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Safety Report according to SEVESO regulation in Catalonia

Informe de Seguretat Química segons la normativa SEVESO a Catalunya

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Dos campus d'excel·lència internacional
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La nostre insignificança és freqüentment la causa de la nostra seguretat
Esopo

Primer de tot voldria agrair al meu tutor, Jaime Giménez per la seva dedicació i ajuda durant la realització del treball. També vull agrair a DEKRA, per continuar-me ensenyant cada dia més sobre la seguretat i obrir-me portes a un nou món.

Finalment, a la meva família i amics per donar-me suport durant tots aquests mesos.

Report

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1. SUMMARY

Although the SEVESO regulation is established in Europe, there are still accidents with catastrophic consequences for people. Therefore, it is necessary to emphasize compliance with this regulation. The SEVESO regulation is European in scope, although its application depends on the different European countries. In the case of Spain, every region can develop its own SEVESO regulation respecting Spanish regulations RD 1196/2003 and RD 840/2015. This project will be focused only on Catalonia. Chemical plants that present hazardous chemical substances are required to submit a series of documents, including the Safety Report. In Catalonia, the Safety Report has to be prepared following the *Instruction 11/2010*. The main idea of this project consists of presenting a Safety Report, following all the steps dictated by the *Instruction 11/2010.* Data are used, at regional level, of the chemical plants present in the province of Barcelona. One of the documents presented in the Safety Report is the Risk Assessment. In there, the most representative accidents, associated with the dangerous substances present in the plant are studied. As a result of the study, areas of dangerous are calculated, depending on the scenario design. The most representative initiating events studied are the partial breakage of the equipment or the unloading/loading arm or hose, the catastrophic breakage of a mobile recipient and the confined explosion of a tank. From these initiating events and through the event tree technique, the possible final accidents have been deduced. These have been modelled to assess their possible consequences and vulnerability for people and the environment. Finally, the corresponding risk analyses have been carried out. These accidents are studied considering a statistical study of the chemical plants placed in the province of Barcelona.

2. SUSTAINABLE DEVELOPMENT OBJECTIVES

In the framework of the 2030 Agenda for sustainable development [1], the United Nations has set 17 objectives towards which it should tend. This work could have a certain impact on four of them: 3) Health and well-being; 8) Decent work and economic growth; 9) Industry, innovation and infrastructure; 12) Responsible production and consumption.

It is obvious that any issue related to industrial safety, as is the case in this work, directly affects the health and well-being of people, since the objective of safety is precisely to protect the health of people, the environment and goods, both inside and outside the plant. This is even more important in the case of the chemical industry in which they use hazardous substances and work conditions (pressure, temperature, etc.) that can also be problematic, producing serious accidents, with an impact on the life of people. Therefore, safety studies help to minimize the risk of accidents and, consequently, protect health of people. This is also linked to objective 8 of the 2030 Agenda, related to decent work. It is evident that the first condition for a job to be decent is that the health of the people was guaranteed. Therefore, safety is also a fundamental tool and safety reports provide the necessary data to influence this improvement in the workplace.

Finally, safety issues also have a key impact on aspects of industrial improvement and innovation (objective 9) and responsible production and consumption (objective 10). The improvement in safety elements is always innovative and, in turn, allows produce in a more responsible manner, given the reduction in the number of accidents and their consequences on people, goods and environment.

From this last perspective, the safety reports, with the aim of detecting weak points in the facilities and possible accidents, allow progress in the improvement of the plants. This entails reducing the environmental impact of working safely. Therefore, this work, in some way, would also make it possible to influence the objectives: 13) Action on the climate; 14) Sustainable life and 15) Life of terrestrial ecosystems. It would be a less direct impact, but it is clear that safety reports make it possible to reduce accidents and, with it, their environmental impact.

These would be the aspects of this work somehow related to the sustainable development goals of the United Nations 2030 Agenda.

3. INTRODUCTION

The SEVESO Directive has its origin in 1976 when there was a catastrophic accident in a small Italian town called Seveso [2]. There was a runaway in the chemical plant ICMESA *(Industrie Chimiche Meda Societá Azionaria)* which caused an increase of pressure and the rupture disk breaking [3]. A huge toxic vapour cloud was extended above the city of Seveso causing damage to people and the environment. Thousands of people had skin damage and a lot of animals died [4].

This accident was the turning point at which the decision was to make some legislation to prevent this kind of accidents [2]. The main objective of the SEVESO Directive is to prevent major accidents involving dangerous substances and minimize the possible consequences of these accidents for people, goods and environment [5].

A major accident is considered an event such as a major release, fire or explosion which derivates from an uncontrolled process during the operation of any establishment and that involves major consequences in human health, goods or the environment, immediately or delayed, inside or outside the establishment and with hazardous substances [6].

This regulation is applied in Europe to every industry, which have substances classified as dangerous and with amounts higher than those set by SEVESO regulations [7]. These industries must report to Member State national authorities which substances are manipulated and the processes carried in the plant [8].

3.1. <u>SEVESO Directive Nowadays</u>

Since the SEVESO Directive was implemented, accidents have been occurring. The normative continue to be updated, now the current regulation is the SEVESO III, to continue to prevent accidents from occurring. Some examples are briefly explained below:

- **Muttenz, Switzerland 1986**

This accident was about a fire in a warehouse, which was entirely destroyed. The air was contaminated with a lot of chemicals and also the Rhine River, because used water to combat the fire swept away pesticides and mercury that ended up in the river [9].

Human heath was affected by the malodorous vapour cloud extended in the city of Muttenz. Some people had respiratory and gastrointestinal irritation. Also, wildlife in the Rhine River was affected by the accident, thousands of fishes were found dead near the river [10].

Figure 1. Toxic vapour cloud in Muttenz caused by the fire.

- **Toulouse, France 2001**

There was an explosion at a fertilizer plant. There was a leak of sodium dichloroisocyanurate that submitted in an amount of off-specification ammonium nitrate [11]. 19 people died and 658 were injured [12].

The accidents did not only occur far away and in the past, but nowadays serious chemical plant accidents also still occur. A clear example of this is the accident occurred in Tarragona in 2020.

- **Tarragona, Spain 2020**

An explosion of a tank of ethylene oxide was produced in the chemical plant IQOXE. The top of the reactor shot out more than two kilometres and impact on a building. As a result of the impact, a person died [13]. There were also two more people dead and eight people injured, all of them were workers of the plant [14].

These are some examples of why it has to be more emphasis on the regulation and make sure all the establishment accomplish with their standards.

Although it is applied in Europe, every country has its own normative, as long as they comply with SEVESO standards. As this project will be focused on Catalonia, first of all the regulations in Spain will be explained.

3.2. SEVESO Directive in Spain

In Spain there are two main regulations which are made according to the SEVESO, and the Real Decreto 840/2015 [16], which is the transposition of the European directive in Spain, and the Real Decreto 1196/2003 [15].

3.2.1. Which plants are under SEVESO scope?

The normative differences two affecting thresholds according to the quantity of substances present in the installation [17].

3.2.2. Which plants are not under SEVESO scope?

Anyway, there are some exceptions which the SEVESO does not affect [16]. These are:

a) Establishments, facilities, or storage that belongs to the Armed Forces and Security Forces and Corps.
b) Ionizing radiation originated from substances.
c) Transport of dangerous substances by road, rail, inland waterway, sea, or air.
d) Transport of dangerous substances by pipelines.
e) The exploitation of minerals in mines, quarries by means of drilling.
f) The exploration and offshore exploitation of minerals.
g) Storage of gas in offshore subway sites.
h) Waste landfills.

3.3. Which levels of affectation are there?

If the SEVESO Directive affects the plant, there are two levels of affectation, and the substances present in the plant must be classified according to these levels.

First, there are the classified substances, grouped for its hazard, and the second group is the nominated substances, which are called by its own name. In every group there are two columns, 2 and 3. Column 2 is for the inferior thresholds, and column 3 is the superior threshold. With this information it can be decided whether the establishment is affected a high or low tier [16][17].

- **Lower - tier establishment:** an establishment which presents hazardous substances in quantities equal to or higher than the quantities specified in the column 2 part 1 or 2 of the Annex I, but less than the quantities specified in the column 3 part 1 or part 2 of the Annex I [16].
- **Upper - tier establishment:** an establishment which presents hazardous substances in quantities equal to or higher than the amount specified in the column 3 part 1 or 2 of the Annex I [14][16].

In order to understand better how it works, an example of an extract of the RD 840/2015 is shown in Figure 2.

Categorías de sustancias peligrosas

La presente parte comprende todas las sustancias peligrosas incluidas en las categorías de peligro enumeradas en la columna 1:

Columna 1	Columna 2	Columna 3
Categorías de peligro de conformidad con el Reglamento (CE) n.º 1272/2008, del Parlamento Europeo y del Consejo, de 16 de diciembre de 2008.	Cantidades umbral (en toneladas) de las sustancias peligrosas a que se hace referencia en el artículo 3, apartado 10, a efectos de aplicación de los	
	Requisitos de nivel inferior	Requisitos de nivel superior
Sección «H» – PELIGROS PARA LA SALUD		
H1 TOXICIDAD AGUDA – Categoría 1, todas las vías de exposición.	5	20
H2 TOXICIDAD AGUDA – Categoría 2, todas las vías de exposición – Categoría 3, vía de exposición por inhalación (véase la nota 7).	50	200
H3 TOXICIDAD ESPECÍFICA EN DETERMINADOS ÓRGANOS (STOT) – EXPOSICIÓN ÚNICA STOT SE Categoría 1.	50	200
Sección «P» – PELIGROS FÍSICOS		
P1a EXPLOSIVOS (véase la nota 8) – Explosivos inestables o – Explosivos de las divisiones 1.1, 1.2, 1.3, 1.5 o 1.6, o – Sustancias o mezclas que tengan propiedades explosivas de acuerdo con el método A.14 del Reglamento (CE) n.º 440/2008, del Parlamento Europeo y del Consejo, de 16 de diciembre de 2008, (véase la nota 9) y no pertenezcan a las clases de peligro «peróxidos orgánicos» o «sustancias o mezclas que reaccionan espontáneamente».	10	50
P1b EXPLOSIVOS (véase la nota 8) Explosivos de la división 1.4 (véase la nota 10).	50	200
P2 GASES INFLAMABLES Gases inflamables de las categorías 1 ó 2.	10	50
P3a AEROSOLES INFLAMABLES Aerosoles «inflamables» de las categorías 1 ó 2, que contengan gases inflamables de las categorías 1 ó 2 o líquidos inflamables de la categoría 1.	150 (neto)	500 (neto)
P3b AEROSOLES INFLAMABLES Aerosoles «inflamables» de las categorías 1 ó 2, que no contengan gases inflamables de las categorías 1 ó 2 o líquidos inflamables de la categoría 1.	5.000 (neto)	50.000 (neto)

Figure 2. Example of the classification of substances in the RD 840/2015 [16].

Depending on the level of the establishment, the documents required are different. Although, in Spain, for every region could be different, because it lets to all the regions make their own regulation as long as they follow the RD 1196/2003 [15] and RD 840/2015 [16].

3.4. SEVESO Directive in Catalonia

As explained before, depending on the level of the establishment, the documents required are different. The following table explains the main differences between levels in Catalonia.

Table 1. Documents required depending on the level of site.

Low-tier establishment:	**Upper-tier establishment:**

• Notification
• SGS (Safety Management System)
• PPAG (Major Accident Prevention Policy)
• Internal Emergency Plan
• Quantitative Risk Assessment
	• Notification
	• SGS (Safety Management System)
	• PPAG (Major Accident Prevention Policy)
	• Internal Emergency Plan
	• Safety Report, including:
	  ○ Risk Analysis
	  ○ IBA (Basic information for external emergency plan)
	• Quantitative Risk Assessment

As mentioned, one of the documents needed when the establishment is at its high level, is the Safety Report, objective of this work. In Catalonia, the main regulation that companies have to follow in order to ensure that the Safety Report has all the requirements needed is the *Instrucció 11/2010* [18].

This instruction has some points to follow. To summarize the different points that a Safety Report must have, Figure 3 shows a schematic diagram of the chapters:

PHASE 1

Identification of substances	Identification of accident initiators	Description of the technologic safeguards	Event tree and fault tree

↓

PHASE 2

Accidents

↓

PHASE 3

Calculation of consequences (modelling): Determination of the ZI[1], ZA[2] and domino effect

↓

PHASE 4

Calculation of vulnerability for the initiating events

↓

PHASE 5

Selection of accidents for the elaboration of PEE[3]

↓

PHASE 6

Relation of major accidents identified

Figure 3. General Schema for the Risk Assessment [18].

[1] ZI: the consequences of the accident, in this zone, produce a level of danger that justifies the immediate application of protection measures.

[2] ZA: the consequences of the accident, in this zone, cause slow effects and, although the population perceive these effects, it is not justified the intervention, except for the critical population groups.

[3] PEE: the organisational and functional framework designed by the competent civil protection authorities to prevent and, where appropriate, mitigate the consequences of major accidents involving dangerous substances, previously analysed, classified and assessed [25].

4. OBJECTIVES

The objective of this work is to explain all the necessary points that a safety report should contain providing data from companies in the chemical sector in the province of Barcelona. To do this, the basic documents used are the Real Decreto 840/2015 [16], the Real Decreto 1196/2003 [15] and the *Instrucció 11/2010* [18].

The main objectives are the following:

- To understand the SEVESO regulations and their applicability in Spain and specifically in Catalonia.
- Use the *Instrucció 11/2010* [18] to carry out a Safety Report
- Provide practical examples of the key points of a Safety Report
- To carry out a summarized study based on the data on the chemical plants present in the province of Barcelona, which includes:
  - What sectors are the chemical plants in the province of Barcelona involved in?
  - Location of these chemical plants
  - Which substances are present in larger quantities?
  - What are the initiating events?
  - What are the most common accidents?
  - What are the consequences of these accidents?

5. DESCRIPTION OF THE ESTABLISHMENT AND THE SURROUNDING

5.1. Surrounding

The location of the SEVESO establishment and its surrounding area is very important because, depending on it, the impact of the consequences of possible accidents could be very different. Figure 4 shows all the establishments affected by the directive SEVESO in Catalonia.

Figure 4. Establishments affected by the normative SEVESO in Catalonia [19].

As it can be seen in Figure 4, the largest number of chemical plants is located in the province of Barcelona and Tarragona. Some of the chemical plants are located together in an industrial park, such as the petrochemical complex of Tarragona or the Zona Franca of Barcelona. But there are also chemical plants which are far away from the others. As an example of how to apply SEVESO regulations, in this work, a Safety Report in the province of Barcelona is done.

5.2. Activities, installations, and processes

The activities that are developed in the chemical plants in the province of Barcelona are divided into different categories as shown in the Figure 5.

