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Hazardous Substances Risk Assessment: a Mini-Guide for Municipalities and Industry

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Hazardous Substances Risk Assessment: a Mini-Guide for Municipalities and Industry

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Major Industrial Accidents Council of Canada
Conseil canadien des accidents industriels majeurs

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The Major Industrial Accidents Council of Canada (MIACC) is a voluntary alliance of interested parties dedicated to reducing the frequency and severity of major industrial accidents. Formed in 1987, this partnership includes the federal, provincial, and municipal governments, industry, labour, emergency response groups, public interest groups, and academia. Organizations currently represented on the MIACC Board of Directors are:

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Through cooperation, consultation, and consensus, MIACC partners develop national standards, guidelines, tools, and other instruments to prevent, prepare for, and respond to major industrial accidents involving hazardous substances. The adoption of these measures by all jurisdictions is promoted to achieve uniformity in applying prevention, preparedness and response programs in Canada. MIACC also fosters the exchange of information, knowledge and experience through workshops, meetings and conferences.

For more information on the assessment of industrial sites containing hazardous substances warranting special attention, on MIACC or on publications available through MIACC, please contact:

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OVERVIEW OF MIACC RISK ASSESSMENT PRODUCTS

A roadmap for applying the *MIACC Lists*, the *Mini-Guide*, and the *Guidelines*

The MIACC risk assessment products comprise a group of four publications dealing with hazardous substances: *Lists of Hazardous Substances*, *Risk Assessment: a Mini-Guide for Municipalities and Industry*, *Risk Assessment Guidelines for Municipalities and Industry*, and potentially computer software. These are intended to form a hierarchy of products capable of addressing risk assessment of sites at which hazardous substances are handled (produced, stored, re-processed or used, etc.) at various levels of sophistication depending on the requirements of the situation and the experience and qualifications of the user. The products are summarised below.

Lists of Hazardous Substances

The *Lists of Hazardous Substances* provide a simple method for identifying hazardous substances and ranking sites handling them. There are three lists:

List 1 is a short list of "top priority" substances commonly found in Canada both in fixed facilities and transport situations. List 1 substances in quantities larger than the listed threshold quantity, if released, have a high probability of causing fatalities off site.

List 2 is a longer list of potentially hazardous substances which, if released, could cause fatalities off site. This includes the substances of List 1, in amounts smaller than the large quantities that merit the top priority of List 1.

List 3 comprises other hazardous substances which are frequently encountered in Canada but present smaller acute risks than those of Lists 1 and 2, and are less likely to cause or be involved in a major accident. They may present environmental or long-term risks.

The Lists give the name of the substance, the usual physical state, Chemical Abstracts Service (CAS) numbers, product identification number/United Nations number (PIN/UN), transport of dangerous goods (TDG) class and division numbers, and a threshold quantity. It is recommended that a risk assessment of a site or activity be undertaken where quantities of a hazardous substance are above the threshold quantity. Priority should be given to the assessment and management of sites holding large amounts (above the threshold quantities) of substances on List 1, followed by substances in amounts above the threshold quantities of List 2, these same substances in smaller quantities, the substances of List 3, and then all remaining sites.

Risk Assessment: A Mini-Guide for Municipalities and Industry

The *Mini-Guide* provides a brief self-contained introduction to the basic concepts involved in risk assessment and some calculated results that allow initial screening assessments to be made for a limited range of simple situations. The *Mini-Guide* provides results in the form of tables of separation distances equivalent to specified risk values, calculated for a limited range of conditions. Using these results a preliminary assessment of the risk can be made without having to perform the calculations. In many cases this will be sufficient to give an indication of the acceptability of the risk associated with

industrial activities. The results in the *Mini-Guide* have been obtained by applying the methodology contained in the *Risk Assessment Guidelines* (see below). When the situation is not covered by the *Mini-Guide* reference should be made to the more comprehensive products described below.

Risk Assessment Guidelines for Municipalities and Industry

The MIACC *Risk Assessment Guidelines for Municipalities and Industry* provides procedures for evaluating the risk due to a wide range of industrial activities. As with the *Mini-Guide*, the *Guidelines* is a self-contained document providing an introduction to the relevant risk assessment concepts and outlining the procedures to obtain estimates of the risk. In the *Guidelines* the procedures provide for more detailed investigation of risk assessment problems. To apply the methodology described in the *Guidelines* the user must have information about the process being considered and must perform calculations to determine the risk.

Computer Software

A computer software product is proposed to implement the risk assessment procedure contained in the *Guidelines* described above. The methodology and results are identical to the *Guidelines*; the software simply makes the application of the MIACC risk assessment procedures more convenient.

Capabilities and Limitations

It should be noted that risk assessment can be a complicated process. However, in many situations simplified methods are sufficient. The MIACC risk assessment products described above are meant to satisfy the needs of users dealing with problems for which more comprehensive methods are not justified.

It is important to review and understand both the capabilities and limitations of each of these methods as described in the relevant product. The products are organized in a manner to provide a range of approaches with increasing sophistication. If the circumstances for which the risk assessment is to be performed lie outside the scope of these screening methods, the problem should be referred to a risk analyst for more detailed treatment. The *MIACC Lists*, *Mini-Guide* and *Guidelines* are not intended to be used for emergency response planning as such, particularly not for the calculation of evacuation distances in the event of a chemical release.

MIACC believes that if a hazardous substance is not included in either List 1 or List 2, or is present at a site in a quantity less than the threshold quantity show in List 2, it does not constitute a risk of a major industrial nature. This is not to say that in the fullness of time, a site assessment should not be undertaken.

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HAZARDOUS SUBSTANCES RISK ASSESSMENT: A MINI-GUIDE FOR MUNICIPALITIES AND INDUSTRY

1. INTRODUCTION

Many industrial and commercial activities, by the nature of their operations, present some risk to the general public in the surrounding area. In particular, growing concern has been expressed by the general public in recent years over those industrial and commercial activities that involve the production, processing, handling, storage or transportation of chemicals, as accidents involving such chemicals have occurred and been widely reported. Such activities may also present hazards to the environment.

Hazardous substances are not only associated with chemical industrial activities (i.e., the manufacture or production of chemicals) but are transported, stored temporarily in transport, used, sold, or distributed in many industrial and commercial activities. A short list of typical industrial or commercial activities in which hazardous substances may be involved in significant quantities is shown in Table 1.

The Major Industrial Accidents Council of Canada (MIACC) has published *Risk Assessment Guidelines for Municipalities and Industry*, which discusses the subject in full and recommends a methodology to be followed. While the methodology laid out in the *Guidelines* will be of great utility to those who may have to evaluate a number of hazardous facilities covering a variety of hazardous substances, many smaller industrial or commercial activities, or smaller municipalities having only one or two such sites within their boundaries, may well be able to resolve their concerns or responsibilities by reference to this *Mini-Guide*, which provides a ready reference for more than 200 common industrial and commercial chemicals, indicating a minimum separation distance appropriate to the substance in question for quantities typically found in industrial or commercial sites. The methodology recommended in the *Risk Assessment Guidelines for Municipalities and Industry* has been followed in the calculation of the separation distances in this *Mini-Guide*.

Chapter 2 of this *Mini-Guide* introduces the concept of risk and Chapter 3 outlines the MIACC approach to risk assessment. Chapter 4 contains the ready-reference tables of recommended separation distances for individual hazardous substances. Chapter 5 provides an introduction to the principles of risk management.

TABLE 1

**MUNICIPAL AND INDUSTRIAL ACTIVITIES
WHERE HAZARDOUS SUBSTANCES MAY BE FOUND**

airports	oil well logging and servicing companies
barges (marine)	paper mills
chemical plants	pharmacological manufacturers
colleges	plastic manufacturers
compressed gas dealers	plating processes
compressed gas facilities	printing plants
construction sites	pipeline operators
construction yards	rail lines
curling rinks	rail sidings and yards
electrical generation facilities	refineries
explosive magazines	schools
farm supply dealers	sewage treatment facilities
fertilizer dealers	ship facilities
fertilizer manufacturers	storage facilities
food processing plants	swimming pools
food storage facilities	tank farms
gas plants	textile plants
government facilities	trucking corridors (routes)
hockey rinks	trucking terminals
hospitals	truck stops and restaurants
hotels	universities
laboratories	waste storage facilities
leather tanning facilities	waste treatment facilities
machine shops	waterfront facilities
manufacturing facilities	warehouses
marine terminals	water slides and parks
medical labs	water treatment facilities
mining operations	welding shops
non-destructive testing companies	wood preservative operations
nuclear facilities	yeast production plants

2. BASIC CONCEPTS OF RISK

2.1 Defining and Estimating Risk

Risk Assessment Guidelines for Municipalities and Industry deals with the risks arising from facilities holding substances which are considered hazardous because they are highly flammable¹, reactive, explosive², or toxic, particularly if the substances possess more than one of these qualities or if they are likely to form a hazardous cloud upon loss of containment.

Risk is commonly calculated as the product of the likelihood that an event will happen and the consequence or degree of harm that would result. There are many possible hazardous events for any facility handling hazardous substances, which depend on the quantity, the nature of storage or process vessels, piping, valving, loading and unloading operations, etc. Each possible hazardous event contributes its share to the overall risk of operating a facility, which is calculated by summing the risks of all possible events that could occur in the facility. Any activity carries some risk, but if the probability of misfortune is low, or if the harm which could result is negligible, the activity is considered safe.

The recommendations in this *Mini-Guide* are based on consideration of only the risk of immediate human fatality, not the risks of injury nor any risk to the environment.

Further, the recommendations in this *Mini-Guide* are based on consideration of *individual* fatality risk. The individual risk of fatality is the chance that, in any year, a person who lives or works near a hazardous facility might die as a result of an accident in that facility. This risk usually diminishes with increasing distance from the facility.

2.2 Risk Acceptability

Risk acceptability criteria are often based on the premise that the risk being evaluated should not make a substantial addition to the existing risk of everyday life. An increase of 1% or less in the individual risk of death, due to a specific hazardous activity, is the basis of many criteria of unacceptable or intolerable risk. Acceptable or tolerable risk criteria are a factor of 10 to 100 lower than for unacceptable risks. In an area where risk lies between unacceptable and acceptable levels, risk reduction is desirable. The reduction in risk levels is achieved by taking risk control measures (see Chapter 5).

