the other categories of explosives. Included as explosives should be: the organic nitro compounds and nitrates (group a), the inorganic nitrates and chloric acid salts (group b) and from group c: dynamite and ammunition. Record the total quantity of this category as kg of TNT.

The 'fireworks' category contains the other three substances from group c, including everything normally associated with fireworks of all kinds. Divide the total quantity by 10 to find the quantity in kg of TNT.

For objects containing an explosive charge (shooting cartridges, for example) multiply the total weight by the fraction of explosive they contain.
This can vary from 0.01 - 1. If there is no information available, assume 10% explosive, i.e. a multiplication factor of 0.1, which can be used to calculate the quantity of TNT.

C Toxic substances

The toxic substance category is subdivided into three main categories, on the basis of the physical state of aggregation, namely:
1 Toxic gases
2 Toxic liquids
3 Toxic solids.

There is the further category of toxic combustion products. This is described separately in D.

The toxic substances are classified from two points of view:
a the toxicity (poisonousness) of the substance, calculated as LC50-rat for four hours' exposure;
b the volatility and the state of aggregation, which together determine the source intensity (this does not of course apply to solids).

1 Gases and liquids
Re a The toxicity of substances has, as stated above, been standardised at LC50-rat-4 hours. A method has been developed [3] for conversions to this unit.

In view of the great uncertainties in these toxic relationships, the substances have first been divided into classes by a factor 10. Then a toxicity class number has been allocated to each category, as shown in the table below:

LC50-rat (4h)(ppm)	**Toxicity class (TOX)**
0.01 - 0.1	8
0.1 - 1	7
1 - 10	6
10 - 100	5
100 - 1000	4
1000 - 10 000	3
10 000 -100 000	2

Re b The volatility (and therefore the source intensity) of the liquids is divided into three classes on the basis of vapour pressure Pv at 20°C. Gases liquefied by compression and by cooling are divided into two classes according to boiling point. Substances that occur as gases are divided into three classes on the basis of (storage) pressure.

The table below shows the numerical values for the different classes for each category of substance:

Substance category+physical parameter			Volatility class (VL)
Toxic liquid			
Pv	<	0.05 bar	1
Pv	=	0.05 – 0.3 bar	2
Pv	>	0.3 bar	3
Toxic gas, liquefied by compression			
Tb	>	265 K	3
Tb	<	265 K	4
Toxic gas, liquefied by cooling			
Tb	>	245 K	3
Tb	<	245 K	4
Toxic gas, gas under pressure			
P	<	3 bar	2
P	=	3 – 25 bar	3
P	>	25 bar	4

Pv = Pv = pressure at 20°C (bar)

Tb = boiling point (K)

The class of substance used for this Guide is determined by adding together the numerical value of the toxicity class and the volatility class for each substance.

The result then corresponds to a verbal substance classification, as is the table below:

TOX + VL	Substance class	Examples	
		toxicity	gas
⩽ 5	very low	sec. butylamine	–
6	low	bromine	vinyl chloride
7	medium	acrylonitrile	ammonia
8	high	hydrocyanic	chlorine
9	very high	methyl isocyanate	carbonyl chloride
⩾ 10	extreme	sulphur pentafluoride	arsine

By way of illustration, two examples:
Acrylonitrile is a toxid liquid
LC50-rat (4h)) = 64 ppm, i.e. TOX = 5
Pv (20° C) = 0.11 bar, i.e. VL = 2
So the SUM is = 5 + 2 = 7, or substance class 'medium'.

Chlorine is a toxic gas
In its stored form: a gas liquified by compression
LC50-rat (4h) = 180 ppm, TOX = 4
Tb = 239 K, i.e. VL = 4
So the sum is = 4 + 4 = 8, or substance class 'high'.

In this way the user can easily classify 'new' substances according to the categories of this Guide (see E).

In terms of responding to a major incident roughly 110 toxic liquids and gases have provisionally been selected as possibly relevant. Selection was based on analogue properties as described above: toxicity and volatility.

Enclosure L lists the 60 or so toxic liquids, including the substance classifications determined as described above.

Enclosures M, N and O give the different classifications for the 50 or so toxic gases; there are three tables here, one for each category of substance (liquefied by compression, liquefied by cooling and gas under pressure).

2 Solids
Enclosure P gives a summary of more than 60 toxic solids (powders), mostly pesticides. Volatility is not a relevant physical consideration for toxic solids. In the immission calculations underlying the distance graphs it has been assumed for the source intensity that 10% of the released quantity of solid substance will blow about as powder.

In general only an LD value is known for the toxicity of solids. A method is given in [3] for the conversion of LD values to LC values. The same measure of exposure for the division into toxicity classes is used here as for gases and liquids: LC50-rat (4 hours).

On the basis of the recommended conversion method, the following classification is used for toxic solids, on the basis of LD50-oral:

Oral LD50 [mg/kg body weight]	Substance class toxicity
<5	7 extreme
5 – 50	6 very high
50 – 500	5 high
500 – 5000	4 medium
>5000	3 low

The list of substances in Enclosure P was compiled using this system of classification.

D Toxic combustion products

In a number of situations toxic reaction products can be produced as a result of the burning of, mostly, solids. Additionally, in the event of fire, there is always the danger of asphyxiation by smoke or lack of oxygen.

The number of substances that can be formed in a fire is so great and unpredictable that a characteristic profile has been used in this methodology. For this purpose the most dangerous representative(s) of the substances that would probably form is (are) chosen for each of the types of 'burning' substance.

The table below shows the substances used for the appraisal:

Burnt substance	Characteristic combustion product	
Fertilisers		
– containing nitrate	nitrogen dioxide	(NO_2)
– containing sulphate	sulphur dioxide	(SO_2)
Pesticides		
– dioxin formers	dioxin	(2,3,7,8 – PCDD)
– non-dioxin formers	hydrogen chloride	(HCl)
Plastics	hydrogen chloride	(HCl)

Account has been taken in the selection of the characteristic substances of characteristic raw materials, the rate of combustion and the (theoretical) amount of toxic substance that can be produced by the raw material.

Enclosure Q contains distance graphs as a function of the area of the fire for the three different categories of substance burnt; the storage area has been chosen for the former.

E Classifying toxic substances yourself

Section C describes the method by which toxic substances selected as relevant for the purposes of responding to a major incident are allocated a toxicity class. Using this method the user can also classify substances himself. What he will need is quantitative information about the toxicity (LC50 value) of the substance in question.

In some cases only an LD value (lethal dose, oral, in mg/kg body weight) will be known. This is particularly relevant for toxic liquids and solids. A method has been devised for converting this value to LC50-rat (4 hours) and this is described in [3].

A simplified version of this conversion technique has been developed for this Guide and this is shown below. But you are advised to refer to [3] for specific situations.

The class derived from this is used as follows:

☐ For a toxic liquid: add to the given number the volatility class VL (according to the table on page 27) and then read off the substance class toxicity from the table below. Use this substance class in the determination of damage.

☐ For a toxic solid: read the substance class toxicity straight off the table below. Use this substance class in the determination of damage.

LD-50 (rat) – oral [mg/kg body weight]	Substance class toxicity Liquid [-]	Solid [-]
<5	7 + VL	extreme
5 – 50	6 + VL	very high
50 – 500	5 + VL	high
500 – 5000	4 + VL	medium
>5000	3 + VL	low

Publication and production
Ministry of Home Affairs
Information Department
Fire Service Directorate
PO Box 20011
2500 EA The Hague
The Netherlands

April 1989

Province of South Holland

Fire Service Directorate
of the Ministry of Home Affairs