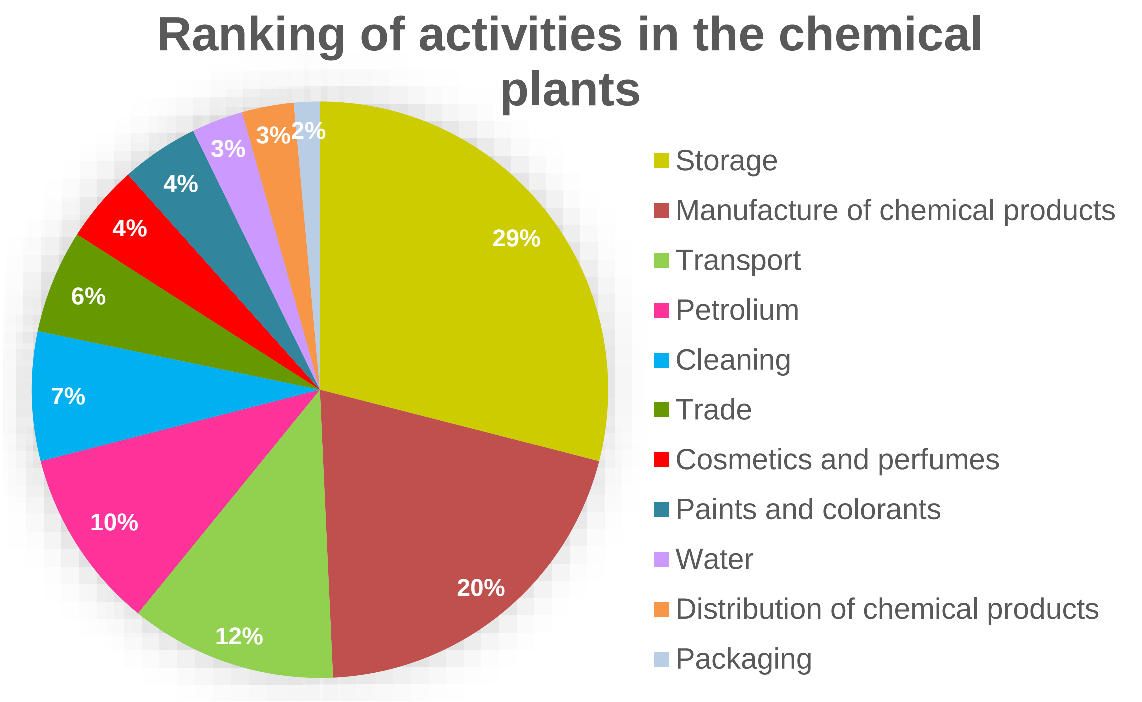


Figure 5. Classification of chemical plants depending on its activity.

As it is shown in Figure 5, the main activity carried out in the chemical plants in the province of Barcelona is the storage of different chemical products. The second place is for the manufacturing of different chemical products such as, oxides, pharmaceuticals, polyurethanes, resins, etc. The process for each manufactured product could be very different, involving different chemical products and equipment. The third category is the transport. In some cases, the same company makes both processes, storage, and transport, as they are very related. The storage and transport could be also for different kind of chemical products.

In the Port of Barcelona, there are a lot of chemical plants devoted to the reception, storage and distribution of LNG, oil derivatives (gasoline, gas-oil, kerosene, etc.) and many other chemicals.

5.3. Substances classification

All the industries affected by the SEVESO regulation must submit the AG-1 notification. In this document, the industries have to notify to the authorities all the dangerous substances that are classified according to the three categories explained below and its quantity. First of all, the substances appearing in Part I of Annex I of the RD 840/2015 [16] are named and classified according to their hazards. For AG-1, only the three substances for each category, in the largest quantity have to be named and the others, if any, are declared as "other substances". There are three different categories:

- **Category H:** health hazards
- **Category P:** physics hazards
- **Category E:** environmental hazards

The category for each substance is determined by analysing its safety data sheets and with the document "AclarimentsAplicacioRD8402015" [20][19].

As an example, a study of the substances present in the chemical plants of the province of Barcelona has been done. The substances shown in Table 2 and Table 3 correspond to the predominant substances in the province of Barcelona, i.e., they are present in most chemical plants in this region. The maximum amount of each substance is not the total amount of these predominant substances considering all the chemical plants in the province of Barcelona. Therefore, the quantity is just a practice in which an imaginary chemical plant have been analyzed.

Table 2. Notified substances of part 1 of Annex 1 of RD 840/2015 [16].

CATEGORY H - Health hazards				
Substance	**Section**	**Maximum amount (t)**	**Threshold (t)**	
			Low	**High**
Sodium cyanide	H1: Acute toxicity, Category 1	20	5	20
Hydrofluoric acid		20	5	20
40% formaldehyde solution	H2: Acute toxicity, Category 2 and 3	76	50	200
Formic acid		102	50	20

CATEGORY P – Physics hazards				
Substance	**Section**	**Maximum amount (t)**	**Threshold (t)**	
			Low	**High**
Ethylene	P2: Flammable gases	4	10	50
Flammable sprays	P3a: Flammable sprays	100	150	500
Isopropylamine	P5a: Flammable liquids	0.5	10	50
Methyl tertiary-butyl ether	P5b: Flammable liquids	4	50	200
Isopropyl alcohol	P5c: Flammable liquids	520	5.000	50.000
tert-Butyl peroxybenzoate	P6b: Spontaneously reacting substances and mixtures and organic peroxides	2	50	200
Sodium chlorite	P8: Oxidizing liquids and solids	95	50	200
Sodium nitrite		30	50	200

CATEGORY E – Environmental hazards				
Substance	**Section**	**Maximum amount (t)**	**Threshold (t)**	
			Low	**High**
Sodium hypochlorite	E1: Hazardous to the aquatic environment in the acute 1 or chronic 1 category	222	100	200
Acrylic acid		250	100	200
Manganese (II) sulphate	E2: Hazardous to the aquatic environment in chronic category 2	45	200	500

Secondly, substances present in Part II of Annex I of the RD 840/2015 [16] are declared. These substances are called as named substances, and all of them has to be in the AG-1 notification.

Table 3. Named substances of part 2 of Annex 1 of RD 840/2015 [16].

Annex 1. Part 2: Named Substance				
Substance	**Classification**	**Maximum amount (t)**	**Threshold (t)**	
			Low	**High**
Natural gas	18. Liquefied flammable gases of category 1 or 2 (including LPG) and natural gas	<< 1	50	200
Methanol	22. Methanol	55	500	5.000
Diesel	34. Petroleum products and alternative fuels	3	2.500	25.000

As it mentioned in the introduction, the amount of hazardous substances is crucial to determine the level of the establishment. Table 4 shows the calculated ratios for the imaginary chemical plant created. The calculations are found in Annex A.

Table 4. Ratio of substances.

	Substance ratios in reference to the lower threshold (column 2)	**Substance ratios in reference to the upper threshold (column 3)**
Ratio of substances with health hazards (Sections H1. H2. H3)	11.67	2.90
Ratio of substances with physics hazards (Section P1a/b, P2. P3a/b, P4. P5a/b/c, P6a/b, P7. P8)	3.97	0.97
Ratio of substances with environmental hazards (Sections E1. E2)	4.97	2.45

The properties of each of these substances can be found in Annex B. The data are taken from the safety data sheets of each of them.

6. IDENTIFICATION OF ACCIDENT INITIATORS

6.1. <u>List of substances</u>

To decide which substances have to be considered in the safety report a screening is carried out following the criteria F1-3 and F1-8 of the *Instrucció 11/2010* [18].

- Substances classified in the major-accident notification (form AG-1) may be excluded if, due to their state, quantity, location or type of classification, they cannot give rise to a major accident (e.g. toxic by ingestion).
- All substances of the part 1 of the Annex I in the RD 840/2015 [16] with quantities above 80% of the lower threshold (column 2) have to be considered.
- One substance of each of the categories of Part 2 of Annex 1 of RD 840/2015 [16] has to be included, chosen for being the most representative, except in the case of toxic and very toxic substances in which accident initiators shall be formulated for the three substances named in form AG-1, provided that the quantity of the substance registered on the AG-1 form exceeds 10 % of column 2.

The next table shows the screening of substances and the taken decision.

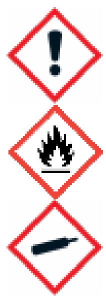
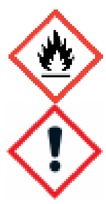
Table 5. Substances screening.

Classification, Part 1 or 2 of Annex RD 840/2015 [16]	**Substance**	**Maximum quantity stored (t)**	**Quantity lower threshold column 2 (t)**	**Study inclusion**	**Reason for inclusion or exclusion**
H1: Acute toxicity, Category 1	Sodium cyanide	20	5	No	According to criterion F1-3 of the *Instrucció 11/2010* [18] it is not considered as it is a solid-state substance.
	Hydrofluoric acid	20	5	Yes	According to criterion F1-8 of the *Instrucció 11/2010* [18] it is a substances notified in quantity above 10% of column 2 of Annex I of RD 840/2015 [16]
H2: Acute toxicity, Category 2 and 3	40% formaldehyde solution	76	50	Yes	
	Formic acid	102	50	Yes	
P2: Flammable gases	Ethylene	4	10	Yes	
P3a: Flammable sprays	Flammable sprays	100	150	No	The aerosols arrive packed in boxes and are stored without handling. It is considered that per unit quantity of each aerosol no scenario could be generated in case of breakage.
P5a: Flammable liquids	Isopropylamine	0.5	10	Yes	According to criterion F1-8 of the *Instrucció 11/2010* [18] it is a substances notified in quantity below 10% of column 2 of Annex I of RD 840/2015 [16]
P5b: Flammable liquids	Methyl tertiary-butyl ether	4	50	No	
P5c: Flammable liquids	Isopropyl alcohol	520	5.000	Yes	According to criterion F1-8 of the *Instrucció 11/2010* [18] it is a substances notified in quantity above 10% of column 2 of Annex I of RD 840/2015 [16]
P6b: Spontaneously reacting substances and mixtures and organic peroxides	tert-Butyl peroxybenzoate	2	50	No	According to criterion F1-8 of the *Instrucció 11/2010* [18] it is a substances notified in quantity below 10% of column 2 of Annex I of RD 840/2015 [16]

Classification, Part 1 or 2 of Annex RD 840/2015 [16]	Substance	Maximum quantity stored (t)	Quantity lower threshold column 2 (t)	Study inclusion	Reason for inclusion or exclusion
P8: Oxidizing liquids and solids	Sodium chlorite	95	50	No	According to criterion F1-3 of the *Instrucció 11/2010* [18] it is not considered as they are oxidizing substances and do not produce any risk scenario such as thermal radiation, toxic cloud, or explosion
	Sodium nitrite	30	50	No	According to criterion F1-3 of the *Instrucció 11/2010* [18] it is not considered as it is a solid-state substance.
E1: Hazardous to the aquatic environment in the acute 1 or chronic 1 category	Sodium hypochlorite	222	100	No	According to criterion F1-3 of the *Instrucció 11/2010* [18] it is not considered as it is hazardous to the environment. These substances are considered in the study of damage to the environment
	Acrylic acid	250	100	No	
E2: Hazardous to the aquatic environment in chronic category 2	Manganese (II) sulphate	45	200	No	
18. Liquefied flammable gases of category 1 or 2 (including LPG) and natural gas	Natural gas	<< 1	50	No	According to criterion F1-8 of the Instrucció 11/2010 [18] it can be discarded when storing a quantity much lower than 10% of column 2 of RD 840/2015 [16].
22. Methanol	Methanol	55	500	Yes	According to criterion F1-8 of the Instrucció 11/2010 [18] it is considered to be a representative substance of Part 2 of Annex I of RD 840/2015 [16] with a quantity greater than 10% of column 2.
34. Petroleum products and alternative fuels	Diesel	3	2.500	No	According to criterion F1-8 of the Instrucció 11/2010 [18] it can be discarded when storing a quantity much lower than 10% of column 2 of RD 840/2015 [16].

The following table summarizes the main characteristics of the substances classified by the Real Decreto 840/2015 [16], with possibility to generate a major accident.

Table 6. Identification of substances classified according to RD 840/2015 [16].

Substance	**Classification according to the Annex I of the RD 840/2015 [16]**	**Identification of hazards according to regulation 1272/2008**	**Classification according to the regulation (CE) nº 1272/2008**	**Labelling according to CLP Regulation (CE) nº 1272/2008**	**Maximum quantity stored (t)**
Hydrofluoric acid	Annex 1. part 1. H1	H300 H310 H330 H314	Acute Tox. 1 Acute Tox. 2 Skin Corr. 1A		20
40% formaldehyde solution	Annex 1. part 1. H2	H301 H311 H314 H317 H331 H335 H341 H350 H371	Acute Tox. 3 Skin corr. 1B Skin sens. 1A STOT SE. 2 STOT SE. 3 Muta. 2 Carc. 1B		76
Formic acid	Annex 1. part 1. H2	H331 H302 H314	Acute Tox. 3 Acute Tox. 4 Skin Corr. 1B Eye Dam. 1		102
Ethylene	Annex 1. part 1. P2	H220 H280 H336	Gas Infl.1 Gas Liq. Tox. Esp. 3		4
Isopropyl alcohol	Annex 1. part 1. P5b	H225 H319 H336	Flam. Liq. 2 Eye Irrit. 2 STOT SE 3		520

Substance	Classification according to the Annex I of the RD 840/2015 [16]	Identification of hazards according to regulation 1272/2008	Classification according to the regulation (CE) nº 1272/2008	Labelling according to CLP Regulation (CE) nº 1272/2008	Maximum quantity stored (t)
Methanol	Annex 1. part 2. 22	H225 H301 H311 H331 H370	Flam. Liq. 2 Acute Tox. 3 STOT SE 1		55

6.2. List of accident initiators

There are two types of initiators according to their nature: generic and specific accident initiators.

6.2.1. Generic accident initiators

In a risk analysis, only representative accident initiators in the plant are chosen, as opposed to a quantitative risk analysis, where all possible accident initiators are analysed.

Generic accident initiators are considered to be the most likely events associated with each of the facilities that are likely to lead to a major accident. The causes are standards, i.e., could be applied in every establishment. According to the criteria F1-7 and F1-8 of *Instrucció 11/2010* [18], based on the reference manual BEVI [21], the most appropriate accident initiators for the facility must be considered for each of the substances reported and included in the study (see Table 7).

Table 7. List of generic accident initiators.

Equipment	Generic accident initiators
Fixed tanks/reactors/ columns/etc.	Leakage from the equipment through an equivalent hole of 10 mm in diameter

Equipment	Generic accident initiators
Mobile liquid containers	Catastrophic breakage unless it can be clearly justified that, due to the constructive characteristics of the vessel, the event can be avoided. In this case, a 50 mm diameter hole in the liquid phase will be considered.
Mobile containers for compressed, liquefied or dissolved gases under pressure (bottles, drums, cylinders, etc.)	Partial breakage of gas outlet valve
Pumps/compressors	Leakage from the equipment through a hole equivalent to 10% of the pipe diameter
Pipes	Partial breakage of 10% of the diameter with a maximum of 50 mm
Truck or tank car loading/unloading stations	Partial breakage of the loading/unloading arm/hose (10% of the diameter with a maximum of 50 mm)
Ammonia refrigeration system	Continuous leakage through an equivalent 10 mm diameter hole of the virtual liquid accumulator tank of the entire system inventory at the most unfavourable temperature and pressure conditions
Inside warehouse	Warehouse fire

Concerning the most probable initiators of accidents, a small statistical study has been carried out with the chemical plants in the province of Barcelona. The Figure 6 shows the ranking obtained, considering that 53 chemical plants are studied.