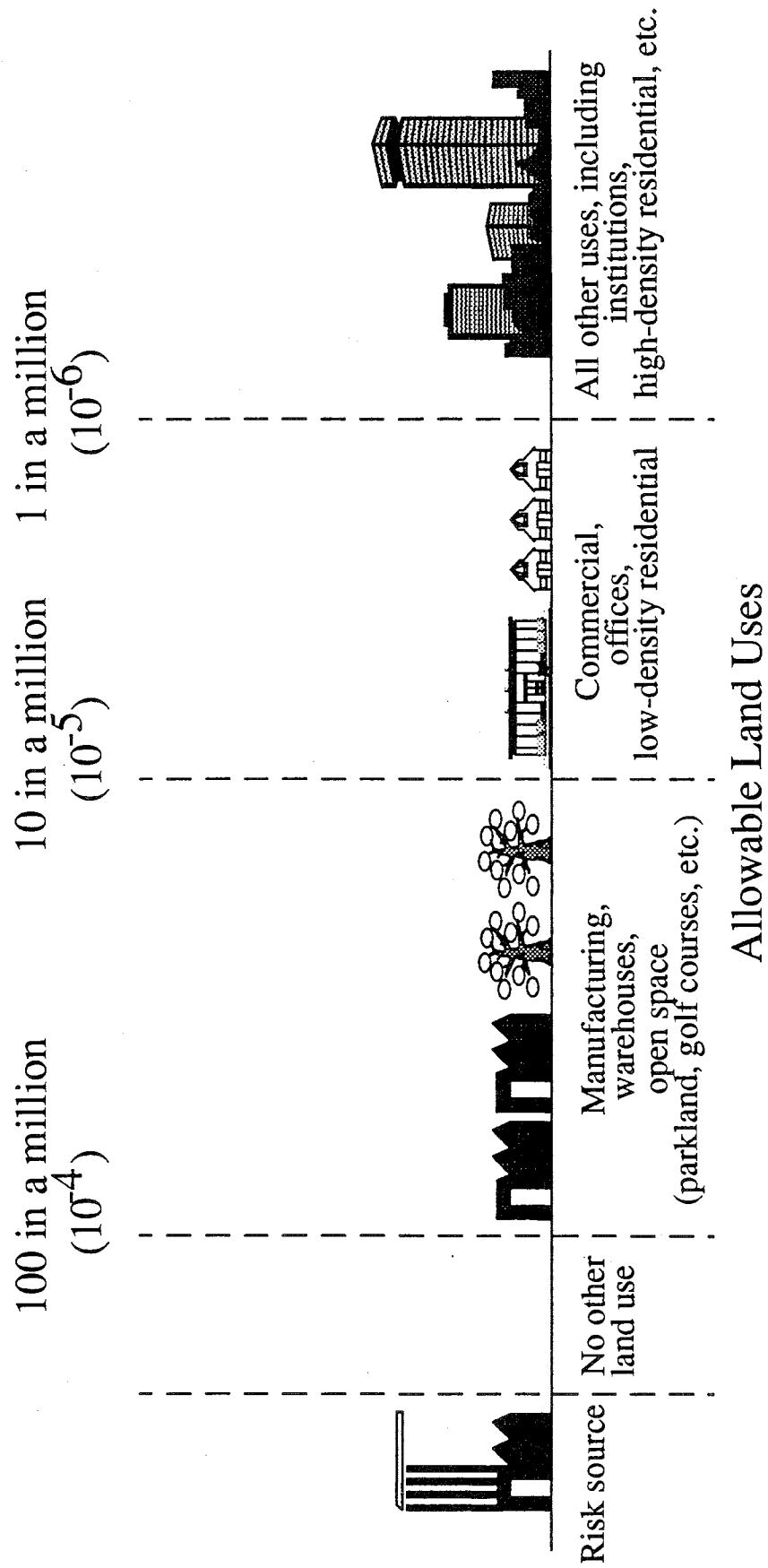
The judgement of risks means that "tolerable" or "acceptable" risk levels will vary with the benefits and costs no matter how they are calculated or by whom. In between the unacceptable risk level and

¹ The term *flammable* is used in this text to signify a substance that will ignite and burn. *Inflammable* has the same meaning.

² *Explosive materials* is not synonymous with *explosives*, which means materials or products manufactured for the express purpose of producing an explosion or pyrotechnic effect and regulated under the *Explosives Act*. *Explosive materials* in the context of the MIACC Lists excludes explosives but includes materials which may explode or cause an explosion resulting in over-compression.

Figure 2.1

**MIACC's Risk Acceptability Criteria
(Annual Individual Risk)**



the acceptable risk level is the area where risks may or may not be tolerable depending on the situation. Risk in this in-between area is generally acceptable only if all reasonably practical measures have already been taken to reduce it.

Individual risk is often expressed in terms of an annual probability of death for the exposed person. An annual probability (or chance) of death of 1 in 1,000,000 (written alternatively as 10^{-6}) is often taken as a tolerable level. An annual probability of death of 1 in 10,000 (or 10^{-4} per year) is considered unacceptable.

In Canada, MIACC developed the risk acceptability criteria presented in Figure 2.1. These criteria are reflected in terms of allowable land-uses for specified levels of individual risk. This approach implicitly provides a guideline for allowable societal risk in one simple statement. An annual individual fatality risk of 1 in 10,000 (or 10^{-4}) from the presence of a facility is considered unacceptable for a member of the general public, and the area defined by this risk contour is called the exclusion zone. A risk of less than 1 in 1,000,000 (or 10^{-6}) is considered negligible, and the use of land beyond this risk contour is not restricted by the presence of the facility. The exclusion zone and unrestricted land-use zone distances for different substances and inventory quantities are presented in the reference tables in Chapter 4.

3. RISK ASSESSMENT METHODOLOGY

3.1 The MIACC Approach

To carry out a detailed risk assessment for a specific hazardous site, one would consider the likelihood and consequences of all possible events at that site and combine the results to give overall risk contours. The MIACC *Risk Assessment Guidelines for Municipalities and Industry* demonstrates a more practical approach, providing a general risk assessment applicable to most facilities or sites holding hazardous materials. The current version of the MIACC approach rests on assumptions and approximations which disallow its use in considering some hazardous substances and some events. Work is under way to develop a revised version which will expand to include these, along with other extensions of detail. This work will require several years to complete. In the meantime, the present version is considered sufficiently accurate to be of assistance to those who face the need to assess the risks posed by fires fuelled by flammable liquids and flammable liquefied gases, by the release of toxic liquefied gases, and by the evaporation of volatile toxic liquids. The approach is not applicable to toxic solids in powdered form (which could become airborne, as a toxic cloud), explosive materials, or flammable compressed gases. It is also not directly applicable to toxic compressed gases, but the separation distances calculated for the same toxic gas *liquefied* by compression would provide more than adequate separation.

The *Risk Assessment Guidelines for Municipalities and Industry* can be used to assess the risk presented by any quantity of a hazardous substance; this *Mini-Guide* provides, for ready reference, tabulations of the results of such assessments for selected quantities which may be found at typical individual sites.

These are the quantities in individual readily isolatable systems such as storage tanks separated from each other, storage tanks isolated by shut-off valves, or process system units separated by shut-off valves. A bulk transport vehicle connected to a storage tank to transfer a product is an isolatable unit, because there is a shut-off valve in the connection. In this text, *container* is used in place of the phrase *single isolatable system*, for convenience; *quantity* and *container* are taken to represent this same isolatable unit.

For the current MIACC approach, hazardous substances are first assembled into groups with similar characteristics; the subsequent results can be applied to the consideration of any member of a given group. To calculate the risk posed by any quantity of a substance, the likelihood and consequences of only two possible events are taken to represent the whole range of events. The two accidents considered are:

- the release of 10% of the quantity of the substance in 30 minutes, and
- the release of the total quantity in 30 minutes.

The risks posed by the possible accidents can be combined, to calculate the overall risk in terms of the individual annual risk of fatality created at any distance away from the site. By extension, it is possible to calculate the distance at which the risk has a specific value, to define contours at which the risk meets specified criteria.

Using the MIACC approach it is possible to calculate the distance at which the risk meets any chosen criterion of acceptability. The reference tables in this *Mini-Guide* give two distances from the site of possible accidents: that at which the annual individual risk of fatality is 1 in 10,000 (or the annual risk is 10^{-4}) and that at which it is 1 in 1,000,000 (or, the annual risk is 10^{-6}). Where the recommended minimum separation distance is or can be met, a reasonable level of public safety can be considered to exist from the point of view of conventional land use planning requirements. If the site holds a quantity of substance different from any listed in this *Mini-Guide* and it is not obvious whether the appropriate separation exists, it is recommended that the user turn to the *Guidelines* to calculate the separation distance for the exact quantity in question. The separation distances given in the *Mini-Guide* have been calculated on consideration of only the simple case of a single container (i.e. a single isolatable system) of only one substance, while the *Guidelines* should be consulted for more complex calculations.

The *Mini-Guide*, however, can be used to calculate an approximate but acceptable value of the appropriate separation distance from a site with several containers, if one of these proves to pose the predominating risk. The separation distance appropriate to each single container should be determined in the usual way, whether the several containers hold the same substance or several; if any one of these distances is more than twice as great as each and every one of the others, that greatest distance can be taken as the separation distance for the site as a whole.

If the recommended separation distance cannot be met around a site, the user is urged to engage risk analysts to undertake a full risk assessment of the facility. A full risk assessment will consider mitigating factors or conditions which are not accounted for in the present approach, and smaller recommended separation distances *may* result.

Between the contours of fatality risk of 10^{-4} and of 10^{-6} per year lies the restricted land use zone. Here, users for whom a higher risk is tolerable may be located, or the land may be dedicated to infrequent or discontinuous use, such as parklands, which would in effect lower the likelihood of exposure (see Figure 2.1). Readers are referred to the MIACC document *Risk-Based Land Use Planning*, produced by Working Group 5. If, on an assessment of the risk posed by an existing site, current land uses are found to be inappropriate, risk control measures can be developed and applied.

3.2 Limitations of the Approach

There are a number of limitations to this approach (or to any risk estimation approach). Nevertheless, the results can be used as a guide and screening tool when making decisions regarding land use. The user of this *Mini-Guide* or the *Guidelines* should be aware of these limitations, and that the actual situations being assessed may be significantly different from those considered in the preparation of these guides.

The MIACC risk assessment methodology deals with the likelihood and consequences of accidents or failures only in a facility or its related operations. The probability of an earthquake, flood, storm, or brush fire which could damage the facility, and lead to an accident or destruction, is often specific to a location, and cannot be included in this calculation, which is intended for general use.