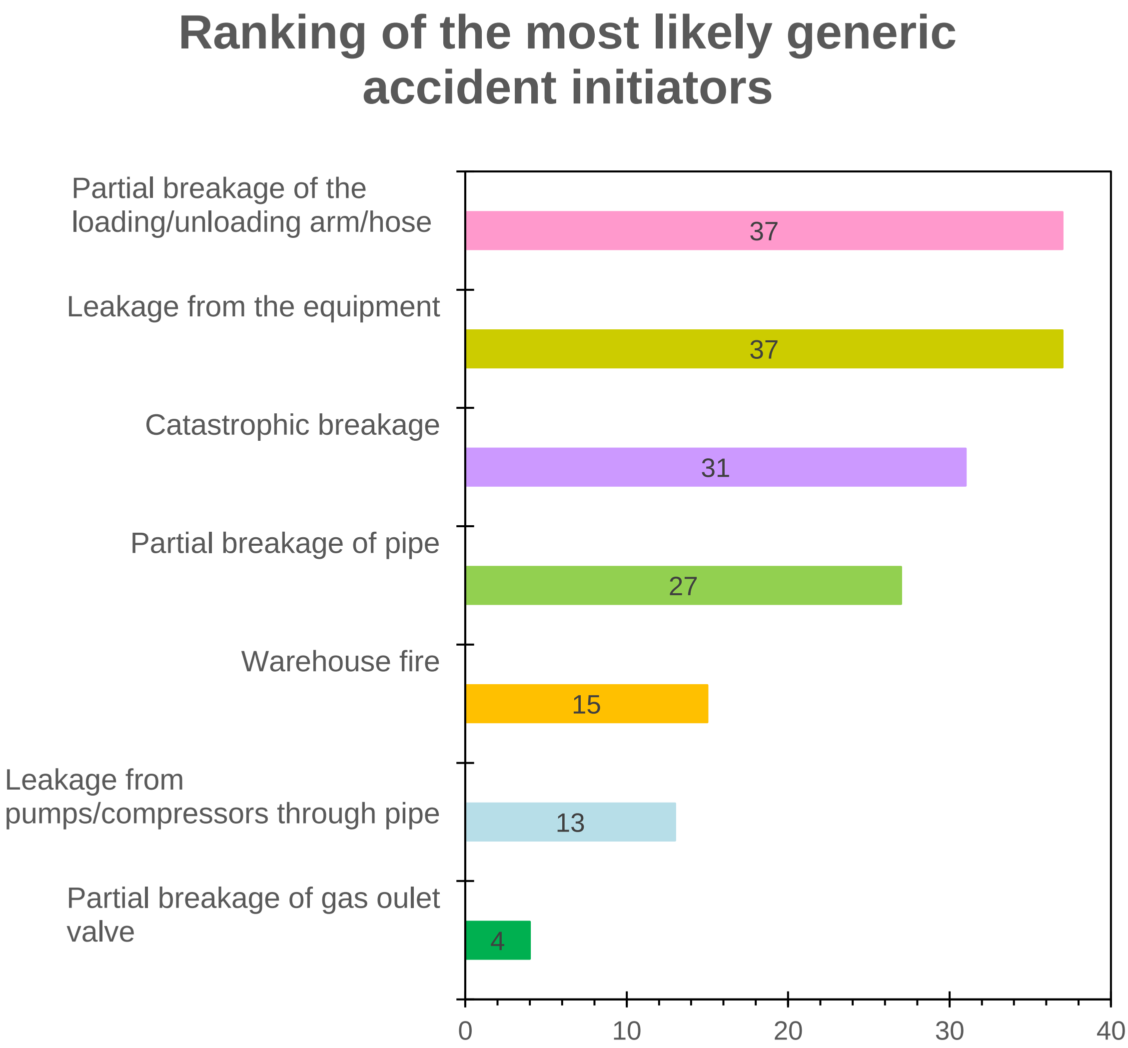


Figure 6. Study of the generic accident initiators.

As it can be seen in Figure 6, the two most likely accidents are the partial breakage of the loading/unloading arm/hose and the leakage from the equipment. On one side, in most of the chemical plants there are some places where the substances are loaded to be taken elsewhere or unloaded for use in the facility. From the other side, most of the equipment existing in the plant is considered in the leakage from the equipment, such as fixed tanks, reactors, columns, mixers, etc. Thus, it is logical that it is also one of the most frequent generic accident initiators. In both cases, a continuous leakage of 30 minutes is considered, except when there are passive safeguards, as will be in the next chapter. In third place, there is the catastrophic breakage of a mobile container. In this case, it is considered an instantaneous leak, i.e., the entire contents are spilled at once.

6.2.2. Specific accident initiators

There are also specific accident initiators, which are considered based on the hazardousness of the substances handled, historical analysis of accidents and the experience of the company. In this case, the causes of the accident initiators are more specific of the chemical plant studied, depending on the process and the equipment installed. These specific accident initiators are listed in Table 8.

Table 8. List of specific accident initiators.

Events	Specific accident initiators
Operational failures	• Overfilling • Runaway • Internal tank explosions • Specific phenomena (BLEVE by external heating, boilover, rollover, etc) • Service failure • Others
External events	Naturals: • Earthquakes • Floods • Extreme weather conditions • Others Technologic: • Domino effect inter-establishment • Plane crash • Others

In terms of specific accident initiators, these can be more varied than the generic one, so it is difficult to make a statistical work. However, they have also been studied. The most common specific accidents are the overfilling, since in normal operation the filling operation is very common, and the internal tank explosion due to parameter deviations.

The frequency of the generic initiating events has to be calculated or by bibliographic research in the reference manual BEVI [21] and for the specific initiating events calculated by the methodology of the fault tree. The calculation is developed in chapter 9.

6.3. Fault tree

In case of the specific initiators the frequency of the accident is calculated by the fault tree analysis.

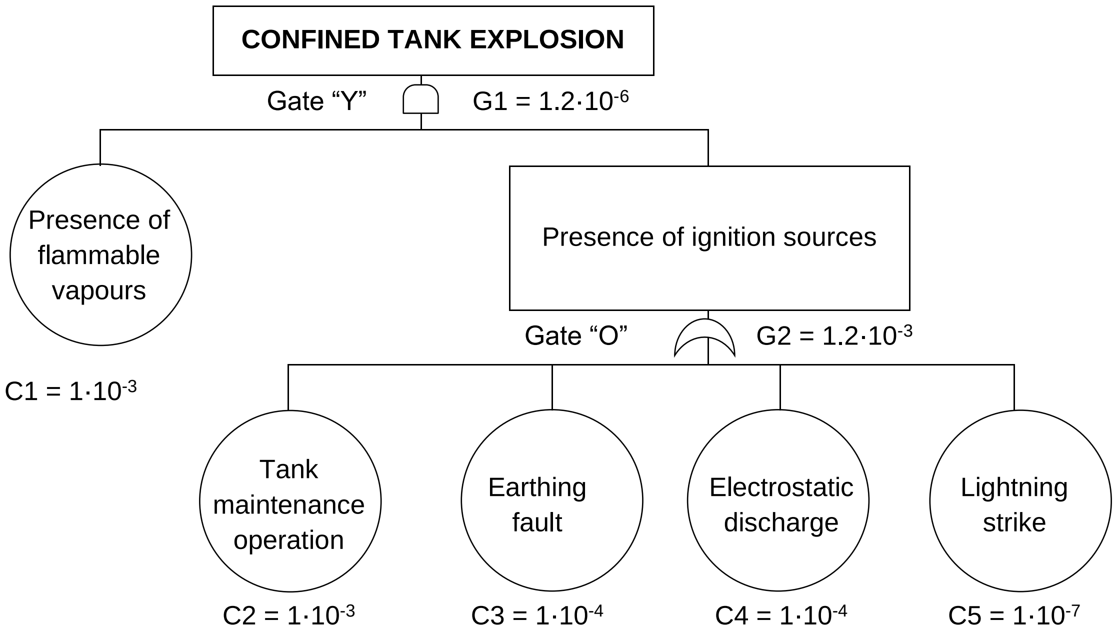


Figure 7. Fault tree for the initiating event E1.

Where de circles are the primary faults and the rectangles the secondary faults. In addition, there are two types of logic gates. The gate "Y" implies that all events have to occur for the input event to happen. In contrary, the gate "O" implies that the input event will occur if one or more events occur [36]. The probabilities are obtained by different safety studies such as HAZOPs where these primary faults are evaluated for a specific chemical plant.

6.4. Event tree

From the generic accident initiators, its consequences are determined by the event trees, according to the reference manual BEVI [21]. The substances considered in the safety report are flammable and toxic. It is considered that all of them are in liquid state except for the ethylene and isopropyl alcohol, which are stored in gas state.

The probability of occurrence of each of the final accidents depends on the initiator, the chain of successive events and the substance involved. The probabilities values have been obtained following the reference manual BEVI [21]. The probability is calculated only for the methanol and the isopropyl alcohol because they are flammable substances of category 1, as its flash points are below 21ºC. The other substances are just toxic; therefore, the only consequence would be the toxic vapour cloud.

The following figures show the consequences that would develop the generic accident initiators considered.

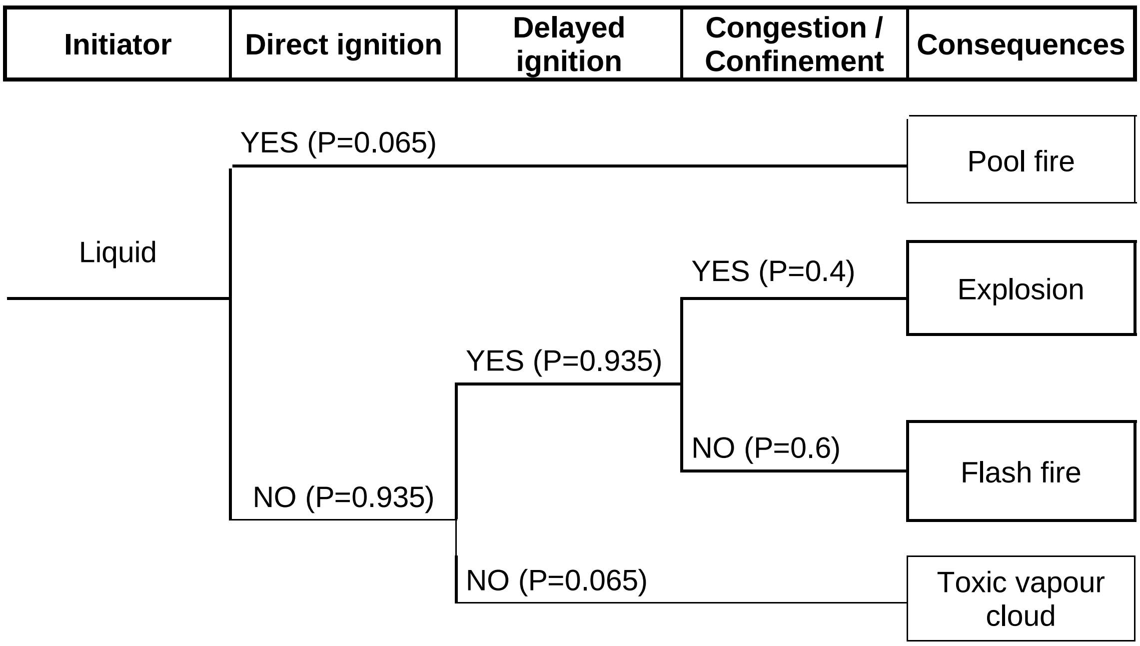


Figure 8. Event tree for a release of a flammable and toxic liquid.

The event tree of Figure 8 is for flammable and toxic liquid. If the substance of the release is just flammable, the event tree would be the same, but instead of toxic vapour could, there would be no consequences as the substance is not toxic.

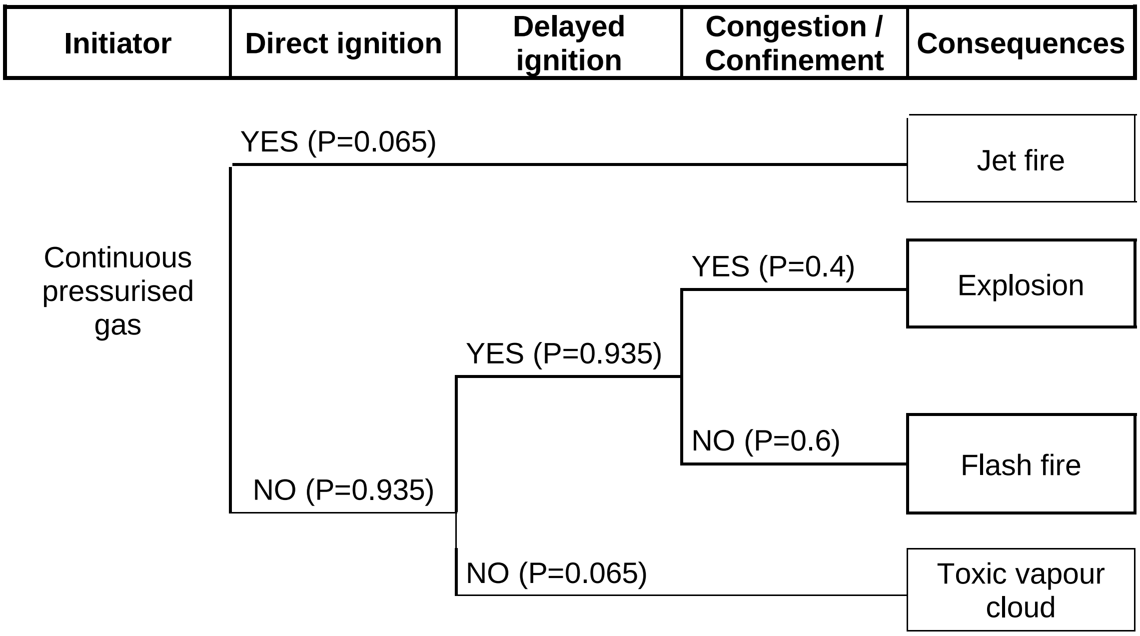


Figure 9. Event tree for a continuous release of flammable and toxic gas.

6.5. <u>Final accidents list considered in the Safety Risk Assessment</u>

Table 9 shows the final initiators considered in the Safety Report and its final accidents related. The substances related with the final accidents are those that have been decided to consider in the screening of substances of the imaginary chemical plant created. The initiating events are some examples of the most common accidents presented in the province of Barcelona, as observed in chapter 6.2.1.

Table 9. List of initiating events and final accidents.

Initiating event		Substance	Potential accidents according to event tree
G1	Leakage from the tank through an equivalent hole of 10 mm in diameter	Methanol	Pool Fire
			Flash Fire
			Explosion
			Toxic vapour cloud
G2	Catastrophic breakage of the mobile recipient.	Hydrofluoric acid	Toxic vapour cloud
G3	Partial breakage of the unloading arm (10% of the diameter with a maximum of 50 mm)	Formic acid	Toxic vapour cloud

Initiating event		Substance	Potential accidents according to event tree
G4	Partial breakage of 10% of the diameter with a maximum of 50 mm	Isopropyl alcohol	Jet Fire
			Flash Fire
			Explosion
G5	Leakage from the deposit through an equivalent hole of 10 mm in diameter	40% formaldehyde solution	Toxic vapour cloud
G6	Leakage from the tank through an equivalent hole of 10 mm in diameter	Sodium hypochlorite	Environmental consequences
G7	Partial breakage of 10% of the diameter with a maximum of 50 mm	Acrylic acid	Environmental consequences
G8	Leakage from the tank through an equivalent hole of 10 mm in diameter	Manganese (II) sulphate	Environmental consequences
E1	Confined tank explosion	Ethylene	Explosion

6.6. <u>Description of technological safeguards</u>

The technological safeguards are used to reduce the consequences of the final accidents in case that there are applicable in the scenario and are not obligatory. There are two principal types of technological safeguards according to the *Instrucció 11/2010* [18].

- Preventive measures which act on the frequency of the accident initiator.
- Mitigation measures that take effect once the release of the classified substance to the outside has started.
    - Passive mitigation such as reduction or drainage bunds
    - Active mitigation which reduces the leak time such as, for example, isolation valves
    - Active mitigation which reduces the dispersion of the gas flow, such as foam systems and gas reduction curtains

The following tables describe the technological safeguards applicable according to the initiating event.

Table 10. Technological safeguards for the initiating event G1.

<table>
<tr><th>Initiating event</th><th>Causes</th><th>Preventive safeguards</th><th>Passive mitigation</th><th>Active mitigation which conditions the duration of the leak</th><th>Active mitigation which reduces the dispersion of the gas flow</th><th>Emergency procedure according to PAU [4]</th></tr>
<tr><td>G1: Leakage from the tank through an equivalent hole of 10 mm in diameter</td><td>Generic accident initiator</td><td>Procedures, work instructions and training.
Appropriate tanks for each case and duly legalized.
Application of ATEX [5] regulations in classified areas.
Properly labelled tanks.</td><td>Retention bund</td><td rowspan="2">Firefighting system: sprinklers, hydrants, foam, fire extinguishers, etc.
Existence of the company's Intervention Team adequately trained to carry out the corresponding intervention according to the PAU procedures.</td><td>Foamogen for hydrants.
Adsorbent material collection kit.</td><td>Procedure in case of flammable product spill.
Procedure in case of toxic product spill.
Procedure in case of fire in outdoor tank farm.</td></tr>
<tr><td>G2: Catastrophic breakage of the mobile recipient.</td><td>Generic accident initiator</td><td>Procedures, work instructions and training.
Application of ATEX regulations in classified areas.
Approved and well labelled containers according to their hazardous nature.
Legalized and adequate storage for the substances.</td><td>Retention bund, confinement in the warehouse</td><td>Sectorized storage building equipped with fire protection measures.
Foamogen for hydrants.
Adsorbent material collection kit.</td><td>Procedure in case of toxic product spill.</td></tr>
</table>

[4] PAU: Autoprotection Plan. It is a document where it is described the response to emergency situations in order to provide effective protection to people, environment and facility assets, ensuring the integration between the resources of the company and the external aid [24].

[5]ATEX: explosive atmosphere. It is an atmosphere where air and flammable substances are mixed in the form of gas, vapours o mists and combustible dusts under atmospheric conditions. In these atmospheres it spreads to the unburned mixture after ignition [26]. This atmosphere could be explosive depending on the circumstances of the environment and the substances implicated. There are special regulations for these situations.

<table>
<tr><th>Initiating event</th><th>Causes</th><th>Preventive safeguards</th><th>Passive mitigation</th><th>Active mitigation which conditions the duration of the leak</th><th>Active mitigation which reduces the dispersion of the gas flow</th><th>Emergency procedure according to PAU [4]</th></tr>
<tr><td>G3: Partial breakage of the unloading arm (10% of the diameter with a maximum of 50 mm)</td><td rowspan="2">Generic accident initiator</td><td rowspan="4">Procedures, work instructions and training.
Appropriate tanks for each case and duly legalized.
Application of ATEX regulations in classified areas.
Properly labelled tanks.</td><td>Retention bund</td><td rowspan="4">Firefighting system: sprinklers, hydrants, foam, fire extinguishers, etc.
Existence of the company's Intervention Team adequately trained to carry out the corresponding intervention according to the PAU procedures.</td><td rowspan="2">Foamogen for hydrants.
Abdsorbent material collection kit.</td><td rowspan="2">Procedure in case of toxic product spill.</td></tr>
<tr><td>G4: Partial breakage of 10% of the diameter with a maximum of 50 mm</td><td>-</td></tr>
<tr><td>G5: Leakage from the deposit through an equivalent hole of 10 mm in diameter</td><td>Generic accident initiator</td><td>-</td><td>Foamogen for hydrants.
Water sprinkler system.</td><td>Procedure in case of toxic product spill.</td></tr>
<tr><td>E1: Confined tank explosion</td><td>Temperature and pressure increase in the tank</td><td>-</td><td>Foamogen for hydrants.
Water sprinkler system.</td><td>Procedure in case of explosion.</td></tr>
</table>

7. CONSEQUENCES CALCULATION

To determinate the affected zones by the final accidents, some criteria are assumed which will be explained in this chapter.

7.1. Meteorological conditions

One important point to consider is the meteorological data. Depending on the location of the chemical plant, temperature, wind velocity and humidity are different.

In Catalonia there are some meteorological stations distributed throughout the territory. For the modelling of accidents, the meteorological data obtained at the station closer to the chemical plant are used. The following figure shows all the meteorological stations and its location.

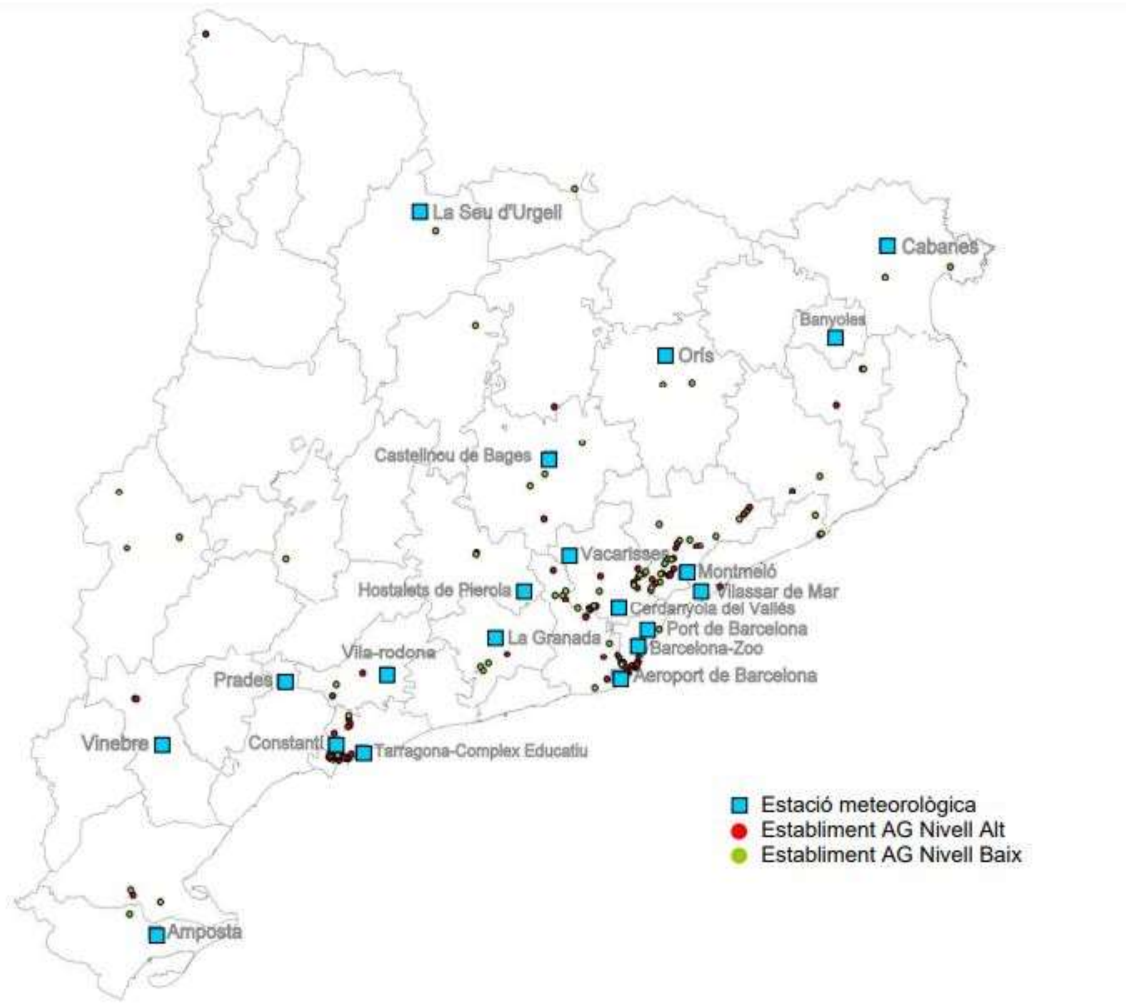


Figure 10. Meteorological stations in Catalonia [22].

Atmospheric stability describes the tendency of mixing in the atmosphere between air and a pollutant, due to the generation of turbulences by natural forces [31]. The most used classification of stabilities is the proposed by Pasquill and Gifford, which assigns a letter from A to G for the different conditions. The following table shows the description of each stability class, in which A is the most unstable and F the most stable.

Table 11. Meteorological conditions that define the Pasquill stability classes [32].

Surface windspeed		Daytime incoming solar radiation			Nighttime cloud cover	
m/s	mi/h	Strong	Moderate	Slight	> 50%	< 50%
< 2	< 5	A	A - B	B	E	F
2 - 3	5 - 7	A - B	B	C	E	F
3 - 5	7 - 11	B	B - C	C	D	E
5 - 6	11 - 13	C	C - D	D	D	D
> 6	> 13	C	D	D	D	D

Note: Class D applies to heavily overcast skies, at any windspeed day or night

According to the *Instrucció 11/2010* [18] the consequences are calculated for two meteorological conditions: Pasquill stability most probable, which is stability D and Pasquill stability F, which is the calmest.

Most of the chemical plants of the study are placed in the Vallès Oriental or Vallès Occidental since there are a large variety of industrial parks. Therefore, for the imaginary chemical plant created, the meteorological station of the Cerdanyola del Vallès, placed in the region of Vallès Occidental, is considered.

Table 12. Meteorological data of the Cerdanyola del Vallès station.

Average temperature (ºC)	Average relative humidity (%)	Pasquill Stability and wind velocity	
15.4	66%	2.80 m/s (Est. D)	1.36 m/s (Est. F)

The complete meteorological data are shown in the Annex C.

7.2. Description of the terms considered

7.2.1. Duration of the leak

The standard or generic duration of the leak standard is 30 minutes, according to the *Instrucció 11/2010* [18], but it can be reduced depending on the safeguards that are applied. The next table shows the times established.

Table 13. Time duration of the leak.

Description	**Total time for detection and action**
Fully automatic detection and actuation (no operator action required).	2 min
Automatic detection and remote actuation (from control room).	10 min
Automatic detection and manual actuation.	30 min

If the time is less than 2 minutes, it is considered also 2 minutes.

For the loading and unloading operations a time of 2 minutes can be considered if the following points from the reference manual BEVI [21] are fulfilled:

1) Presence of an operator during all the operation on-site and with a direct vision of the arm or hose.
2) Guarantee the presence of an operator on-site by a deadman's handle or by a specific procedure.
3) The activation of the emergency stop button, in case of fire, during the operation is included in the procedure.
4) The operator is adequately trained and knows the procedure.
5) The emergency stop button is located in accordance with the standards in such a way as to guarantee a short intervention regardless of the direction of the fire.

7.2.2. Extension of the pool

There are two options according to the criteria F3-12 and F3-13 of the *Instrucció 11/2010* [18]:

- If there is no confinement, such a retention bund, it is considered a maximum extension of 1,500 m^2 in land and 10,000 m^2 in case of spill into the sea.
- If there is a confinement, the extension is the area of the retention bund.

In addition, when there is no leak, and there is a catastrophic breakage, the entire content of the equipment releases immediately, considering it as an instantaneous leakage.

7.2.3. Explosions

In case of explosions, the consequences are only calculated when the amount of gas between the flammability limits is higher than 1,000 kg, according to the criteria F3-20 of the *Instrucció 11/2010* [18]. To determinate the explosion, of the maximum cloud, is used the model of the Yellow Book [23] implemented in the program EFFECTS, with a curve of 6 and a confinement value of 0.08, as indicated in the criteria F3-21 of the *Instrucció 11/2010* [18]. The curve indicates the type of explosion considered, which, the case of curve 6, means that is a strong deflagration. The confinement value of 0.08 is associated with the mass fraction of the total flammable cloud that occupies obstructed regions as an average value since a detailed obstructed regions analysis is not carried out for the Seveso Safety Report.

The parameters decided for each initiating event are described in the Annex D. As an example, one of these tables is shown here.

Table 14. Parameters for the initiating event G1.

EQUIPMENT DATA			SOURCE TERM		
Product	Methanol		Amount released	487.66	kg
Type of vessel	Horizontal cylinder				
Volume	67	m^3	Leak time	1800	s
Filling degree	90	%			
Length cylinder	10	m	Average leakage rate	0.27	kg/s
Process temperature	15.4	ºC			

EQUIPMENT DATA			SOURCE TERM		
Process pressure	1.01551	bar	Active mitigation safeguard	- Firefighting system - Existence of the company's Intervention Team	
LEAKAGE SCENARIO DATA			**SOURCE TERM EVAPORATION / DISPERSION FLAMMABLE AND TOXIC DISPERSION**		
Confined leak	Yes		Size of the puddle	90.3 m^2	
Passive mitigation safeguard	Retention bund		Evaporation rate 2.80D:	0.047	kg/s
Area of the retention bund	1.316	m^2	Evaporation rate 1.36F:	0.035	kg/s
Nature of the soil	Concrete		Evaporation time	1800	s
Roughness	-	m	Active mitigation safeguards	-	
Reference meteorological station	Cerdanyola del Valès		Evaporation time after safeguarding	-	s
Ambient temperature	15.4	ºC	**SOURCE TERM EXPLOSION**		
Humidity	66	%	Amount of gas between LII – 2.80D:	< 1000	kg
Ground temperature	15.4	ºC			
Most likely weather conditions	D/F		Amount of gas between LII – 1.36F:	< 1000	kg
Wind velocity	2.80/1.36	m/s			

7.3. <u>Definition of thresholds for the planification zones and domino effect</u>

A risk zone is defined as a zone situated around the focus of an accident, where the magnitude of the hazard exceeds the thresholds defined. The Real Decreto 1196/2003 [15] defines 3 levels of danger:

- <u>Intervention zone:</u> the consequences of the accident, in this zone, produce a level of danger that justifies the immediate application of protection measures.
- <u>Alert zone:</u> the consequences of the accident, in this zone, cause slow effects and, although the population perceive these effects, it is not justified the intervention, except for the critical population groups.