The models used may engender under- or over-estimates of the safe separation distances, and further work will be carried on by MIACC to resolve the uncertainty. Nevertheless, decisions have to be made at the present time and with the present state of knowledge. The distances shown in the next chapter are considered to be the best judgement possible at this time. The assumptions and approximations of the particular models used here are outlined in the Appendix.

4. CLASSIFICATION OF HAZARDOUS SUBSTANCES AND THE RECOMMENDED RISK-BASED SEPARATION DISTANCES

The MIACC *Risk Assessment Guidelines for Municipalities and Industry* assigns substances to groups, outlined in Table 2 of this *Mini-Guide*, depending on their hazardous characteristics. The group of liquefied flammable gases is further divided into two subgroups, of substances having higher or lower boiling points. The groups of toxic substances are also subdivided, according to a hazard rating combining measures of toxicity and volatility. Compressed flammable gases which are not liquefied, powdered toxic solids, or explosive materials are not covered.

Hazardous substances from the *MIACC Lists of Hazardous Substances* and *Priority Hazardous Substances* (*MIACC List 1* and *List 2*) to which the present method of assessment is applicable are given together in Table 3 of this *Mini-Guide*. This Table includes the group and subgroup designation of each substance. Table 4 repeats this list of hazardous substances along with their alternative names, all in alphabetical order.

TABLE 2
MIACC GROUP CHARACTERISTICS

GROUP	GROUP CHARACTERISTICS
A	Flammable liquids (pool fire hazard)
B	Flammable liquids (flash fire hazard)
C	Liquefied flammable gases (flash fire hazard)
D	Toxic gases liquefied by compression (toxic cloud hazard)
E	Toxic gases liquefied by cooling (toxic cloud hazard)
F	Toxic liquids (toxic cloud hazard due to evaporation)

The *List of Environmentally Hazardous Substances (MIACC List 3)* is not included in the *Mini-Guide*; substances in *List 3*, while presenting hazards, are not appropriate for consideration in risk assessments of the nature presented in the *Mini-Guide* or the *Guidelines*. These substances, while they may cause on- and off-site injuries, are very much less likely to be an acute threat to the public. Most present a threat to the environment through aquatic toxicity and impact on aquatic ecosystem food chains; some may present other hazards such as biological or radiation hazards.

The *MIACC Lists* include a threshold quantity for each substance. If the quantity of a substance held at the facility or site under consideration is below this threshold, the risk from an accident is tolerable and a further risk assessment is not immediately necessary. This does not mean the site presents no risk at all, but rather that under normal circumstances the assessment of such sites can be postponed, in the absence of other considerations such as a history of spills or accidents at the site.

The lettered tables which follow this chapter, one for each Group, show suggested separation distances for common quantities of hazardous substances which may be found in various facilities, based upon the MIACC risk acceptability criteria. The risk measure used in these criteria is the increased individual risk of fatality (in any one year) due to the given type of hazard for an individual exposed to the risk source. The "exclusion zone" is defined as the zone **within** an individual risk contour of 10^{-4} , and the "unrestricted land use zone" is defined as the zone **beyond** an individual risk contour of 10^{-6} . Note that the quantities are given at the heads of these tables in either tonnes or cubic metres, whichever is more appropriate to the usual circumstances.

Some substances present more than one hazard; for instance, some substances could form clouds which are both toxic and flammable. For such substances, a reference is given in Table 3 to every lettered table of separation distances that could apply, so that the user will be aware of the hazards possible. The user should select the greatest of the separation distances read from the several tables.

Toxic gases liquefied by compression or by cooling present different levels of hazard and so are assigned to different groups (Groups D and E); reference to both groups is given in Table 3, and the user should select the one applicable to the container under consideration. Toxic gases stored as compressed gases are not specifically covered by the *Guidelines*, but the separation distances given in Table D (appropriate for the same gases compressed to liquefaction) could be applied, as they would be larger than necessary.

TABLE 3

LIST OF HAZARDOUS SUBSTANCES

Background

The *MIACC Lists of Hazardous Substances* were developed by members of MIACC who had expertise in the areas of toxicology, health and safety, emergency response, and enforcement, as the basis for identifying and ranking sites at which handling of hazardous substances takes place from the perspective of public safety risks.

The process involved review of existing lists of hazardous substances. These included the following Canadian lists: *Transportation of Dangerous Goods Regulations, Schedule XII*, Environment Canada's Lists of Spilled Chemicals, The Montreal Urban Community's List of Dangerous Substances, the substances listed in the regulations promulgated under the *Pest Control Products Act*, and the Workplace Hazardous Materials Information Systems Lists. Other lists reviewed included the U.S. Environmental Protection Agency *Superfund Amendments and Re-authorization Act, Extremely Hazardous Substance List* and the *Toxic Substances Control Act (TSCA) Inventory*, the U.S. Occupational Safety and Health (OSHA 1910.119) List, the International Labour Office *Lists of Dangerous Substances*, Appendices A and B of the Organization Resources Counsellors *Recommendations for Process Hazards Management of Substances with Catastrophic Potential*, the *List of Substances* from the Netherlands Organization of Applied Scientific Research (TNO) *Guide to Hazardous Industrial Activities*, and the ECE *Seveso Directive Annex III*. Criteria for inclusion in the *MIACC Lists* were developed considering those used in the creation of the above lists along with other Canadian experience. Hazardous substances not currently produced or allowed to be imported into Canada were eliminated from the *MIACC Lists*.

The *MIACC Lists* are intended to be reviewed on a regular basis and changes will be made to keep them current with commercial and industrial developments. Any comments concerning the *MIACC Lists of Hazardous Substances* should be made to the MIACC Office.

This *Mini-Guide List* includes only those substances from *MIACC List 1 (Priority Hazardous Substances)* and *MIACC List 2 (Hazardous Substances)* to which the method of the *Risk Assessment Guidelines* is applicable.

Legend to the Mini-Guide List

- Column 1 The name of the hazardous substance.
- UPPER CASE**
The names of priority substances found commonly in Canada in large quantities are printed in ALL CAPITAL letters . Priority is to be given to sites holding these substances in large quantities as they have the potential to be involved in acute catastrophic events. These are the substances on *MIACC List 1, Priority Hazardous Substances*.
- Normal type**
The names of hazardous substances which have the potential to cause acute events but it are not priority substances. These are from *MIACC List 2, Hazardous Substances*.
- Column 2 The usual physical state(s) of the substance. The phrase *in situ* appears in Column 2, with the physical state, to indicate the substance is usually found as an intermediate product in a chemical system, not as a commodity.
- Column 3 The Chemical Abstract Service number assigned to the substance by the American Chemical Society. This numbering system is based on chemical structure.
- Column 4 The product identification number (PIN) for the substance, assigned by the United Nations or used only in North America. Any PIN beginning with 0 identifies an explosive, and any PIN beginning with 9 is a North American number; all others are UN numbers.
- Column 5 The *Transportation of Dangerous Goods Regulations* class and division for each substance. The phrase *in situ* appears in Column 5, with the TDG Class, to indicate the substance is *prohibited for transport in bulk*, or *completely prohibited for transport*, and so is probably made at the industrial site where it is used, or is used in small quantities. Some substances fall into more than one TDG class and division. When this is the case, the primary class appears first in Column 5. The TDG classes are:

Class and Division	Description
Class 1, Divisions 1 to 6 (1.1-1.6)	Explosives
Class 2, Division 1 (2.1)	Flammable Gases
Class 2, Division 2 (2.2)	Other Gases
Class 2, Division 3 (2.3)	Toxic Gases

Class and Division	Description
Class 3 (3)	Flammable Liquids
Class 4, Division 1 (4.1)	Flammable Solids
Class 4, Division 2 (4.2)	Spontaneously Combustible Materials
Class 4, Division 3 (4.3)	Water-reactive Materials
Class 5, Division 1 (5.1)	Oxidizing Substances
Class 5, Division 2 (5.2)	Organic Peroxides
Class 6, Division 1 (6.1)	Poisonous Substances
Class 6, Division 2 (6.2)	Infectious Substances
Class 7 (7)	Radioactive Materials
Class 8 (8)	Corrosive Materials
Class 9, Division 1 (9.1)	Miscellaneous Dangerous Goods
Class 9, Division 2 (9.2)	Environmentally Hazardous Substances

Column 6

The recommended threshold quantity. If this quantity is met or exceeded at a site, an assessment of risk should be carried out. Priority should be given to the assessment of sites which hold large quantities of *MIACC List 1* hazardous substances; the thresholds defining these larger quantities are given in **bold print**. The threshold quantity is given in tonnes (1 000 kg).

Column 7

The reference tables of separation distances. These tables are:

Table	Substances
A	Flammable liquids (pool fire hazard)
B	Flammable liquids (flash fire hazard)
C	Liquefied flammable gases
D	Toxic gases liquefied by compression
E	Toxic gases liquefied by cooling
F	Toxic liquids

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
Carbonyl sulphide	Comp-Gas <i>in situ</i>	463-58-1	2204	2.3, 2.1 <i>in situ</i>	0.1	D/E high, C low bp
CHLORINE	Liquefied Gas	7782-50-5	1017	2.3, 5.1	10 1	D/E high
Chlorine dioxide	Gas <i>in situ</i>			<i>in situ</i>	1	F very high
Chloropicrin	Liquid	76-06-2	1580, 1583	6.1 6.1	0.1	F low
Chlorosulphonic acid	Liquid	7790-94-5	1754	8	1	F med
Cobalt carbonyl	Solid <i>in situ</i>	10210-68-1			0.1	F very high
Cyanogen	Liquefied Gas	460-19-5	1026	2.3, 2.1 <i>in situ</i>	0.5	D very high /E high
Cyanogen bromide	Solid	506-68-3	1889	6.1, 8 <i>in situ</i>	1	F med
CYCLOHEXANE	Liquid	110-82-7	1145	3, 9.2	200 50	A
Cyclohexane, methyl-	Liquid	108-87-2	2296	3	50	A
Cyclohexene	Liquid	110-83-8	2256	3	50	A
Cyclopentane	Liquid	287-92-3	1146	3	50	A, B
Cyclopropane	Liquefied Gas	75-19-4	1027	2.1 <i>in situ</i>	10	C low bp, A
Diborane (6)	Comp. Gas	19287-45-7	1911	2.3, 2.1 <i>in situ</i>	0.1	D/E very high, C low bp
Dichlorodimethyl ether	Liquid	542-88-1	2249	6.1 <i>in situ</i>	1	F high
Diethylamine	Liquid	109-89-7	1154	3, 9.2	10	A
Diethyl ether	Liquid	60-29-7	1155	3	50	A, B
Diisobutylene	Liquid	25167-70-8	2050	3	50	A
Diisopropylether	Liquid	108-20-3	1159	3	50	A