- Domino effect: an accident in a plant has consequences for a neighbouring chemical plant or for different facilities inside the same plant.

The thresholds defined are different for each accident. The following table shows these values according to the *Instrucció 11/2010* [18] and Real Decreto 1196/2003 [15].

Table 15. Thresholds for each physical effect.

<table>
<tr><th colspan="2">Physical effect</th><th>Intervention zone</th><th>Alert zone</th><th>Domino effect</th></tr>
<tr><td colspan="2">Thermic radiation 1</td><td>250 $(kW/m^2)^{4/3}\cdot s$</td><td>115 $(kW/m^2)^{4/3}\cdot s$</td><td>8 kW/m^2</td></tr>
<tr><td rowspan="2">Overpressure</td><td>Integrated local value of the impulse due to the pressure wave</td><td>150 mbar·s</td><td>100 mbar·s</td><td rowspan="2">160 mbar</td></tr>
<tr><td>Local static overpressure of the wave pressure</td><td>125 mbar</td><td>50 mbar</td></tr>
<tr><td colspan="2">Projectiles</td><td>Maximum range of projectile with an impulse exceeding 10 mbar·s at a rate of 95%.</td><td>Maximum range of projectile with an impulse exceeding 10 mbar·s at a rate of 99%.</td><td>-</td></tr>
<tr><td colspan="2">Toxic concentration</td><td>AEGL-2 o ERPG-2/PAC-2 o TEEL.2</td><td>AEGL-1 o ERPG-1/PAC-1 o TEEL.1</td><td>-</td></tr>
</table>

For dispersion of flammable substances, the intervention zone is defined by the LFL (Low Flammability Limit), and the alert zone by the 50% of the LFL.

Finally, for the dispersion of toxic substances, the definition of planification zones depends on these tree values, AEGL[6] or ERPG[7] or TEEL[8], in this order, according to the *Instrucció 11/2010* [18] and Real Decreto 1196/2003 [15].

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[6] AEGL: Acute Exposure Guideline Level. It describes the human health effects from once-in-a-lifetime, or rare, exposure to airborne chemicals [27].

[7] ERPG: Emergency Response Planning Guideline. It is an air concentration guideline for single exposures to agents [33].

[8] Temporary Emergency Exposure Limits. Estimate the concentrations at which most people will begin to experience health effects if they are exposed to a hazardous airborne chemical for a given duration [34].

Table 16. Criteria for the definition of zones.

Substance	**Intervention zone**		**Alert zone**		**Reference**
	Rate	**Value**	**Rate**	**Value**	
Methanol	AEGL-2	4000 ppm	AEGL-1	670 ppm	For an exposition of 30 minutes (U.S Environmental Protection Agency, EPA [27])
Hydrofluoric acid	AEGL-2	34 ppm	AEGL-1	1 ppm	
Formic acid	ERPG-2	25 ppm	ERPG-1	3 ppm	Values for an exposition 60 minutes (CAMEO Chemicals [28])
40% formaldehyde solution	ERPG-2	10 ppm	ERPG-1	1 ppm	

The difference between the AEGL-1 and the AEGL-2 is the consequences of the inhalation of the toxic substance. In the AEGL-1 the population may experience significant discomfort such as slight odour, taste, or other mild sensory irritation, that disappear when you stop being in contact with the toxic substance. In the AEGL-2 the population may experience serious or irreversible long-term effects or be hindered in their ability to escape. The same concept is for the ERPG-1 and ERPG-2.

Table 17. Results obtained for the planification and domino effect zones.

Initiating event		Substance	Final accidents according to the even tree	Planification and domino effect zones					
				Ratio ZI (m)		Ratio ZA (m)		Ratio ZD (m)	
				2.8[9]D	1.36F	2.8D	1.36F	2.8D	1.36F
G1	Leakage from the tank through an equivalent hole of 10 mm in diameter	Methanol	Pool Fire	5	5	6	6	5	5
			Flash Fire	-	-	-	-	NA	NA
			Explosion	NC	NC	NC	NC	NC	NC
			Toxic vapour cloud	54	76	20	25	NA	NA
G2	Catastrophic breakage of the mobile recipient	Hydrofluoric acid	Toxic vapour cloud	213	631	1400	5600	NA	NA
G3	Partial breakage of the unloading arm (10% of the diameter with a maximum of 50 mm)	Formic acid	Toxic vapour cloud	93	243	285	894	NA	NA
G4	Partial breakage of 10% of the diameter with a maximum of 50 mm	Isopropyl alcohol	Jet Fire	7	6	9	8	7	6
			Flash Fire	6	12	10	20	NA	NA
			Explosion	NC	NC	NC	NC	NC	NC
G5	Leakage from the deposit through an equivalent hole of 10 mm in diameter	40% formaldehyde solution	Toxic vapour cloud	31	63	98	209	NA	NA
E1	Confined tank explosion	Ethylene	Explosion	21		41		18	

The plans of the features with the curves of the planning and domino effect areas are shown in Annex E.

[9] The values 2.8 and 1.36 refer to the wind velocity considered for the corresponding stability D and F.

These are the distances obtained for the initiating events suggested. In addition, Protecció Civil made a map with the maximum distances of the intervention and alert zone.

Figure 11. Maximum distances for the intervention and alert zone [19].

As it can be seen in Figure 11, the large intervention and alert zones are found in the provinces of Tarragona and Barcelona, where there are a large number of chemical plants placed in industrial parks.

7.4. <u>Environmental assessment</u>

In the imaginary chemical plant created there are 3 substances that are hazardous for the environment:

- Sodium hypochlorite

- Acrylic acid
- Manganese (II) sulphate

The risk associated to these substances has to be evaluated. There are some methods to do that, but the *Instrucció 11/2010* [18] recommend the application CIRMA developed by the *Dirección general de Protección Civil y Emergencias.* This study is semiquantitative and considers one initiating event for each hazardous substance involved. The methodology is based on the estimation of an environmental risk index from the evaluation and parameterization of the four components that constitute the risk system: sources of risk, primary control systems, transport systems and vulnerable receivers.

7.4.1. Sources of risk

First, the sources of risk for the environment have to be determined. As the substances present in the plant appear in the part 1 of the Annex of the Real Decreto 840/2015 [16], the score for the source of risk is obtained directly related to the substance implied.

Table 18. Score for the source of risk.

Aquatic Environment Phrase [R]	**Points**	**Non-Aquatic Environment Phrase [R]**	**Points**
R50 (H400)	10	R54/R57	10
R50/R53 (H410)	10	R54	10
R51/R53 (H411)	8	R55/R57	8
R52/R53 (H412)	5	R56/R57	5
R52 y / o R53 (H412 / H413)	5	R58	4
		R59 (EUH059)	4

In addition, there are three more factors that could affect the score:

- Mix of substances
- Synergy effects
- The amount of substance stored or involved in the accident.

7.4.2. Primary control systems

The primary control systems are the prevention and protection measures implemented in order to keep the source of risk in control conditions every time.

This evaluation is done considering the efficiency of the control systems, the amount involved in the accident and the particular conditions of the risk source.

Table 19. Score depending on the amount involved.

Amount involved on the accident (t)	Points
> 500	10
50-500	7
5-49	5
0.5-4,9	3
< 0.5	1

7.4.3. Transport systems

The assessment should describe how the hazardous compound may reach the receiving environment, the affected area (air, surface or groundwater, soil) and the magnitude of the potential impact.

The maximum punctuation is established according to the following thresholds.

Table 20. Score for the transport systems

Type of medium	Size affected	Points
River, canal, stream, etc.	> 10km	10
Lake, pond, delta, etc.	> 2Ha	10
Non-aquatic environment (including air, soil and groundwater)	> 0.180km	10

When the extension does not exceed the boundaries of the site, a value of 1 is assigned.

7.4.4. Vulnerable receivers

The vulnerable receivers are the elements of the environment that could be affected if they are exposed to the source of risk (hazardous compounds). The evaluation of the quality/vulnerability of these elements is essential to limit the consequences associated with an accident and its impact on the environment. This evaluation includes an assessment of the natural environment, the socio-economic environment and the magnitude of the potential impact.

The receivers vulnerability is determined following the next steps:

1) Definition of habitat type according to the UTM coordinates of the site.
2) Obtaining the naturalness index and cover type using Annex I of Directive 92/43/EEC, in cases where the data are not included in the above Directive, a consultation of the EUNIS habitat classification is carried out.

The evaluation is based on the following table:

Table 21. Score of the vulnerable receivers.

Habitat	Naturalness index	Priority habitat	Comments / Recommendations	Points
Code J Habitat of industrial developments and other habitat types	-	-	Code J1, Code J3, Code J4,	1
	-	-	Code J4, Code J6	
	-	-	Code J2, Code J5	2
Code I Agricultural, horticultural habitats regularly or recently cultivated	-	-	Code I2	3
	-	-	Code I1	4
Habitats classified under Annex I of the Habitats Directive 92/43/EEC	1	NO	-	5
	1	YES	-	6
	2	NO	-	7
	2	YES	-	8
	3	NO	-	9
	3	YES	-	10

There are some conditioning factors that may modify the score awarded using the criteria in the table above.

Table 22. Increases according to conditioning factors.

Habitat		Points
Protected natural areas in the area of influence	Existent	30
	Does not existent	0
Species protection categories	In danger of extinction	10
	Sensitive to habitat alteration	8
	Vulnerable	5
	Of special concern	2
	No protection category	0
Historical and artistic heritage	Immovable property with the category of property of cultural interest	10

Habitat		Points
	Immovable property with any other type of protection category	5
	None of the above	0
Reversibility of damage / recovery	Possible permanent damage	10
	Recuperation time of 5 to 20 years	
	Recuperation time of 1 to 5 years	
	Recuperation time of weeks to 1 year	5
	Days	
Socio – economic impact	Disruption of economic activity (one or more to a significant degree) AND impact on some type of infrastructure in the vicinity	40
	Disruption of economic activity (one or more to a significant degree) OR impact on some form of infrastructure in the environment	20
	None of the above	0

7.4.5. Global index of environmental consequences

The global index of environmental consequences (IGCM) is the value associated to the total punctuations for each component of the assessment. The score achieved is between 3 and 40 points. Then, the score is converted to a global scale between 1 and 20, considering the relative weight that the methodology gives to each component within the IGCM.

7.4.6. Likelihood / frequency of the event

Table 23. Score of the frequency of the event.

Frequency	Score
Between once a year and once every 5 years	5
Between once every 5 years and once every 25 years	4
Between once every 25 years and once every 50 years	3
Between once every 50 years and once every 100 years	2
Between once every 100 years and once every 500 years	1

Table 24: Likelihood of the event

Likelihood of the event	Score
$x > 10^{-2}$	5
$10^{-4} < x < 10^{-2}$	4
$10^{-6} < x < 10^{-4}$	3
$10^{-8} < x < 10^{-6}$	2
$x < 10^{-8}$	1

7.4.7. Environmental Risk Index (IRM)

The environmental risk index is calculated as the product of the global index of environmental consequences by the frequency.

The score obtained of this index is in a scale between 1 and 100 considering the frequency and the likelihood.

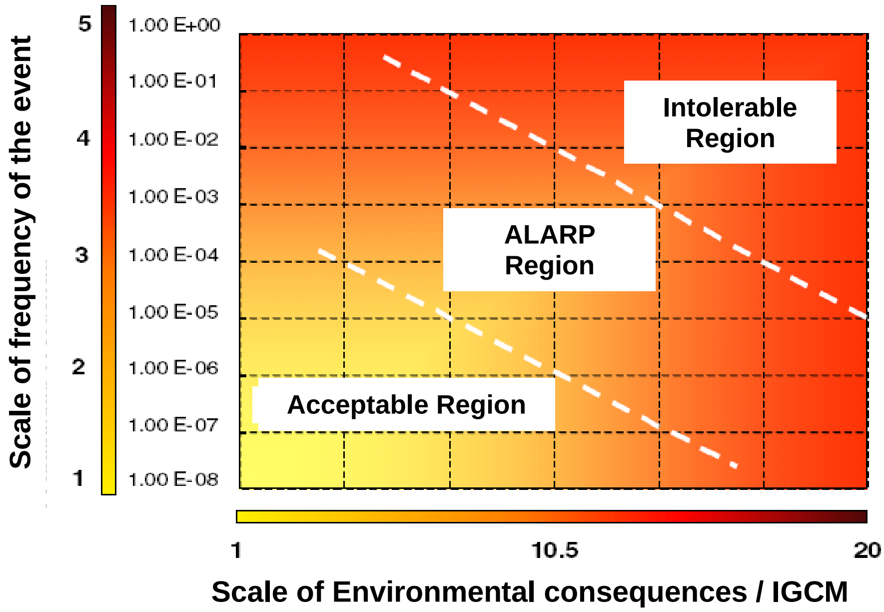

Figure 12. Environmental risk assessment and tolerability [35]

Intolerable Region: in this case risk reduction measures should be implemented, irrespective of the associated cost.

ALARP (As Low As Reasonably Practicable) zone: in this case the risk is tolerable, but should be reduced to as low a level as practicable without incurring disproportionate costs.

Acceptable Risk: here the level of risk is acceptable, and excessive costs are likely to be incurred if measures are taken to achieve further reduction.

The calculation of each scenario is shown in Annex G and the following table summarises the results.

Table 25. Results from the environmental assessment.

Hypothesis		Substance	Score FR	Score ST	Score RV	IGCM	Likelihood/ Frequency	Environmental Risk Index or Value	Risk Assessment
G6	Leakage from the tank through an equivalent hole of 10 mm in diameter	Sodium hypochlorite	5.16	1.00	1.05	4.03	3	12.08	Acceptable Risk
G7	Partial breakage of 10% of the diameter with a maximum of 50 mm	Acrylic acid	5.16	1.00	1.05	4.03	4	16.10	Acceptable Risk
G8	Leakage from the tank through an equivalent hole of 10 mm in diameter	Manganese (II) sulphate	3.92	1.00	1.05	3.42	3	10.26	Acceptable Risk

7.5. Domino effect study

According to the Real Decreto 1196/2003 [15], the domino effect is the concatenation of risk-causing effects that multiplies the consequences, because the hazardous phenomena may affect, in addition, to the external vulnerable elements, other containers, pipes or equipment of the same or of other nearby sites, in such a way that a new leak, fire, explosion may occur in them, which in turn cause new hazardous phenomena. There are two types of domino effect: intra-establishment and inter-establishment. In the following sections these two concepts are described.

7.5.1. Domino effect intra-establishment

The domino effect intra-establishment means that an accident in one equipment in the plant causes, in turn, an accident in another equipment, and so on. In this way, a series of chained and successive accidents occur that can cause great damage. Summarizing, a sequence of accidents could develop in a major accident.

As shown in Table 15, the dispersion of the toxic vapour cloud does not produce a domino effect on the other equipment in the chemical plant. As a result, only the scenarios G1, G4 and E1 could develop and impact on the other equipment.

Table 26. Domino effect intra-establishment.

Initiating event		**Substance**	**Final accidents according to the even tree**	**Ratio domino effect (m)**	**Equipment/units affected**
G1	Leakage from the tank through an equivalent hole of 10 mm in diameter	Methanol	Pool Fire	5	Tanks adjacent to the affected tank
			Flash Fire	NA	
			Explosion	NC	
G4	Partial breakage of 10% of the diameter with a maximum of 50 mm	Isopropyl alcohol	Jet Fire	7	Equipment in the pipeline route
			Flash Fire	NA	
			Explosion	NC	
E1	Confined tank explosion	Ethylene	Explosion	18	Tanks adjacent to the affected tank

7.5.2. Domino effect inter-establishment

In this case, if an accident occurs, the consequence of it could affect other chemical plants that are nearby in the same industrial park. This occurs when the different chemical plants are very close to each other and sometimes sharing walls. In this case, as it is an imaginary case, it is not considered the domino effect inter-establishment.

Not only the final accidents occurred could damage other installations but, also, the accident in the other chemical plants could affect the chemical plant studied.

8. CALCULATION OF VULNERABILITY

The calculation of vulnerability is carried out by the PROBIT methodology. According to the equations shown in table 19, the Probit value (Y) is calculated. This value relates the concentration, the radiation intensity or the overpressure, depending on the accident type, with the percentage of persons affected in the accident considered. In the Risk Assessment, two percentages are considered: the affectation of 1% and the affectation of 0.1% of the population. For the concentration of toxic dispersions, the ratio of 0.1% is considered inside the buildings next to the chemical plant where the accident takes place, therefore the ventilation of the building is very important. According to the criteria F4-2 of the *Instrucció 11/2010* [18], two types of ventilation are considered: 0.5 renovations/hour and 1 renovation/hour.

The lethality areas of 1% are calculated for the effects of thermic radiation, overpressure and concentration of toxic dispersions. The next table shows how to calculate the lethality thresholds.

Table 27. Thresholds for lethality.

Accident	DL1 (Lethality dose 1%)	DL 0.1 (Lethality dose 0.1%)
Pool fire	Y = 2.67 Probit Y = -36.38+2.56 ln($I^{4/3}$ t) t ≥ 20s (I= 9.8W/m^2)	NA
Jet fire	-	NA
BLEVE	Y=2.67 Probit Y= -36.5+2.56 ln($I^{4/3}$ t) t = duration of the BLEVE	NA
Flash fire	-	NA
Explosion	300 mbar	NA
Toxic dispersion	Calculation of the dose D($C^{n\cdot}$*t) Y = 2.67 Probit Y = a + b ln D	Calculation of the dose D(C^n*t) Y = 1.97 Probit Y = a + b ln D

For flash fire and jet fire it is not considered the calculation of the lethality since matches with the intervention zone calculated in the previous chapter, according to the criteria F4-4 of the *Instrucció 11/2010* [18].

For the toxic substances, the Probit parameters a, b and n are necessary to calculate the lethality dose.

Table 28. Probit parameters.

Substance	**a**	**b**	**n**	**Units**	**References**
Methanol	-20.41	1	2	mg/m^3	Criteria Probit Generalitat [29]
Hydrofluoric acid	-8.4	1	1.5	mg/m^3	
Formic acid	-14.8	1	2	mg/m^3	Rijksinstituut voor Volksgezondheid en Milieu [30]
40% formaldehyde solution	-11.33	1	2	mg/m^3	Criteria Probit Generalitat [29]

The lethality dose is calculated as explained in Table 27. The results are shown in Table 29.

Table 29. Concentration and Dose Lethality for toxic substances.

Lethality (%)	**Probit Y**	**Substance**	**Concentration (mg/m^3)**	**Dose ($(mg/m^3)^n \cdot min$)**
0.1%	1.97	Methanol	13218.9	$5.24 \cdot 10^9$
1%	2.67		18758.5	$1.06 \cdot 10^{10}$
0.1%	1.97	Hydrofluoric acid	104.2	$3.19 \cdot 10^4$
1%	2.67		166.1	$6.42 \cdot 10^4$
0.1%	1.97	Formic acid	799.8	$1.92 \cdot 10^7$
1%	2.67		1135.0	$3.86 \cdot 10^7$
0.1%	1.97	40% formaldehyde solution	141.1	$5.97 \cdot 10^5$
1%	2.67		200.2	$1.20 \cdot 10^6$

Table 30. Results obtained for the vulnerability.

Initiating event		Substance	Final accidents according to the even tree	Lethality areas (m)					
				Ratio DL1%		Ratio DL01%			
				2.8D	1.36F	2.8D		1.36F	
						0.5 h^{-1}	1 h^{-1}	0.5 h^{-1}	1 h^{-1}
G1	Leakage from the tank through an equivalent hole of 10 mm in diameter	Methanol	Pool Fire	5	5	NA	NA	NA	NA
			Flash Fire	-	-	-	-	NA	NA
			Explosion	NC	NC	NC	NC	NC	NC
			Toxic vapour cloud	11	11	11	11.3	11	11.4
G2	Catastrophic breakage of the mobile recipient.	Hydrofluoric acid	Toxic vapour cloud	88	260	69	88	195	251
G3	Partial breakage of the unloading arm (10% of the diameter with a maximum of 50 mm)	Formic acid	Toxic vapour cloud	18	33	11.5	17	23	32
G4	Partial breakage of 10% of the diameter with a maximum of 50 mm	Isopropyl alcohol	Jet Fire	6	5	NA	NA	NA	NA
			Flash Fire	10	20	NA	NA	NA	NA
			Explosion	NC	NC	NC	NC	NC	NC
G5	Leakage from the deposit through an equivalent hole of 10 mm in diameter	40% formaldehyde solution	Toxic vapour cloud	< 10	16	5.8	7.3	11.6	14.7
E1	Confined tank explosion	Ethylene	Explosion	14		NA		NA	

9. SELECTION OF ACCIDENTS FOR THE EXTERNAL EMERGENCY PLAN PEE

The idea of this chapter is to determine the accidents that must be considered in the external emergency plan according to its frequency and the *Instrucció 11/2010* [18]. All the final accidents are considered except for the ones that have a frequency of occurrence of the initiator lower than 10^{-6}/year.

The frequency is obtained according to the reference manual BEVI [21] for each generic accident initiator. For the specific accident initiator, the frequency is determined by the technique of fault tree.

Table 31: Base frequency for the generic accident initiators

Equipment	Generic accident initiators	Base frequency	Reference BEVI 3.2
Fixed tanks /reactors /columns / etc.	Continuous leakage from the equipment through an equivalent hole of 10 mm in diameter	Aboveground or underground pressure tank: 10^{-5}/year	Sections 3.4.3 and 3.5.3
		Atmospheric storage tank, process and reactor or distillation column: 10^{-4}/year	Sections 3.6.3., 3.9.3. and 3.10.3
Pumps / compressors	Leakage from the tank through an equivalent hole of 10 mm in diameter of the pipe	Centrifuge: - Without seal: $5 \cdot 10^{-5}$ año^{-1} - With seal: $4.4 \cdot 10^{-3}$ año^{-1} Reciprocal: $4.4 \cdot 10^{-3}$ año^{-1}	Section 3.11.2
Mobile liquid containers	Catastrophic rupture unless it can be clearly justified that due to the constructional characteristics of the equipment the event can be avoided. In such a case a 50 mm diameter orifice in the liquid phase shall be considered.	10^{-5}/year and container	Sections 8.7.3 and 8.7.5
Pipes	Partial breakage of 10% of the diameter with a maximum of 50 mm	$5 \cdot 10^{-6}$/year·m for diameter < 75 mm $2 \cdot 10^{-6}$/year·m for diameter between 75 mm to 150 mm $5 \cdot 10^{-7}$/year·m for diameter > 150 mm	Section 3.8.2
Truck or tank car loading/unloading stations	Partial breakage of the loading/unloading arm/hose (10% of the diameter with a maximum of 50 mm)	10^{-7}/hour for arms of loading/unloading $4 \cdot 10^{-5}$/hour for hose of loading/unloading	Section 3.15

The results of the frequency of occurrence of the generic accident initiators considered in the Safety Report are shown in Table 32.

Table 32. Frequency of occurrence of the initiating event considered in the Safety Report.

Initiating event		**Frequency of the initiator**			**Final accidents**			
		Base frequency	**Considerations**	**Initiator frequency (times/year)**	**Type**	**Final frequency (times/year)**		**Discarded from PEE**
						2.8D	**1.36F**	
G1	Leakage from the tank through an equivalent hole of 10 mm in diameter	$1 \cdot 10^{-4}$ year^{-1}	The tank is atmospheric and is always full. There are 2 tanks.	$2.0 \cdot 10^{-4}$	Thermic radiation	$2.0 \cdot 10^{-4}$		NO
					Dispersion of the toxic vapour cloud [10]	$1.89 \cdot 10^{-5}$	$2.10 \cdot 10^{-5}$	NO
G2	Catastrophic breakage of the mobile recipient	$1 \cdot 10^{-5}$ container^{-1}	It is considered that there are 13 containers	$1.3 \cdot 10^{-4}$	Dispersion of the toxic vapour cloud	$1.23 \cdot 10^{-5}$	$1.37 \cdot 10^{-5}$	NO
G3	Partial breakage of the unloading arm (10% of the diameter with a maximum of 50 mm)	$4 \cdot 10^{-5}$ h^{-1}	It is used 2 arms 12 hours when the acid formic is packed	$9.60 \cdot 10^{-4}$	Dispersion of the toxic vapour cloud	$9.08 \cdot 10^{-5}$	$1.01 \cdot 10^{-4}$	NO
G4	Partial breakage of 10% of the diameter with a maximum of 50 mm	$5 \cdot 10^{-6}$ a^{-1} m^{-1}	Pipe (ø < 75 mm) which is always full and with a longitude of 20 m	$1.0 \cdot 10^{-4}$	Thermic radiation	$1.0 \cdot 10^{-4}$		NO
					Dispersion of the toxic vapour cloud	$9.46 \cdot 10^{-5}$	$1.05 \cdot 10^{-5}$	NO
G5	Leakage from the deposit through an equivalent hole of 10 mm in diameter	$1 \cdot 10^{-4}$ year^{-1}	The deposit is atmospheric and is always full. There are 3 tanks	$3.0 \cdot 10^{-4}$	Dispersion of the toxic vapour cloud	$2.84 \cdot 10^{-5}$	$3.16 \cdot 10^{-5}$	NO

[10] For the dispersion of the toxic vapour cloud the final frequency is calculated considering the probability of stabilities of the wind velocity following the point 5.2 of the *Instrucció 11/2010* [18].

Initiating event		Frequency of the initiator				Final accidents		
		Base frequency	Considerations	Initiator frequency (times/year)	Type	Final frequency (times/year)		Discarded from PEE
						2.8D	1.36F	
G6	Leakage from the tank through an equivalent hole of 10 mm in diameter	$1 \cdot 10^{-4}$ $year^{-1}$	The tank is atmospheric and is always full. There is one tank.	$1.0 \cdot 10^{-4}$	Spill of content. Environmental consequences	$1.0 \cdot 10^{-4}$		NO
G7	Partial breakage of 10% of the diameter with a maximum of 50 mm	$2 \cdot 10^{-6}$ a^{-1} m^{-1}	Pipe (75 mm < ø < 150 mm) which is always full and with a longitude of 45 m	$1.3 \cdot 10^{-4}$	Spill of content. Environmental consequences	$1.3 \cdot 10^{-4}$		NO
G8	Leakage from the tank through an equivalent hole of 10 mm in diameter	$1 \cdot 10^{-4}$ $year^{-1}$	The tank is atmospheric and is always full. There are 2 tanks.	$9.0 \cdot 10^{-5}$	Spill of content. Environmental consequences	$9.0 \cdot 10^{-5}$		NO
E1	Confined tank explosion[11]	-	-	-	-	$1.2 \cdot 10^{-6}$		NO

[11] The final frequency of the initiating event E1 is calculated by the methodology of the fault tree, described in the chapter 6.3.

10. RELATION OF MAJOR ACCIDENTS IDENTIFIED

After ruling out scenarios not included in the external emergency plan, the accidents considered are classified in three categories, depending on the consequences, according to the Real Decreto 1196/2003 [15]. The categories are the following ones:

- **Category 1:** accidents with the only consequence of the property damage in the site and no damage in the exterior.
- **Category 2:** accidents with possible deaths and property damage inside the plant and minor damage outside the plant or adverse effects on the environment in limited areas.
- **Category 3:** accident with deaths and serious damage to property or serious disturbance of the environment in large areas inside and outside the site.

The Table 33 shows the classification of the accidents studied in the Risk Assessment.

Table 33. Classification of accidents.

Initiating event		Substance	Final accidents according to the even tree	Planification and domino effect zones										Category of the accident
				Ratio ZA [m]		Ratio ZI [m]		Ratio ZD [m]		Ratio DL 1% [m]		Radio DL 0.1% inside the building [m]		
				2.8D	1.36F	2.8D	1.36F	2.8D	1.36F	2.8D	1.36F	2.8D	1.36F	
G1	Leakage from the tank through an equivalent hole of 10 mm in diameter	Methanol	Pool Fire	5	5	6	6	5	5	5	5	NA	NA	2
			Flash Fire	-	-	-	-	NA	NA	-	-	-	NA	
			Explosion	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	
			Toxic vapour cloud	54	76	20	25	NA	NA	11	11	11.3	11.4	
G2	Catastrophic breakage of the mobile recipient	Hydrofluoric acid	Toxic vapour cloud	213	631	1400	5600	NA	NA	88	260	88	251	3
G3	Partial breakage of the unloading arm (10% of the diameter with a maximum of 50 mm)	Formic acid	Toxic vapour cloud	93	243	285	894	NA	NA	18	33	17	32	3
G4	Partial breakage of 10% of the diameter with a maximum of 50 mm	Isopropyl alcohol	Jet Fire	7	6	9	8	7	6	6	5	NA	NA	1
			Flash Fire	6	12	10	20	NA	NA	10	20	NA	NA	
			Explosion	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	
G5	Leakage from the deposit through an equivalent hole of 10 mm in diameter	40% formaldehyde solution	Toxic vapour cloud	31	63	98	209	NA	NA	< 10	16	7.3	14.7	2
E1	Confined tank explosion	Ethylene	Explosion	21		41		18		14		NA		1

11. CONCLUSIONS

In this work, 53 chemical plants in the province of Barcelona have been studied. The main sectors in the chemical plants involved are storage, manufacturing, and transport of chemical substances. In these chemical plants there is a lot of equipment that could generate accidents. Doing this study, the basic methodology of the Safety Report can be understood, considering the *Instrucció 11/2010* [18] as the main base for it.