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
Dimethylamine, anhydrous	Liquefied Gas	124-40-3	1032	2.1, 8	10	D/E med, C high bp, A
Dimethylamine, solutions	Liquid	124-40-3	1160	3, 9.2	50	B, F low
Dimethyldichlorosilane	Liquid	75-78-5	1162	3, 8	0.1	F med, A
Dimethyl ether	Liquefied Gas	115-10-6	1033	2.1	10	D very high /E high, A
Dimethyl sulphide	Liquid	75-18-3	1164	3	10	F low, A
1,4-Dioxane	Liquid	123-91-1	1165	3	10	A
Ethane & Ethane mixtures	Comp. Gas Ref. Liq.	74-84-0	1035 1961	2.1 2.1	10	C low bp, A
Ethyl acetate	Liquid	141-78-6	1173	3	1000	A
Ethyl acrylate	Liquid	140-88-5	1917	3	1	A
ETHYLBENZENE	Liquid	100-41-4	1175	3, 9.2	200 50	A
Ethyl bromide	Liquid	74-96-4	1891	6.1	10	A, B, F low
Ethyl chloride	Liquefied Gas	75-00-3	1037	2.1	10	C high bp, A
Ethyl chloroformate	Liquid	541-41-3	1182	6.1, 3	1	F med, A
Ethyl formate	Liquid	109-94-4	1190	3	50	A
Ethyl isocyanate	Liquid	109-90-0	2481	3, 6.1	1	F low, A
Ethyl mercaptan	Liquid	75-08-1	2363	3	1	F low, A
Ethyl methyl ketone	Liquid	78-93-3	1193	3	100	A
Ethylamine or Ethylamine solutions	Comp. Gas; Liquid	75-04-7	1036 2270	2.1, 8 3, 9.2	10	D/E low
ETHYLENE	Ref. liquid Gas Under Pressure	74-85-1	1038 1962	2.1	100 10	C low bp, A
Ethylene chlorohydrin	Liquid	107-07-3	1135	6.1	1	F low

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
Ethylene diamine	Liquid	107-15-3	1604	8, 3, 9.2	10	A, F med
Ethylene dibromide	Liquid	106-93-4	1605	6.1, 9.2	1	F low
ETHYLENE DICHLORIDE	Liquid	107-06-2	1184	3, 6.1, 9.2	200 50	A, F low
ETHYLENE OXIDE	Liquid: Gas Under Pressure	75-21-8	1040	2.1	50 10	D/E med, A
FLUORINE	Gas	7782-41-4	1045	2.3, 5.1 <i>in situ</i>	10 1	D/E very high
Formaldehyde	Liquid	50-00-0	1198, 2209	3, 8, 9.2	1	D high /E med, A
Furan	Liquid	110-00-9	2389	3	50	A
Furfural	Liquid	98-01-1	1199	3, 9.2	10	A
GASOLINE	Liquid	86290-81-5	1203	3	200 50	A, B
Germane	Liquefied gas	7782-65-2	2192	2.3, 2.1 <i>in situ</i>	10	C low bp, D/E very high
Heptane	Liquid	142-82-5	1206	3	50	A
Hexane	Liquid	110-54-3	1208	3	50	A
Hydrazine	Liquid	302-01-2	2029, 2030	3, 6.1, 8	10	F very low A
Hydrocyanic acid	Liquefied gas/liquid	74-90-8	1051 1613	6.1, 9.2	0.5	F high
Hydrogen	Comp. or liquefied gas	1333-74-0	1049 1966	2.1	1	C low bp
Hydrogen bromide	Liquefied gas/liquid	10035-10-6	1048 1788	2.3, 8 <i>in situ</i>	1	D/E high
HYDROGEN CHLORIDE/ACID	Liquefied Gas/Liquid	7647-01-0	2186 1789	2.4 8, 9.2	50 10	D/E high
HYDROGEN FLUORIDE/ACID	Liquefied Gas/Liquid	7664-39-3	1052 1790	8, 6.1 8, 6.1, 9.2	50 10	D/E med

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
Hydrogen iodide	Liquefied gas/liquid	10034-85-2	2197 1787	2.3, 8 <i>in situ</i>	1	D/E high
Hydrogen peroxide	Liquid	7722-84-1	2984, 2014 2015	5.1, 8	10	
	Hydrogen peroxide is an oxidizing substance and will accelerate burning when involved in a fire; it may ignite combustibles.					
Hydrogen selenide	Liquefied gas	7783-07-5	2202	2.3, 2.1 <i>in situ</i>	0.5	D/E extreme, C low bp
HYDROGEN SULPHIDE	Gas/Liquid Under Pressure	7783-06-4	1053	2.3, 2.1	10 1	D/E high, C low bp
Iron pentacarbonyl	Liquid <i>in situ</i>	13463-40-6	1994	6.1 <i>in situ</i>	1	F low
Isoamyl alcohol	Liquid	123-51-3	1105		50	A
Isobutylamine	Liquid	78-81-9	1214	3, 9.2	10	F med, A
Isobutylene	Liquid	115-11-7	1055	2.1	10	C high bp, A
Isobutyronitrile	Liquid	78-82-0	2284	3, 6.1	10	A
Isofluorophate	Liquid	55-91-4	----	6.1, 9.2	0.1	F high
Isophorone diisocyanate	Liquid	4098-71-9	2290	6.1	1	F low
Isoprene	Liquid	78-79-5	1218	3, 9.2	50	A, B
Ketene	Liquefied Gas <i>in situ</i>	463-51-4		2.3	0.1	D/E very high
Liquefied natural gases	Liquefied Gas	8006-14-2		2.1	10	C low bp, A
LIQUEFIED PETROLEUM GASES	Liquefied Gas	68476-85-7	1075	2.1	100 10	C low bp, A
Manganese trichlorocarbonyl	Liquid <i>in situ</i>	12108-13-3	1649	6.1, 3	1	F very high
MERCURY	Liquid	7439-97-6	2809	8 <i>in situ</i>	100 1	F med
Methacrylaldehyde	Liquid	78-85-3	2396	3, 6.1	1	F med, A

<i>Col 1</i>	<i>Col 2</i>	<i>Col 3</i>	<i>Col 4</i>	<i>Col 5</i>	<i>Col 6</i>	<i>Col 7</i>
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
Methacryloyloxyethyl isocyanate	Liquid	30674-80-7	2478	3, 6.1	1	F med, A
METHANE	Liquefied Gas; Ref. Liquid	74-82-8	1971 1972	2.1	100 10	C low bp, A
Methanol	Liquid	67-56-1	1230	3, 6.1	50	A
Methyl acetate	Liquid	79-20-9	1231	3	1000	A
Methyl acetylene and Propadiene mixtures	Liquefied Gas	74-99-7	1060	2.1	10	C low bp, A
Methyl acrylate	Liquid	96-33-3	1919	3	1	A
Methyl bromide	Liquefied Gas	74-83-9	1062	2.3	0.5	D/E high
Methyl chloride	Liquefied Gas	74-87-3	1063	2.1	1	D high /E med
Methyl chloromethyl ether	Liquid	107-30-2	1239	6.1, 3	1	F med, A
Methyl formate	Liquid	107-31-3	1243	3	50	A, B
Methyl iodide	Liquid	74-88-4	2644	6.1	1	F med
Methyl isobutyl ketone	Liquid	108-10-1	1245	3	50	A
Methyl isothiocyanate	Solid or Liquid	556-61-1	2477	3, 6.1	1	F med, A
Methyl magnesium bromide in ethyl ether	Liquid Solution <i>in situ</i>	75-16-1	1928	4.3, 3	10	A, B
Methyl mercaptan	Liquefied Gas	74-93-1	1064	2.3, 2.1	1	F low, C high bp
Methyl methacrylate	Liquid	80-62-6	1247	3, 9.2	1	A
Methyl vinyl ketone	Liquid	78-94-4	1251	3	50	A
NAPHTHA, PETROLEUM NAPHTHA or NAPHTHA SOLVENT	Liquid	8030-30-6	2553 1256 2553	3	200 50	A, B
Nickel carbonyl	Liquid <i>in situ</i>	13463-39-3	1259	6.1, 3 <i>in situ</i>	0.1	F very high, A

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
NITRIC ACID, FUMING or RED FUMING	Liquid	7697-37-2	2031, 2032	8, 9.2 8, 5.1, 6.1, 9.2	10 1	F high
Nitric oxide	Comp-Gas	10102-43-9	1660	2.3, 5.1, 8 <i>in situ</i>	0.5	D/E high
Nitrogen dioxide	Liquefied Gas	10102-44-0	1067	2.3, 5.1	0.5	F high
Nitrosylsulphuric acid	Liquid	7782-78-7	2308	8	1	F med
Octanes	Liquid	111-65-9	1262	3	50	A
Osmium tetroxide	Solid	20816-12-0	2471	6.1 <i>in situ</i>	10	F low
Oxygen	Liquefied Gas, Ref. Liquid	7782-44-7	1072 1073	2.2, 5.1	10	
	Oxygen does not burn, but supports the combustion of other substances, and may ignite combustibles.					
Pentane and pentane mixtures	Liquid	109-66-0	1265	3	50	A, B
Perchloryl fluoride	Gas <i>in situ</i>	7616-94-6	3083	2.3, 5.1 <i>in situ</i>	0.1	D med /E low
Phenol	Solid, Molten or Liquid	108-95-2	1671 2312 2821	6.1, 9.2	10	A
Phosgene	Liquid; Liquefied Gas <i>in situ</i>	75-44-5	1076	2.3, 8	0.01	D very high
Phosphine	Comp. Gas	7803-51-2	2199	2.3, 2.1 <i>in situ</i>	0.5	D/E very high, C low bp
Phosphorus, white or yellow, dry or in solution; white molten; amorphous or amorphous red.	Solid or Liquid, Molten, Solid	7723-14-0	1381 2447 1338	4.2, 6.1, 9.2 4.2, 6.1, 9.2 4.1, 9.2	1	A
Phosphorus oxychloride	Liquid	10025-87-3	1810	8, 9.2	0.1	F low
Phosphorus trichloride	Liquid	7719-12-2	1809	8, 9.2	0.1	F low