Six initiating events, mentioned in the Table 33, with hazard consequences for people are studied and also three initiating events with hazard consequences for the environment. Of the six initiating events, two of them are category 1, two more category 2 and the last two are category 3. Therefore, these four scenarios, the two leakages from the equipment, the catastrophic breakage of the mobile recipient and the partial breakage of the unloading arm, have consequences outside the plant and two of them (catastrophic breakage and the partial breakage of the unloading arm) have serious consequences for people and the environment.

The main accidents produced are the leakage from the equipment and the partial breakage of the arm or hose in loading or unloading activities. In case of the leakage from the equipment, as the leaked substance is methanol, the consequences are pool fire and toxic vapour cloud, which this last have consequences outside the plant. On the other hand, the partial breakage of the unloading arm only have as a consequence the toxic vapour cloud with huge distances, as the leaked substance is the hydrofluoric acid.

12. NOTATION

AEGL: Acute Exposure Guideline Level

ATEX: Explosive atmosphere. It is an atmosphere where air and flammable substances are mixed in the form of gas, vapours o mists and combustible dusts under atmospheric conditions. In these atmospheres it spreads to the unburned mixture after ignition [26]. This atmosphere could be explosive depending on the circumstances of the environment and the substances implied.

E: Specific

ERPG: Emergency Response Planning Guidelines

G: generic

LFL: Lower flammability limit

N/A: Not available

NA: Not applicable

PAU: Autoprotection Plan. It describes the response to emergency situations to provide effective protection to people, environment and facility assets, ensuring the integration between the resources of the company and the external aid [24].

PEE: External Emergency Plan. The organisational and functional framework designed by the competent civil protection authorities to prevent and, where appropriate, mitigate the consequences of major accidents involving dangerous substances, previously analysed, classified and assessed.

TEEL: Temporary Emergency Exposure Limits

UFL: Upper flammability limit

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Annex A. Calculation of Ratios of substances

Section "H" Health hazards						
Substance	**Amount storage (t)**	**Category**	**Thresholds**		**q_x/Q**	
Part 1						
Sodium cyanide	20	H1	5	20	4	1
Hydrofluoric acid	20	H1	5	20	4	1
40% formaldehyde solution	76	H2	50	200	1.52	0.38
Formic acid	102	H2	50	200	2.04	0.51
Part 2						
Methanol	55	H2	500	5000	0.11	0.011
				Total	**11.67**	**2.90**

Section "P" – Physics hazards						
Substance	**Amount storage (t)**	**Category**	**Thresholds**		**q_x/Q**	
Part 1						
Ethylene	4	P2	10	50	0.4	0.08
Flammable sprays	100	P3a	150	500	0.667	0.2
Isopropylamine	50	P5a	10	50	5	1
Methyl tertiary-butyl ether	4	P5b	50	200	0.08	0.02
Isopropyl alcohol	520	P5c	5000	50000	0.104	0.0104
tert-Butyl peroxybenzoate	2	P6b	50	200	0.04	0.01
Sodium chlorite	95	P8	50	200	1.9	0.475
Sodium nitrite	30	P8	50	200	0.6	0.15
Part 2						
Flammable liquefied gases of category 1 or 2 (including LPG)	0.99	P2	50	200	0.0198	0.00495
Petroleum products and alternative fuels	3	P5b	2500	25000	0.0012	0.00012
Methanol	55	P5b	500	5000	0.11	0.011
				Total	**8.921**	**1.961**

Section "E" – Environmental hazards						
Substance	**Amount storage (t)**	**Category**	**Thresholds**		**q_x/Q**	
Part 1						
Sodium hypochlorite	222	E1	100	200	2.22	1.11
Acrylic acid	250	E1	100	200	2.5	1.25
Manganese (II) sulphate	45	E2	200	500	0.225	0.09
Part 2						
Flammable liquefied gases of category 1 or 2 (including LPG)	0.99	E1	50	200	0.0198	0.00495
Petroleum products and alternative fuels	3	E2	2500	25000	0.0012	0.00012
				Total	**4.966**	**2.455**

Final ratios						
SEVESO	**Category H**		**Category P**		**Category E**	
	Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
Total Part 1	11.560	2.890	8.791	1.945	4.945	2.450
Total Part 2	0.110	0.011	0.131	0.016	0.021	0.005
Total	11.670	2.901	8.922	1.961	4.966	2.455

Annex B. Properties of the substances

Table 34. Properties of the notified substances.

Properties	Sodium cyanide	Hydrofluoric acid	40% formaldehyde solution	Formic acid	Flammable sprays	Ethylene
CAS Number	143-33-9	7664-39-3	N/A	64-18-6	67-64-1	74-85-1
Molecular weight	4.05	36.46	N/A	46.03	N/A	28.05
Classification	N/A	Liquid	Toxic, corrosive, carcinogenic	Tox. Ag. 4 Tox. Ag. 3 Skin Corr. 1A	Flammable, irritant	Flammable gas, gas under pressure
Vapor density (relative to air), g/cm^3	0.93	N/A	1.03	N/A	N/A	N/A
Liquid density, $g·cm^{-3}$ (20ºC)	1.16	1.23	1.14	1.201	N/A	N/A
Melting point ºC	0	-90	N/A	-13.5	N/A	N/A
Boiling point, ºC	112	60	96.7 - 101.1	107.3	-40	-103.77
Flash point, ºC	N/A	N/A	N/A	65	-18	-136
Lower flammability limit (LFL), %	N/A	N/A	7/7.3	14.9	N/A	2.7
Upper flammability limit (UFL), %	N/A	N/A	33/73	47.6	N/A	36
GHS hazard statements	H290 H300 H310. H330 H315 H319. H372 H400 H410	H300 H310 H314 H330	H301 H311 H314 H317 H331 H335 H341 H350 H371	H302 H314 H331	H222 H229 H319 H336	H220 H280 H336
IPVS (ppm)	N/A	N/A	N/A	N/A	N/A	N/A
LC01 (ppm) a 10'	N/A	N/A	N/A	N/A	N/A	N/A
LC01 (ppm) a 30'	N/A	N/A	N/A	N/A	N/A	N/A
Constant a del Probit	N/A	-14.8	N/A	-14.8	N/A	N/A
Constant b del Probit	N/A	1	N/A	1	N/A	N/A
Constant n del Probit	N/A	2	N/A	2	N/A	N/A
Autoignition temperature, ºC	N/A	N/A	N/A	500	N/A	450
Vapor pressure at 20ºC, mmHg.	0.022	200	1-1.3	24.2	N/A	N/A
Specific heat capacity J·kg-1·K-1	N/A	N/A	N/A	N/A	N/A	N/A
Enthalpy of vaporization, J·kg-1	N/A	N/A	N/A	N/A	N/A	N/A
Liquid viscosity at 20ºC, N·s·m-2	N/A	N/A	N/A	0.0017	N/A	N/A

Properties	Isopropylamine	Methyl tertiary-butyl ether	Isopropyl alcohol	Sodium chlorite	Sodium nitrite	tert-Butyl peroxybenzoate
CAS Number	75-31-0	1634-04-4	67-63-0	7758-19-2	7632-00-0	614-45-9
Molecular weight	59.11	88.15	60.1	90.44	68.99	194.23
Classification	Extremely flammable, toxic, harmful	N/A	Liquid	Combustible, hazardous to the environment	Solid, oxidizing, toxic	N/A
Vapor density (relative to air), g/cm^3	2.04	N/D	2.1	N/A	N/A	N/A
Liquid density, g·cm^{-3} (20ºC)	N/A	1.125 – 1.140	0.8	1.21 – 1.31	1.10 – 1.14	1.04
Melting point ºC	<-90	-109	-89	-18	280	10
Boiling point, ºC	32	55	82	112	N/A	N/A
Flash point, ºC	<-25	-28	12	N/A	N/A	100
Lower flammability limit (LFL), %	2	1.6	2	N/A	N/A	N/A
Upper flammability limit (UFL), %	11.5	8.4	12	N/A	N/A	N/A
GHS hazard statements	H224 H301 H311 H331 H315 H319 H335	H225 H315	H225 H319 H336	H271 H302 H318 H373 H400 H412	H272 H301 H400	H242 H315 H317 H332 H410
IPVS (ppm)	N/A	N/A	N/A	N/A	N/A	N/A
LC01 (ppm) a 10'	N/A	N/A	N/A	N/A	N/A	N/A
LC01 (ppm) a 30'	N/A	N/A	N/A	N/A	N/A	N/A
Constant a del Probit	N/A	N/D	N/A	N/A	N/A	N/A
Constant b del Probit	N/A	N/D	N/A	N/A	N/A	N/A
Constant n del Probit	N/A	N/D	N/A	N/A	N/A	N/A
Autoignition temperature, ºC	355	460	399-455.6	N/A	N/A	N/A
Vapor pressure at 20ºC, mmHg.	473.5	0.325	30	15.45	N/A	N/A
Specific heat capacity J·kg-1·K-1	N/A	N/D	N/A	N/A	N/A	N/A
Enthalpy of vaporization, J·kg-1	N/A	N/D	N/A	N/A	N/A	N/A
Liquid viscosity at 20ºC, N·s·m-2	N/A	N/D	N/A	2.33E-03	N/A	8

Properties	Sodium hypochlorite	Acrylic acid	Manganese (II) sulphate	Natural gas	Methanol	Diesel
CAS Number	7681-52-9	79-10-7	10034-96-5	8006-14-2	67-556-1	68334-30-5
Molecular weight	74.44	72.06	151	N/D	32.04	N/A
Classification	Corrosive, contaminant	Corrosive, irritant, flammable,	Solid	N/D	Líquid	Líquid
Vapor density (relative to air), g/cm^3	N/A	N/A	N/A	0.54 – 0.66	1.11	N/A
Liquid density, g·cm^{-3} (20ºC)	1.23	1.051	2.974	0.7 – 0.85	0.79-0.8	0.8-0.91
Melting point ºC	N/A	13	449.85	- 183	N/A	-40
Boiling point, ºC	102.2	141	N/A	- 161	64.7	141
Flash point, ºC	>60ºC	51	N/A	- 188	9.7	>56
Lower flammability limit (LFL), %	N/A	2.4	N/A	4.14	N/A	6
Upper flammability limit (UFL), %	N/A	20.2	N/A	17	N/A	1
GHS hazard statements	H290 H314 H400	H302 H312 H332 H400 H411 H226 H314 H335	H318 H373 H411	H220 H280	H225 H301 H370 H311 H331	H226 H304 H351 H315 H332 H373 H411
IPVS (ppm)	N/A	N/A	N/A	N/D	N/A	N/A
LC01 (ppm) a 10'	N/A	N/A	N/A	N/D	N/A	N/A
LC01 (ppm) a 30'	N/A	N/A	N/A	N/D	N/A	N/A
Constant a del Probit	N/A	N/A	N/A	N/D	-20.41	N/A
Constant b del Probit	N/A	N/A	N/A	N/D	1	N/A
Constant n del Probit	N/A	N/A	N/A	N/D	2	N/A
Autoignition temperature, ºC	N/A	438	N/A	600	<455	>225
Vapor pressure at 20ºC, mmHg.	18.8	2.85	N/A	1102.6	96.5	N/A
Specific heat capacity J·kg-1·K-1	N/A	N/A	N/A	N/D	N/A	N/A
Enthalpy of vaporization, J·kg-1	N/A	N/A	N/A	N/D	N/A	N/A
Liquid viscosity at 20ºC, N·s·m-2	N/A	0.0011	N/A	N/D	N/A	N/A

Annex C. Meteorological data of the Cerdanyola del Vallès station

FITXA D'ESTACIÓ

Estació:	**Cerdanyola del Vallès**
Comarca:	Vallès Occidental
Coordenades:	427248;4593068
Alçada de mesura:	2 m

Font de dades: Servei Meteorològic de Catalunya

Periode d'estudi:

Direcció del vent i estabilitat atmosfèrica: 2000-2004
Temperatura i humitat absoluta: 1999-2003

Estadística de l'anàlisi:

Punts totals:	43835		
Punts vàlids:	**43835**	100,0%	(sobre punts totals)
Punts dia:	22272	50,8%	(sobre punts vàlids)
Punts nit:	21563	49,2%	(sobre punts vàlids)

Resum de resultats

Resum de resultats:

Temperatura mitjana: **15,4** °C

Humitat mitjana: **66%**

Horari	Velocitat mitjana ([1]) del vent / $m \cdot s^{-1}$	Períodes de calma
Global	1,94	14,0%
Diürn	2,45	6,2%
Nocturn	1,42	22,0%

Horari	Estabilitat atmosfèrica més freqüent	Probabilitat	Velocitat mitjana ([2]) del vent / $m \cdot s^{-1}$
Global ([3])	F	33,8%	1,36
Diürn	B	33,7%	2,26
Nocturn	F	64,5%	1,36

Anotacions:

[1] El càlcul de la velocitat mitjana considera la totalitat dels punts vàlids. És a dir, inclou els períodes de calma.
[2] El càlcul de la velocitat mitjana inclou la totalitat dels punts vàlids.
[3] Inclou la totalitat dels punts vàlids.

Annex D. Parameters for the initiating events

G1: Leakage from the tank through an equivalent hole of 10 mm in diameter

Table 35. Parameters for the initiating event G1.

EQUIPMENT DATA			SOURCE TERM		
Product	Methanol		Amount released	487.66	kg
Type of vessel	Horizontal cylinder				
Volume	67	m^3	Leak time	1800	s
Filling degree	90	%			
Length cylinder	10	m	Average leakage rate	0.27	kg/s
Process temperature	15.4	ºC			
Process pressure	1.01551	bar	Active mitigation safeguard	- Firefighting system - Existence of the company's Intervention Team	
LEAKAGE SCENARIO DATA			**SOURCE TERM EVAPORATION / DISPERSION FLAMMABLE AND TOXIC DISPERSION**		
Confined leak	Yes		Size of the puddle	90.3 m^2	
Passive mitigation safeguard	Retention bund		Evaporation rate 2.80D:	0.047	kg/s
Area of the retention bund	1.316	m^2	Evaporation rate 1.36F:	0.035	kg/s
Nature of the soil	Concrete		Evaporation time	1800	s
Roughness	-	m	Active mitigation safeguards	-	
Reference meteorological station	Cerdanyola del Valès		Evaporation time after safeguarding	-	s
Ambient temperature	15.4	ºC	**SOURCE TERM EXPLOSION**		
Humidity	66	%	Amount of gas between LII – 2.80D:	< 1000	kg
Ground temperature	15.4	ºC			
Most likely weather conditions	D/F		Amount of gas between LII – 1.36F:	< 1000	kg
Wind velocity	2.80/1.36	m/s			

G2: Catastrophic breakage of the mobile recipient.

Table 36. Parameters for the initiating event G2.