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
Propadiene	Liquefied Gas	463-49-0	2200	2.1 <i>in situ</i>	10	C low bp, A
PROPANE, and PROPANE MIXTURES	Liquefied Gas	74-98-6	1075 1978	2.1	100 10	C low bp, A
Propane, 2-methyl-	Liquefied Gas	75-28-5	1969	2.1	10	C low bp, A
Propionaldehyde	Liquid	123-38-6	1275	3	10	A
Propionitrile	Liquid	107-12-0	2404	3, 6.1	1	F high, A
n-Propylamine	Liquid	107-10-8	1277	3	10	F very low A
PROPYLENE OXIDE	Liquid	75-56-9	1280	3.1, 9.2	50 1	A, B
Pyridine	Liquid	110-86-1	1282	3, 6.1	10	A
Silicon tetrafluoride	Comp-Gas	7783-61-1	1859	2.3, 8 <i>in situ</i>	0.5	D/E high
SODIUM CHLORATE	Solid; Liquid	7775-09-9	1495, 2428	5.1	200 10	
Sodium chlorate is an oxidizing substance and will accelerate burning when involved in a fire; it may ignite combustibles.						
Stibine	Comp-Gas	7803-52-3	2676	2.3, 2.1 <i>in situ</i>	0.1	D/E very high, C high bp
Styrene monomer	Liquid	100-42-5	2055	3, 9.2	50	A
Sulphur dichloride	Liquid	10545-99-0	1828	8	1	F high
SULPHUR DIOXIDE	Liquefied Gas	7446-09-5	1079	2.3	100 0.5	D high /E med
Sulphur tetrafluoride	Comp-Gas	7783-60-0	2418	2.3 <i>in situ</i>	0.5	D/E very high
Sulphur trioxide	Solid	7446-11-9	1829	8	1	F high
SULPHURIC ACID, FUMING	Liquid	8014-95-7	1831	8, 6.1, 9.2	10 1	F med
Sulphuryl chloride	Liquid	7791-25-5	1834	8	1	F low
TETRAETHYL LEAD	Liquid	78-00-2	1649	6.1, 3	1 1	F low

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
Substance	Usual State	CAS Number	PIN/UN Number	TDG Class & Div.	Threshold Quantity tonnes	Table
Tetrafluoroethylene	Comp-Gas	116-14-3	1081	2.1 <i>in situ</i>	1	C high bp
Tetramethyl lead	Liquid	75-74-1	1649	6.1, 3	50 1	F low
Thionyl chloride	Liquid	7719-09-7	1836	8	1	F med
Thiophosgene	Liquid	463-71-8	2474	6.1	1	F high
Titanium tetrachloride	Liquid	7550-45-0	1838	8	1	F high
TOLUENE	Liquid	108-88-3	1294	3, 9.2	100 50	A
Toluene-2,4-diisocyanate	Liquid	584-84-9	2078	6.1	1	F low
2, 4 - Toluylenediamine	Solid	95-80-7	1709	6.1	50	F med
Triethylamine	Liquid	121-44-8	1296	3, 9.2	10	A
Trimethylamine	Liquefied Gas	75-50-3	1083	2.1, 8	10	D/E med
Trimethylchlorosilane	Liquid	75-77-4	1298	3, 8	10	F very low A
Tungsten hexafluoride	Liquid	7783-82-6	2196	2.3 <i>in situ</i>	0.5	F high
Uranium hexafluoride	Solid	7783-81-5	2977, 2978	7, 8 7, 8	1	F high
Vinyl acetate	Liquid	108-05-4	1301	3, 9.2	50	A
VINYL CHLORIDE	Liquefied Gas	75-01-4	1086	2.1	200 10	C low bp, A, D med /E low
Vinyl methyl ether	Liquefied Gas	107-25-5	1087	2.1	50	C high bp
Vinylidene chloride	Liquid	75-35-4	1303	3, 9.2	10	F low, A
XYLENE	Liquid	1330-20-7	1307	3, 9.2	200 50	A

TABLE 4

ALPHABETICAL LIST
OF HAZARDOUS SUBSTANCES

1,1'-Biphenyl	3-Chloropropene, see Allyl chloride
1,1'-Oxybis-ethane, see Diethyl ether	ACETALDEHYDE
1,1-Dichloro-ethylene, see Vinylidene chloride	Acetaldehyde, chloro- Acetanhydride, see Acetic anhydride
1,3-Butadiene	Acetic aldehyde, see ACETALDEHYDE
1,4-Dioxane	Acetic anhydride
1-Aminoethane, see Ethylamine	Acetic chloride, see Acetyl chloride
1-Chloro-butane, see Butyl chloride	Acetone
1-Methyl propylamine, see sec-Butylamine	Acetonitrile
2,4-Toluylenediamine	Acetoxyethane, see Ethyl acetate
2,4,4-Trimethylpentene, see Diisobutylene	Acetyl chloride
2-Amino-2-methylpropane, see tert-Butylamine	Acetyl chloride, chloro- Acetyl chloride, dichloro- Acetyl chloride, trichloro- ACETYLENE
2-Aminobutane, see sec-Butylamine	Acrolein
2-Butanone, see Methyl ethyl ketone	Acryladlehyde, see Acrolein
2-Butenal	Aethylis chloridum, see Ethyl chloride
2-Chloroethanol, see Ethylene chlorohydrin	Alcide, see Chlorine dioxide
2-Isocyanatoethyl, see Methacryloyloxyethyl isocyanate	Allene, see Propadiene
2-Isopropoxypropane, see Diisopropyl ether	Allyl alcohol
2-Methyl-1,3-butadiene, see Isoprene	Allyl bromide
2-Methyl-2-propenoic acid methyl ester, see Methyl methacrylate	Allyl chloride
2-Methylbutadiene, see Isoprene	Allylamine
2-Propen-1-amine, see Allylamine	Allylene, see Methyl acetylene
3-Aminopropene, see Allylamine	alpha,alpha-Dichloroacetyl chloride, see Acetyl chloride, dichloro- alpha-Chloro-toluene, see Benzyl chloride
3-Bromo-propene, see Allyl bromide	AMMONIA
3-Butanone, see Methyl ethyl ketone	Ammonium hydroxide solutions, see Ammonia
	Anaesthesia ether, see Diethyl ether
	Anthium dioxide, see Chlorine dioxide

- Antimony fluoride,
 see Antimony pentafluoride
- Antimony hydride,
 see Stibine
- Antimony pentafluoride
- Antimony trihydride,
 see Stibine
- Arsenic butter,
 see Arsenic trichloride
- Arsenic chloride,
 see Arsenic trichloride
- Arsenic hydride,
 see ARSINE
- Arsenic trichloride
- ARSINE
- Atlacide,
 see SODIUM CHLORATE
- Azabenzene,
 see Pyridine
- Azine, see Pyridine
- BENZENE
- Benzeneacetonitrile,
 see Benzyl cyanide
- Benzenetetrahydride,
 see cyclohexene
- Benzenol,
 see Phenol
- Benzine,
 see NAPHTHA
- Benzol, see BENZENE
- Benzyl chloride
- Benzyl cyanide
- Bertholite,
 see CHLORINE
- beta-Methylacrolein,
 see 2-Butenal
- Bimethyl,
 see Ethane
- Biphenyl,
 see 1,1'-Biphenyl
- Bisulphite,
 see SULPHUR DIOXIDE
- Boroethane,
 see Diborane (6)
- Boron chloride,
 see Boron trichloride
- Boron fluoride,
 see Boron trifluoride
- Boron hydride,
 see Diborane (6)
- Boron trichloride
- Boron trifluoride
- Brocide,
 see ETHYLENE DICHLORIDE
- Bromallylene,
 see Allyl bromide
- Bromic Ether,
 see Ethyl bromide
- BROMINE
- Bromine cyanide,
 see Cyanogen bromide
- Bromoethane,
 see Ethyl bromide
- Bromomethane,
 see Methyl bromide
- Butadiene,
 see 1,3-Butadiene
- Butafume,
 see sec-Butylamine
- Butal, see Butyraldehyde
- Butanal,
 see Butyraldehyde
- BUTANE AND BUTANE MIXTURES
- Butanol
- Butanone,
 see Methyl ethyl ketone
- Butene
- Butenone,
 see Methyl vinyl ketone
- Butyl alcohol,
 see Butanol
- Butyl chloride
- Butylene,
 see Butene
- Butyraldehyde
- Calcium carbide
- Carbinol,
 see Methanol
- Carbolic acid,
 see Phenol
- Carbon chlorosulphide,
 see Thiophosgene
- Carbon disulphide
- Carbon monoxide
- Carbon nitride,
 see Cyanogen
- Carbon oxychloride,
 see Phosgene

- Carbonyl chloride,
see Phosgene
- Carbonyl sulphide
- Chlorate of soda,
see SODIUM CHLORATE
- CHLORINE
- Chlorine dioxide
- Chloro(chloromethoxy)methane,
see Dichlorodimethyl ether
- Chloroacetaldehyde,
see Acetaldehyde, chloro-
- Chloroacetic acid chloride,
see Acetyl chloride, chloro-
- Chloroallylene,
see Allyl chloride
- Chloroethylene,
see VINYL CHLORIDE
- Chloroformyl chloride,
see Phosgene
- Chloromethane,
see Methyl chloride
- Chloromethylmethylether,
see Methyl chloromethyl ether
- Chlorophenylmethane,
see Benzyl chloride
- Chloropicrin
- Chlorosulphonic acid
- Chlorotrimethylsilane,
see Trimethylchlorosilane
- Chloryl anaesthetic,
see Ethyl chloride
- Cinnamenol,
see Styrene
- Coal Tar naphtha,
see NAPHTHA
- Cobalt carbonyl
- Cyanoethane,
see Propionitrile
- Cyanogen
- Cyanogen bromide
- Cyanogen monobromide,
see Cyanogen bromide
- Cyanomethane,
see Acetonitrile
- CYCLOHEXANE
- Cyclohexane, methyl-
- Cyclohexatriene,
see BENZENE
- Cyclohexene
- Cyclopentane
- Cyclopropane
- Diaminotoluene,
see 2,4-Toluylenediamine
- Diborane (6)
- Diborane mixture,
see Diborane (6)
- Dichlorodimethyl ether
- Dichlorodimethylsilane,
see Dimethyldichlorosilane
- Dichloroethane,
see ETHYLENE DICHLORIDE
- Dichlorosulphane,
see Sulphur dichloride
- Diethyl ether
- Diethylamine
- (Diethylamino)ethane,
see Triethylamine
- Diethylene dioxide,
see 1,4-Dioxane
- Diisobutene,
see Diisobutylene
- Diisobutylene
- Diisopropoxyphosphoryl fluoride,
see Isofluorophate
- Diisopropyl ether
- Diisopropyl oxide,
see Diisopropyl ether
- Dimethyl ether
- Dimethyl sulphide
- Dimethylamine
- Dimethylbenzene,
see XYLENE
- Dimethylchloroether,
see Methyl chloromethyl ether
- Dimethyldichlorosilane
- Dimethylenemethane,
see Propadiene
- Dimethylformaldehyde,
see Acetone
- Dimethylmethane,
see PROPANE
- Dinitrogen tetroxide,
see Nitrogen dioxide
- Dioxan, see 1,4-Dioxane
- Diphenyl,
see 1,1'-Biphenyl
- Disulphuric acid,
see SULPHURIC ACID, FUMING
- Dithio-sulphocarbonic anhydride,
see Carbon disulphide

- Elayl, see ETHYLENE
Epoxypropane,
 see PROPYLENE OXIDE
Ethanal,
 see ACETALDEHYDE
Ethanamine,
 see Ethylamine
Ethane
Ethanethiol,
 see Ethyl mercaptan
Ethanoic anhydrate,
 see Acetic anhydride
Ethanol, 2-chloro-,
 see Ethylene chlorohydrin
Ethanoyl chloride,
 see Acetyl chloride
Ethene, see ETHYLENE
Ethenyl ethanoate,
 see Vinyl acetate
Ethenylbenzene,
 see Styrene
Ether, see Diethyl ether
Ethine, see ACETYLENE
Ethoxycarbonylethylene,
 see Ethyl acrylate
Ethyl acetate
Ethyl acrylate
Ethyl bromide
Ethyl chloride
Ethyl chloroformate
Ethyl ester acetic acid,
 see Ethyl acetate
Ethyl ethylene,
 see Butene
Ethyl formate
Ethyl hydride,
 see Ethane
Ethyl isocyanate
Ethyl mercaptan
Ethyl methyl ketone
Ethyl nitrile,
 see Acetonitrile
Ethyl propenoate,
 see Ethyl acrylate
Ethylaldehyde,
 see ACETALDEHYDE
Ethylamine
ETHYLBENZENE
Ethylbenzol,
 see ETHYLBENZENE
ETHYLENE
Ethylene aldehyde,
 see Acrolein
Ethylene chloride,
 see ETHYLENE DICHLORIDE
Ethylene chlorohydrin
Ethylene diamine
Ethylene dibromide
ETHYLENE DICHLORIDE
Ethylene ether acetic acid,
 see Vinyl acetate
ETHYLENE OXIDE
Ethyne, see ACETYLENE
FLUORINE
Formaldehyde
Furan
Furfural
Gas, see GASOLINE
GASOLINE
Germane
Glycol monochlorohydrin,
 see Ethylene chlorohydrin
Heptane
Hexahydrobenzene,
 see CYCLOHEXANE
Hexahydrotoluene,
 see Cyclohexane, methyl-
Hexamethylene,
 see CYCLOHEXANE
Hexanaphthene,
 see CYCLOHEXANE
Hexanaphthylene,
 see Cyclohexene
Hexane
Hexone,
 see Methyl isobutyl ketone
Hydrargyrum,
 see MERCURY
Hydrazine
Hydrochloric acid,
 see HYDROGEN CHLORIDE /ACID
Hydrocyanic acid
Hydrocyanic ether,
 see Propionitrile
Hydrofluoric acid gas,
 see HYDROGEN FLUORIDE/ACID
Hydrogen
Hydrogen arsenide,
 see ARSINE
Hydrogen bromide

- HYDROGEN CHLORIDE /ACID
HYDROGEN FLUORIDE/ACID
Hydrogen iodide
Hydrogen peroxide
Hydrogen phosphide,
 see Phosphine
Hydrogen selenide
HYDROGEN SULPHIDE
Hydrosulphuric Acid,
 see HYDROGEN SULPHIDE
Iodomethane,
 see Methyl iodide
Iron pentacarbonyl
Isoamyl alcohol
Isobutane,
 see Propane, 2-methyl-
Isobutylamine
Isobutylene
Isobutyronitrile
Isofluorophate
Isophorone diamine diisocyanate,
 see Isophorone diisocyanate
Isophorone diisocyanate
Isoprene
Isopropyl ether,
 see Diisopropyl ether
Isopropylacetone,
 see Methyl isobutyl ketone
Isothiocyanatomethane,
 see Methyl isothiocyanate
Ketene
Ketone, see Acetone
Ketones, see individual compound entries
Liquefied natural gases
LIQUEFIED PETROLEUM GASES
Manganese trichlorocarbonyl
Marsh gas,
 see METHANE
MERCURY
Metallic mercury,
 see MERCURY
Methacrylaldehyde
Methacrylic aldehyde,
 see Methacrylaldehyde
Methacryloyloxyethyl isocyanate
Methanamine, n-methyl-,
 see Dimethylamine
METHANE
Methanethiol,
 see Methyl mercaptan
Methanol
Methoxycarbonylethylene,
 see Methyl acrylate
Methoxy-ethene,
 see Vinyl methyl ether
Methyl acetate
Methyl acetylene
Methyl acrylate
Methyl alcohol,
 see Methanol
Methyl bromide
Methyl chloride
Methyl chloromethyl ether
Methyl cyanide,
 see Acetonitrile
Methyl ester acetic acid,
 see Methyl acetate
Methyl ester formic acid,
 see Methyl formate
Methyl ethanoate,
 see Methyl acetate
Methyl ether,
 see Dimethyl ether
Methyl ethyl ketone,
 see Ethyl methyl ketone
Methyl ethylene oxide,
 see PROPYLENE OXIDE
Methyl formate
Methyl hydride,
 see METHANE
Methyl iodide
Methyl isobutyl ketone
Methyl isothiocyanate
Methyl magnesium bromide
Methyl mercaptan
Methyl methacrylate
Methyl methanoate,
 see Methyl formate
Methyl mustard oil,
 see Methyl isothiocyanate
Methyl propenoate,
 see Methyl acrylate
Methyl sulphide,
 see Dimethyl sulphide
Methyl vinyl ketone
Methyl vinyl ether,
 see Vinyl methyl ether
Methylacetaldehyde,
 see Propionaldehyde

- Methylbenzene,
 see TOLUENE
 Methylbenzol,
 see TOLUENE
 Methylcyclohexane,
 see Cyclohexane, methyl-
 Methylene-acetone,
 see Methyl vinyl ketone
 Methylethylmethane,
 see BUTANE & BUTANE MIXTURES
 Methylmethane,
 see Ethane
 Methylthiomethane,
 see Dimethyl sulphide
 Methyltoluene,
 see XYLENE
 Molecular chlorine,
 see CHLORINE
 Monobromoethane,
 see Ethyl bromide
 Monobromomethane,
 see Methyl bromide
 Monochloroacetaldehyde,
 see Acetaldehyde, chloro-
 Monochlorodimethyl ether,
 see Methyl chloromethyl ether
 Monochloroethylene,
 see VINYL CHLORIDE
 Monochloromethane,
 see Methyl chloride
 Monoethylamine,
 see Ethylamine
 Monohydroxymethane,
 see Methanol
 Motor fuel antiknock mixtures,
 see Manganese trichlorocarbonyl
 NAPHTHA
 Naphtha petroleum,
 see NAPHTHA
 Natural gas,
 see Liquefied natural gases
 n-Butene,
 see Butene
 n-Butyl aldehyde,
 see Butyraldehyde
 n-Ethyl-ethanamine,
 see Diethylamine
 Nickel carbonyl
 NITRIC ACID, FUMING OR RED FUMING
 Nitric acid (non-fuming) is not included in the
 Lists
 Nitric oxide
 Nitrochloroform,
 see Chloropicrin
 Nitrogen dioxide
 Nitrogen monoxide,
 see Nitric oxide
 Nitrogen peroxide,
 see Nitrogen dioxide
 Nitrosonium bisulphate,
 see Nitrosylsulphuric acid
 Nitrosyl bisulphate,
 see Nitrosylsulphuric acid
 Nitrosylsulphuric acid
 n,n-Diethylamine,
 see Diethylamine
 n,n-Dimethyl-methanamine,
 see Trimethylamine
 n-Propylamine
 n-Propylcarbonyl chloride,
 see Butyl chloride
 Octane
 Olefiant gas,
 see ETHYLENE
 Oleum, see SULPHURIC ACID, FUMING
 Osmic acid,
 see Osmium tetroxide
 Osmium tetroxide
 Oxalic acid dinitrile,
 see Cyanogen
 Oxirane, see ETHYLENE OXIDE
 Oxygen
 p-Dioxane,
 see 1,4-Dioxane
 Pentafluoroantimony,
 see Antimony pentafluoride
 Pentamethylene,
 see Cyclopentane
 Pentane and pentane mixtures
 Perchloryl fluoride
 Perfluoroethylene,
 see Tetrafluoroethylene
 Petrol, see GASOLINE
 Petroleum benzin,
 see NAPHTHA
 Petroleum ether,
 see NAPHTHA
 Petroleum fluid,
 see GASOLINE

- Phenol
Phenyl hydrate,
 see Phenol
Phenyl hydride,
 see BENZENE
Phenylacetonitrile,
 see Benzyl cyanide
Phenylbenzene,
 see 1,1'-Biphenyl
Phenylethane,
 see Ethylbenzene
Phenylethene,
 see Styrene
Phenylmethane,
 see TOLUENE
Phosgene
Phosphine
Phosphorous chloride,
 see Phosphorus trichloride
Phosphorous oxytrichloride,
 see Phosphorus oxychloride
Phosphorus oxychloride
Phosphorus trichloride
Phosphorus trihydride,
 see Phosphine
Phosphorus, white or yellow
Propadiene
Propanal,
 see Propionaldehyde
Propane, 2-methyl-
PROPANE AND PROPANE MIXTURES
Propanone,
 see Acetone
Propene oxide,
 see PROPYLENE OXIDE
Propene,
 see Methyl acetylene
Propenyl alcohol,
 see Allyl alcohol
Propionaldehyde
Propionitrile
Propyl hydride,
 see PROPANE
Propylamine,
 see n-Propylamine
Propylcarbinol,
 see Butanol
PROPYLENE OXIDE
Propylic aldehyde,
 see Propionaldehyde
Propylmethanol,
 see Butanol
Propyne,
 see Methyl acetylene
Pyridine
Pyrrolylene,
 see 1,3-Butadiene
Quicksilver,
 see MERCURY
sec-Butylamine
Silicon fluoride,
 see Silicon tetrafluoride
Silicon tetrafluoride
SODIUM CHLORATE
Stibine
Styrene
Sulforous oxide,
 see SULPHUR DIOXIDE
Sulphan,
 see Sulphur trioxide
Sulphinyl chloride,
 see Thionyl chloride
Sulphonyl chloride,
 see Sulphuryl chloride
Sulphur chloride Oxide,
 see Thionyl chloride
Sulphur dichloride
SULPHUR DIOXIDE
Sulphur tetrafluoride
Sulphur trioxide
Sulphuretted hydrogen,
 see HYDROGEN SULPHIDE
SULPHURIC ACID, FUMING
Sulphuric acid (non-fuming) is not included in
 the Lists
Sulphuric anhydride,
 see Sulphur trioxide
Sulphuric chlorohydrin,
 see Chlorosulphonic acid
Sulphuric oxide,
 see Sulphur trioxide
Sulphuric oxychloride,
 see Sulphuryl chloride
Sulphurous anhydride,
 see SULPHUR DIOXIDE
Sulphuryl chloride
TDI, see Toluene-2,4-diisocyanate
tert-Butylamine
TETRAETHYL LEAD

Tetraethylplumbane,
see TETRAETHYL LEAD
Tetraethylplumbium,
see TETRAETHYL LEAD
Tetrafluoroethylene
Tetrafluoro-silane,
see Silicon tetrafluoride
Tetrafluorosulphurane,
see Sulphur tetrafluoride
Tetramethyl lead
Tetramethylplumbane,
see Tetramethyl lead
Thioethyl alcohol,
see Ethyl mercaptan
Thiomethanol,
see Methyl mercaptan
Thionyl chloride
Thiophosgene
Titanium chloride,
see Titanium tetrachloride
Titanium tetrachloride
TOLUENE
Toluene-2,4-diisocyanate
Toluene diamine,
see 2,4-Toluylenediamine
Trichloroacetic acid chloride,
see Acetyl chloride, trichloro-
Trichloro-borane,
see Boron trichloride
Trichloronitromethane,
see Chloropicrin
Trichlorophosphine,
see Phosphorus trichloride

Triethylamine
Trifluoro-borane,
see Boron trifluoride
Trimethylamine
Trimethylaminomethane,
see tert-Butylamine
Trimethylchlorosilane
Trimethylene,
see Cyclopropane
Tungsten fluoride,
see Tungsten hexafluoride
Tungsten hexafluoride
Uranium hexafluoride
Vinyl acetate
VINYL CHLORIDE
Vinyl methyl ketone,
see Methyl vinyl ketone
Vinyl methyl ether
Vinylcarbinol,
see Allyl alcohol
Vinylethylene,
see 1,3-Butadiene
Vinylidene chloride
Vinylidene dichloride,
see Vinylidene chloride
Wood alcohol,
see Methanol
Wood ether,
see Dimethyl ether
Xenene,
see 1,1'-Biphenyl
XYLENE

TABLE A

**Recommended risk-based separation distances for
FLAMMABLE LIQUIDS (Pool-fire hazard)**

Quantity (m ³)	1	10	100	1000	5000	10,000	25,000
Exclusion zone within	5 m	9 m	17 m	dike = 22 m	dike = 28 m	dike = 38 m	dike = 56 m
Unrestricted land use beyond	8 m	16 m	26 m				

A pool fire will be restricted by the dike which should surround a large container of flammable liquid. The separation distances given here for quantities of more than 100 m³ represent typical dike distances; a risk assessment should use the actual distance to the dike, when it becomes available.

Some of the substances that are referred to this Table also have a flash-fire potential, and so are also referred to Table B.

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TABLE B

**Recommended risk-based separation distances for
FLAMMABLE LIQUIDS (Flash-fire hazard)**

Quantity (m ³)	5000	10,000	25,000
typical dike (m)	28	38	56
Exclusion zone within	dike +30 m	dike +45 m	dike +70 m
Unrestricted land use beyond			

TABLE C

**Recommended risk-based separation distances for
LIQUEFIED FLAMMABLE GASES (Flash-fire hazard)**

Boiling point	Quantity (tonnes)	1	10	100	1000
Low	Exclusion zone within	50 m	90 m	150 m	250 m
	Unrestricted land use beyond	80 m	130 m	230 m	360 m
High	Exclusion zone within	25 m	40 m	70 m	120 m
	Unrestricted land use beyond	35 m	60 m	110 m	180 m

The frequencies of BLEVEs (Boiling Liquid Expanding Vapour Explosions) or other catastrophic releases are very low, and the additional risk from such events would not significantly increase these separation distances.

Oxygen, usually stored as a liquefied gas, is not flammable, but it greatly enhances the flammability of other substances and a release of oxygen thus can create a fire hazard.

TABLE D

**Recommended risk-based separation distances for
TOXIC GASES LIQUEFIED BY COMPRESSION (Toxic gas cloud hazard)**

Hazard Rating	Quantity (tonnes)	0.1	1	10	100	1000
Extreme	Exclusion zone within	0.4 km	1.2 km	2.8 km		
	Unrestricted land use beyond	0.8 km	2.2 km			
Very High	Exclusion zone within	200 m	0.4 km	0.7 km	1.3 km	2.5 km
	Unrestricted land use beyond	330 m	0.6 km	1.1 km	2.1 km	3.9 km
High	Exclusion zone within	100 m	170 m	0.3 km	0.5 km	0.9 km
	Unrestricted land use beyond	160 m	270 m	0.5 km	0.8 km	1.3 km
Medium	Exclusion zone within	9 m	20 m	50 m	130 m	0.3 km
	Unrestricted land use beyond	16 m	40 m	95 m	230 m	0.6 km
Low	Exclusion zone within			10 m	20 m	40 m
	Unrestricted land use beyond			17 m	30 m	60 m

TABLE E

**Recommended risk-based separation distances for
TOXIC GASES LIQUEFIED BY COOLING (Toxic gas cloud hazard)**

Hazard Rating	Quantity (m ³)	0.1	1	10	100	1000	10,000
Extreme	Exclusion zone within	1.1 km	1.9 km	2.8 km	4.3 km		
	Unrestricted land use beyond	1.6 km	2.6 km	4.0 km			
Very High	Exclusion zone within	0.3 km	0.4 km	0.7 km	1.0 km	1.6 km	2.5 km
	Unrestricted land use beyond	0.4 km	0.6 km	0.9 km	1.5 km	2.3 km	3.5 km
High	Exclusion zone within	70 m	120 m	190 m	0.3 km	0.5 km	0.8 km
	Unrestricted land use beyond	110 m	170 m	270 m	0.5 km	0.7 km	1.1 km
Medium	Exclusion zone within	30 m	40 m	70 m	110 m	170 m	260 m
	Unrestricted land use beyond	40 m	60 m	100 m	150 m	240 m	380 m
Low	Exclusion zone within	7 m	10 m	15 m	20 m	30 m	40 m
	Unrestricted land use beyond	9 m	15 m	20 m	30 m	40 m	60 m

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TABLE F

Recommended risk-based separation distances for
TOXIC LIQUIDS (Toxic gas cloud hazard due to evaporation)

Hazard Rating	Quantity (m ³)	0.1	1	10	100	1000	10,000	25,000
	typical dike (m)					22	38	56
Very High	Exclusion zone within	160 m	0.4 km	1.0 km	2.2 km	dike + 2.8 km	dike + 6 km	dike + 10 km
	Unrestricted land use beyond	280 m	0.7 km	1.9 km	3.6 km			
High	Exclusion zone within	50 m	110 m	0.3 km	0.6 km	dike + 0.8 km	dike + 1.6 km	dike + 2.6 km
	Unrestricted land use beyond	80 m	200 m	0.5 km	1.0 km			
Medium	Exclusion zone within	20 m	50 m	120 m	0.2 km	dike + 0.3 km	dike + 0.6 km	dike + 0.9 km
	Unrestricted land use beyond	40 m	90 m	210 m	0.4 km			
Low	Exclusion zone within	4 m	10 m	20 m	40 m	dike + 40 m	dike + 80 m	dike + 140 m
	Unrestricted land use beyond	8 m	20 m	40 m	70 m			
Very Low	Exclusion zone within			10 m	20 m	dike + 4 m	dike + 8 m	dike + 16 m
	Unrestricted land use beyond			20 m	30 m			

Actual dike distances should be used when they are available. Quantities of 100 m³ or less are assumed to form unrestricted pools.

5. RISK MANAGEMENT

5.1 The Risk Management Process

The process of consulting the public, estimating the risks of a facility, judging its safety, and developing risk control measures if required, are inter-twined in a continuous manner and make up the risk management process. The key steps in a typical risk management process are shown in flow chart form in Figure 5.1. It should be noted that public participation should be encouraged throughout the risk management process and be a component of each step.

System description comprises understanding the components of the facility and how it operates, establishing an inventory of hazardous substances used, produced during the process, or manufactured for sale, and being familiar with the surrounding area that might be affected by hazardous events in the facility, in terms of population, land-use, climate, etc.

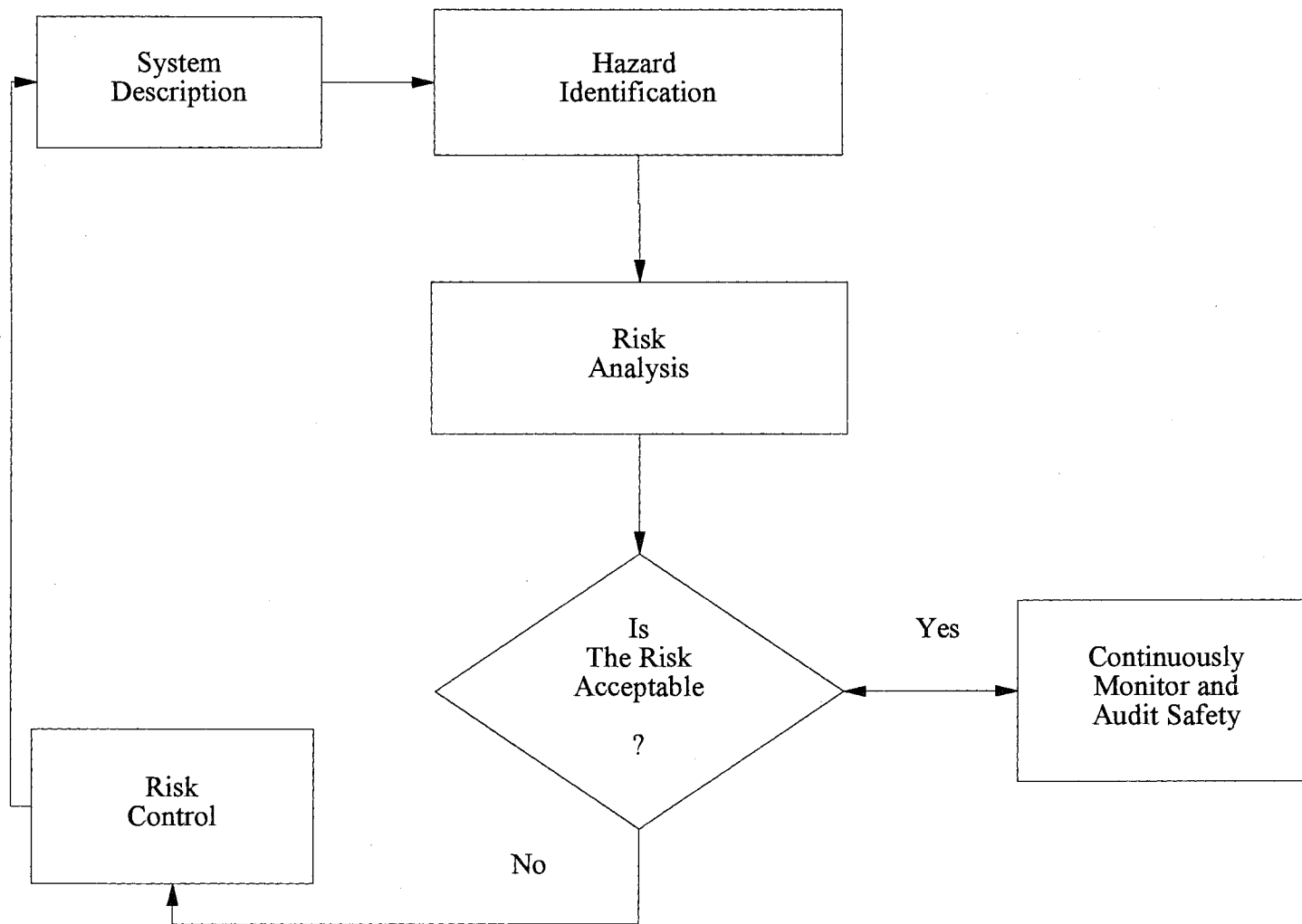
Hazard identification answers the question: *What can go wrong?* Potentially hazardous events are identified and defined in this step. For example, in a flammable-liquid storage facility, the realization that a release might lead to a pool fire or an explosion, and that there could be small, large, or catastrophic releases, constitutes the hazard identification step.

Before risk can be managed, it must be understood. *Risk analysis* defines the risk of a hazardous facility and the reductions in risk achievable under certain risk control measures. It answers the following questions for the identified events: *How often is the event expected to occur?* and, if it occurs, *What are the consequences of the event?* *Frequency analysis* makes use of *historical accident data* in similar facilities. For very rare events, fault and event trees are also used. *Consequence analysis* comprises modelling the behaviour of releases of hazardous substances and their impact on critical receptors, making use of models and *dose/response (vulnerability) data*. *Risk estimation* is the process by which the frequencies and consequences of events are combined to quantify risk. The results of risk analyses are used extensively in risk management decisions throughout the world. The uncertainties in estimating the chance of rare events, and in projecting the effects on human populations, are considerable, but high uncertainty does not mean high risk. Estimation of uncertainties in risk estimates is currently an area of active research.

5.2 Risk Evaluation

Risk evaluation answers the questions: *Is the risk judged to be acceptable?*, or, *Do we need to do anything about it?* **Safety is relative. It is a judgement of the acceptability of risk: an activity is considered safe if its risks are considered acceptable.** This definition of safety emphasizes the decision-making process. It recognizes that there is no such thing as "zero risk" because no matter what precautionary steps are taken there is always some chance of an accidental release of a hazardous substance, and a chance that someone may be adversely affected. The objective of risk management in the present context is to prevent or reduce the loss of life due to the operation of hazardous facilities. If the purview of the risk management exercise is expanded, it could take into account other consequences such as personal injury, property damage, or damage to the environment. In such cases,

Figure 5.1 The Risk Management Process



Public participation should be encouraged throughout the risk management process

other consequence information will be needed. Acceptability of risk depends on the nature of the risk and on those who may bear it. Every person faces risk in every aspect of his life; some risks are faced voluntarily, some are imposed. Generally individuals will adjust behaviour or activities to reduce voluntary risks to an acceptable level, but they may have little or no control or influence over imposed risks.

Broadly, there are levels of risk that people will accept and other levels that they will not. Adjusting risk levels often implies costs (of risk reduction activities) that may be borne by persons other than those who bear the risk, just as the benefits of the activity are often attributed to persons other than those who bear the risks. The levels of costs and benefits, as well as who bears or receives them, will affect the acceptability of risk.

Whether we judge a risk to be small or large, acceptable or unacceptable, depends on many factors. Voluntary risks are those we willingly assume because we perceive some pleasure or benefit, e.g., smoking, or sky-diving. Involuntary risks are imposed on people by decisions made by others or by natural occurrences, e.g., second-hand smoke, or violent storms. A recently-constructed hazardous facility is often seen as imposing an involuntary risk on someone already living nearby, but it might be seen as a voluntary risk if someone chooses to live near an existing facility provided that the person is aware of the risks before moving there. The MIACC risk acceptability criteria are selected for cases of involuntary risk such those as due to hazardous facilities. They are intended to be used as public safety guidelines, along with economic and socio-political considerations in making a decision. The combined process of risk analysis and risk evaluation is usually called *risk assessment*.

Once the risks are judged to be acceptable, then further risk control measures, or system changes, will not be required. However, in this case it is essential to develop programs to *monitor* the situation so that it does not deteriorate over a period of time. *Safety audits* are among the tools used for this purpose. If it is judged that further safety improvements are required, risk control options introducing system modifications will be examined.

5.3 Risk Control

Risk control answers the question: *What can be done to reduce the risks?* Risk can be reduced by decreasing the likelihood of hazardous events or by lessening the severity of the potential consequences. Risk control measures can be broadly classified into:

- process safety management, which includes technological measures, such as design changes, inventory reduction, and isolation, and management measures, such as inspection, maintenance, training and work practices,
- land-use restrictions, and
- incident management.

Readers are referred to the MIACC publications *Process Safety Management* and *Risk-based Land Use Planning* and the MIACC-CSA publication *CSA Z731: Industrial Emergency Planning* for more information.

Risk control measures will have certain costs associated with them. Estimates of the risk reduction possible through every option and of the costs of implementation provide the basis for informed decisions selecting risk control measures.

The risk levels of any hazardous activity or facility are calculated on the basis of the known or estimated frequency of accidents from similar activities or facilities. This is known as the base case. Risk control methods and procedures can be applied to the base case to reduce either the likelihood of a hazardous event occurring or the consequence of the event.

Risk control methods to reduce the likelihood of an event typically include:

- rigorous equipment checks and inspections,
- improved training and attentiveness of the operating crew,
- complete process and site documentation,
- automatic isolation systems to prevent a release,
- fail-safe operating equipment,
- reduced operating pressures or temperatures, and
- back-up instruments or equipment.

Those methods that reduce the consequence of a release include:

- decreasing the size of chemical storage or process tanks, and making any such tanks independent of each other,
- substituting less hazardous chemicals for hazardous chemicals,
- automatic shut-down systems to reduce the size or duration of a release,
- alarm systems both internal and external to the plant, and
- development and testing, on a routine basis, of emergency response plans, including evacuations.

The appropriateness and applicability of such risk control measures can be determined only after a detailed assessment of the specific hazardous facility, including the adjacent areas and their uses.

Risk management is the process by which the risks associated with hazardous activities are estimated, evaluated, and reduced if necessary. Communication of the risks to the public exposed to these risks, and public participation regarding the acceptability of these risks and the risk control measures that would be implemented, are essential components of the risk management process.

APPENDIX

Assumptions and Approximations

Several approximations have been made to reach the general assessments of the MIACC approach. The user of this *Mini-Guide* or the *Guidelines* should be aware of these assumptions, and that the actual situations being assessed may be significantly different from those considered in the preparation of these guides.

The frequencies of the two possible accidents considered in the approach, of a small (10%) or a total release of inventory, have been taken as 0.01 (10^{-2}) per year and 0.0001 (10^{-4}) per year for *any* facility. Clearly this is a very broad approximation. Furthermore, these values have been estimated from the past performance of all types of facilities, of all ages. Facilities of a particular type or facilities using current technologies and processes may give rise to different frequencies.

It has been assumed every possible event is represented by one or other of the two representative accidents, and so that the total risk due to all possible events is equal to the sum of the risks due to these two. Boiling liquid expanding vapour explosions (BLEVEs) or other catastrophic total releases have greater consequences, and cannot be represented by a slower total release. However, they occur with very low frequency (less than 10^{-6} per year) and so pose very low risks.

The consequences of an accident involving any member of one of the groups or sub-groups of hazardous substances have been derived on consideration of one of the most hazardous members, so the assumed severity of those consequences will be over-estimated in almost every case, and the resulting separation distances somewhat larger than necessary.

For the models describing the consequences of the two assumed possible accidents, further less apparent approximations have been made. Typical weather conditions have been taken to be neutral atmospheric stability, or generally cloudy with a moderate wind of 5 m/s (20 km/hr); the storage temperature has been taken to be 20°C. These are typical or average conditions, so the calculated consequences will be typical or average, not at one or the other extreme of the possible range.

The models describe the effects downwind from the site of a release. Since the probability of the wind blowing in any particular direction at the time of the incident is less than 100%, the total annual risk at the calculated 10^{-6} risk contour must be actually less than 10^{-6} and the quoted separation distance is farther than the actual contour. (Known wind patterns allow the calculation of non-circular contours around specific sites; only circular, approximate contours are reasonable for a general method).

It has been assumed that only 10% of the individuals normally in the neighbourhood which might be affected would be out-of-doors at the time of an accident, not sheltered by being indoors or removed altogether. This is again thought to be a typical, not extreme, value. It has also been assumed that an individual exposed to a cloud of hazardous substance passing over an area after a release would be exposed to a uniform concentration of the substance for 30 minutes, which may not be a realistic assumption but nevertheless provides a sensible basis for assessing exposure.

MIN. ENVIRONNEMENT ET FAUNE



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