EQUIPMENT DATA			SOURCE TERM		
Product	Hydrofluoric acid		Amount released	100	kg
Type of vessel	Horizontal cylinder				
Mass released	100	kg	Leak time	Instant	
Process temperature	15.4	ºC	Average leakage rate	-	kg/s
Process pressure	1.01551	bar	Active mitigation safeguard	- Firefighting system - Existence of the company's Intervention Team	
LEAKAGE SCENARIO DATA			**SOURCE TERM EVAPORATION / DISPERSION FLAMMABLE AND TOXIC DISPERSION**		
Confined leak	Yes		Size of the puddle	16.2 m^2	
Passive mitigation safeguard	Retention bund		Evaporation rate 2.80D:	0.07	kg/s
Area of the retention bund	> 1.500	m^2	Evaporation rate 1.36F:	0.05	kg/s
Nature of the soil	Concrete		Evaporation time	1800	s
Roughness	-	m	Active mitigation safeguards	-	
Reference meteorological station	Cerdanyola del Vallès		Evaporation time after safeguarding	-	s
Ambient temperature	15.4	ºC	**SOURCE TERM EXPLOSION**		
Humidity	66	%	Amount of gas between LII – 2.80D:	< 1000	kg
Ground temperature	15.4	ºC			
Most likely weather conditions	D/F		Amount of gas between LII – 1.36F:	< 1000	kg
Wind velocity	2.80/1.36	m/s			

G3: Partial breakage of the unloading arm (10% of the diameter with a maximum of 50 mm)

Table 37. Parameters for the initiating event G3.

EQUIPMENT DATA			**SOURCE TERM**		
Product	Formic acid		Amount released	174	kg
Type of vessel	Horizontal cylinder				
Volume	30	m^3	Leak time	1800	s
Filling degree	90	%			
Length cylinder	6	m	Average leakage rate	0.096	kg/s
Pipeline diameter	50	mm			
Hole diameter	10	mm	Active mitigation safeguard	- Firefighting system - Existence of the company's Intervention Team	
Process temperature	15.4	ºC			
Process pressure	1.01551	bar			
LEAKAGE SCENARIO DATA			**SOURCE TERM EVAPORATION / DISPERSION FLAMMABLE AND TOXIC DISPERSION**		
Confined leak	Yes		Size of the puddle	22.4 m^2	
Passive mitigation safeguard	Retention bund		Evaporation rate 2.80D:	0.011	kg/s
Area of the retention bund	1.783	m^2	Evaporation rate 1.36F:	0.007	kg/s
Nature of the soil	Concrete		Evaporation time	1800	s
Roughness	-	m	Active mitigation safeguards	-	
Reference meteorological station	Cerdanyola del Vallès		Evaporation time after safeguarding	-	s
Ambient temperature	15.4	ºC	**SOURCE TERM EXPLOSION**		
Humidity	66	%	Amount of gas between LII – 2.80D:	< 1000	kg
Ground temperature	15.4	ºC			
Most likely weather conditions	D/F		Amount of gas between LII – 1.36F:	< 1000	kg
Wind velocity	2.80/1.36	m/s			

G4: Partial breakage of 10% of the diameter with a maximum of 50 mm

Table 38. Parameters for the initiating event G4.

EQUIPMENT DATA			**SOURCE TERM**		
Product	Isopropyl alcohol		Amount released	1154.8	kg
Type of vessel	Vertical cylinder				
Volume	100	m^3	Leak time	1800	s
Filling degree	90	%			
Hole diameter	10	mm	Average leakage rate	0.64	kg/s
Pipe length	20	m			
Process temperature	100	ºC	Active mitigation safeguard	- Firefighting system - Existence of the company's Intervention Team	
Process pressure	1.01551	bar			
LEAKAGE SCENARIO DATA			**SOURCE TERM EVAPORATION / DISPERSION FLAMMABLE AND TOXIC DISPERSION**		
Confined leak	-		Size of the puddle	-	
Passive mitigation safeguard	-		Evaporation rate 2.80D:	-	kg/s
Area of the retention bund	-	m^2	Evaporation rate 1.36F:	-	kg/s
Nature of the soil	Concrete		Evaporation time	-	s
Roughness	-	m	Active mitigation safeguards	-	
Reference meteorological station	Cerdanyola del Vallès		Evaporation time after safeguarding	-	s
Ambient temperature	15.4	ºC	**SOURCE TERM EXPLOSION**		
Humidity	66	%	Amount of gas between LII – 2.80D:	< 1000	kg
Ground temperature	15.4	ºC			
Most likely weather conditions	D/F		Amount of gas between LII – 1.36F:	< 1000	kg
Wind velocity	2.80/1.36	m/s			

G5: Leakage from the deposit through an equivalent hole of 10 mm in diameter

Table 39. Parameters for the initiating event G5.

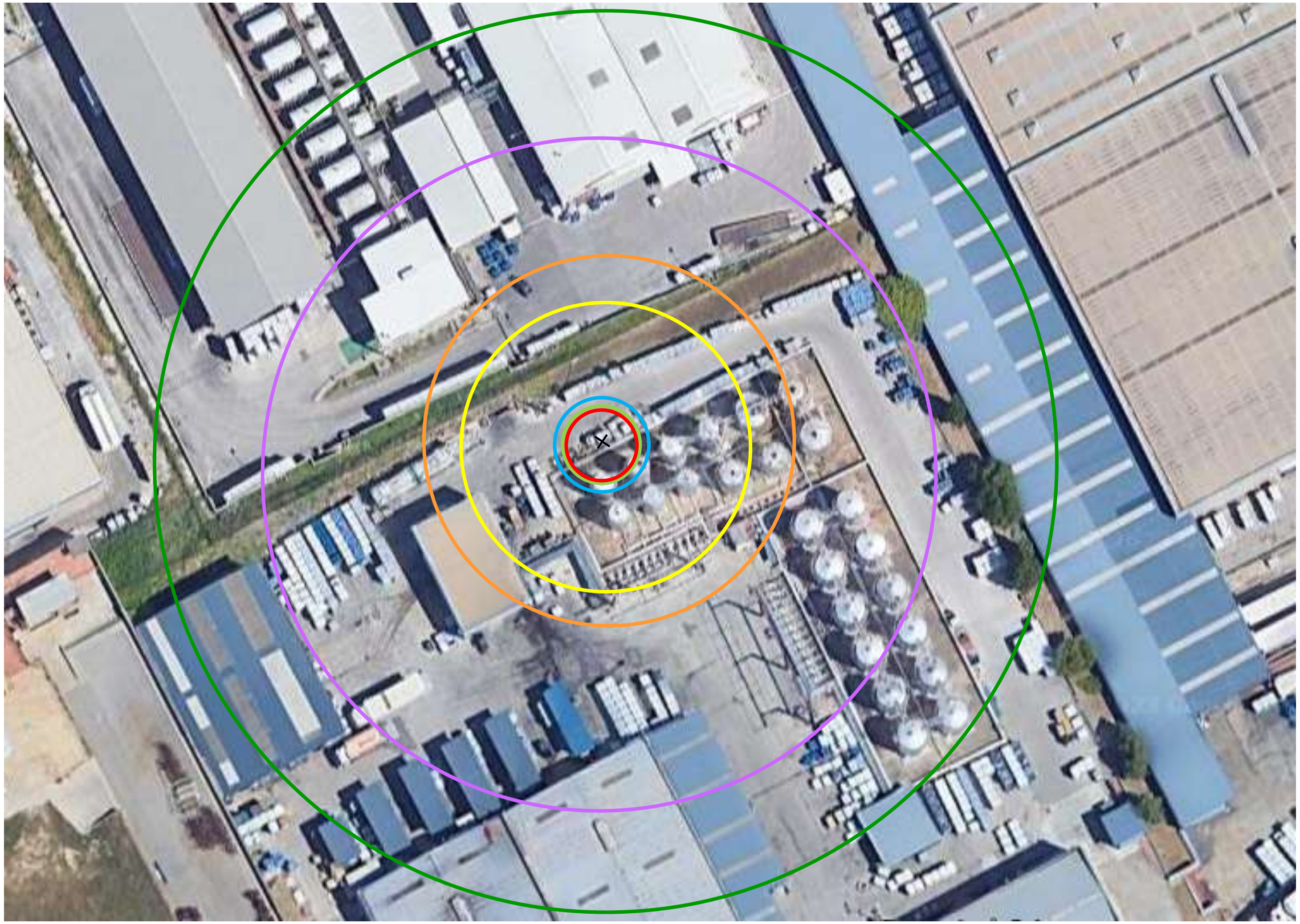
EQUIPMENT DATA			SOURCE TERM		
Product	40% formaldehyde solution		Amount released	1013.2	kg
Type of vessel	Vertical cylinder				
Volume	43	m^3	Leak time	1800	s
Filling degree	90	%			
Hole diameter	10	mm	Average leakage rate	0.56	kg/s
Process temperature	15.4	ºC			
Process pressure	1.01551	bar	Active mitigation safeguard	- Firefighting system - Existence of the company's Intervention Team	
LEAKAGE SCENARIO DATA			**SOURCE TERM EVAPORATION / DISPERSION FLAMMABLE AND TOXIC DISPERSION**		
Confined leak	No		Size of the puddle	88.7 m^2	
Passive mitigation safeguard	-		Evaporation rate 2.80D:	$6.8 \cdot 10^{-4}$	kg/s
Area of the retention bund	1500	m^2	Evaporation rate 1.36F:	$3.0 \cdot 10^{-4}$	kg/s
Nature of the soil	Concrete		Evaporation time	1800	s
Roughness	-	m	Active mitigation safeguards	-	
Reference meteorological station	Cerdanyola del Vallès		Evaporation time after safeguarding	-	s
Ambient temperature	15.4	ºC	**SOURCE TERM EXPLOSION**		
Humidity	66	%	Amount of gas between LII – 2.80D:	< 1000	kg
Ground temperature	15.4	ºC			
Most likely weather conditions	D/F		Amount of gas between LII – 1.36F:	< 1000	kg
Wind velocity	2.80/1.36	m/s			

E1: Confined tank explosion

Table 40. Parameters for the initiating event E1.

EQUIPMENT DATA			SOURCE TERM		
Product	Ethylene		Mass of the heaviest fragment	750	kg
Type of vessel	Vertical cylinder				
Volume	50	m^3	Leak time	-	s
Filling degree	90	%			
Height cylinder	7	m	Average leakage rate	-	kg/s
Process temperature	25	ºC			
Process pressure	10	bar	Active mitigation safeguard	- Firefighting system - Existence of the company's Intervention Team	
LEAKAGE SCENARIO DATA			**SOURCE TERM EVAPORATION / DISPERSION FLAMMABLE AND TOXIC DISPERSION**		
Confined leak	-		Size of the puddle	-	
Passive mitigation safeguard	-		Evaporation rate 2.80D:	-	kg/s
Area of the retention bund	-	m^2	Evaporation rate 1.36F:	-	kg/s
Nature of the soil	Concrete		Evaporation time	-	s
Roughness	-	m	Active mitigation safeguards	-	
Reference meteorological station	Cerdanyola del Vallès		Evaporation time after safeguarding	-	s
Ambient temperature	15.4	ºC	**SOURCE TERM EXPLOSION**		
Humidity	66	%	Amount of gas between LII – 2.80D:	< 1000	kg
Ground temperature	15.4	ºC			
Most likely weather conditions	D/F		Amount of gas between LII – 1.36F:	< 1000	kg
Wind velocity	2.80/1.36	m/s			

Annex E. Plans



G1: Leakage from the tank through an equivalent hole of 10 mm in diameter

Pool fire

- ZA = 5 m
- ZI = 6 m
- ZD = 5 m

Toxic vapour cloud

- ZA stability D = 54 m
- ZA stability F = 76 m
- ZI stability D = 20 m
- ZI stability F = 25 m

The plans for the other scenarios are very similar to this plan.

Annex F. Calculation of the scenarios

G1: Leakage from the tank through an equivalent hole of 10 mm in diameter

Model: Liquid Release

version: v2022.12.274fa32 (18/12/2022)
Reference: Yellow Book, CPR-14E, 3rd edition 1997. Paragraph 2.5.4

Parameters	
Inputs	
Process Conditions	
Chemical name	METHANOL (DIPPR)
Initial temperature in vessel (°C)	15.4
Overpressure above liquid (assuming closed system) (bar)	0
Calculation Method	
Use which representative rate	Second 20% average (toxic)
Type of vessel outflow	Release through hole in vessel
Type of release calculation	Calculate until specified time
Maximum release duration (s)	1800
Process Dimensions	
Vessel volume (m3)	67
Filling degree (%)	90
Vessel type	Horizontal cylinder
Length cylinder (m)	10
Hole diameter (mm)	10
Hole rounding	Sharp edges
Height leak above tank bottom (m)	0
Environment	
Ambient pressure (bar)	1.0151

Results	
Source Definition	
Initial mass in vessel (kg)	48163
Mass flow rate at time t (kg/s)	0.2688
Total mass released at time t (kg)	487.66
Filling degree at time t (%)	89.089
Height of liquid at time t (m)	2.4353
Maximum mass flow rate (kg/s)	0.27036
Representative release rate (kg/s)	0.26989
Representative outflow duration (s)	1800
Representative pressure (bar)	1.2074

Contour dimensions

Other information	
Main program	EFFECTS 11.5.2.22031 viewer
Last calculation	18/12/2022 11:51:41
Last duration	1s 961ms
Chemical database	
Chemical source	DIPPR
Chemical source date	01/05/2015

Model: Pool Fire

version: v2022.12.274fa32 (18/12/2022)
Reference: Yellow Book (CPR-14E), 3rd edition 1997. Paragraph 6.5.4~Rew, P.J. & Hulbert, W.G. (1997) Modelling of Thermal radiation from external hydrocarbon poolfires, in Trans IChemE, Vol.75 part B,~Rew, P.J. & Hulbert, W.G. (1996), Development of a pool fire thermal radiation model', HSE Contract research report no. 96. ~ Damage: Green Book 1st edition 1992. chapter 1 (Heat radiation); pages 11-36~

Parameters		
Inputs	**D:Pool Fire**	**F:Pool Fire**

Process Conditions		
Chemical name	METHANOL (DIPPR)	METHANOL (DIPPR)
Calculation Method		
Type of pool fire calculation	Two zone model Rew & Hulbert	Two zone model Rew & Hulbert
Type of pool fire source	Semi-continuous	Semi-continuous
Soot definition	User defined	User defined
Fraction of the flame covered by soot (-)	0.8	0.8
Source Definition		
Mass flow rate of the source (kg/s)	0.26989	0.26989
Duration of the release (s)	1800	1800
Temperature of the pool (°C)	15.4	15.4
Process Dimensions		
Type of pool shape (pool fire)	Circular	Circular
Max. pool fire surface area (m2)	1316	1316
Height of the confined pool above ground level (m)	0	0
Include shielding at bottomside flame	No	No
Meteo Definition		
Wind speed at 10 m height (m/s)	2.8	**1.36**
Predefined wind direction	W	W
Environment		
Ambient temperature (°C)	15.4	15.4
Ambient pressure (bar)	1.0151	1.0151
Ambient relative humidity (%)	66	66
Amount of CO2 in atmosphere (-)	0.0003	0.0003
Vulnerability		
Maximum heat exposure duration (s)	20	20
Take protective effects of clothing into account	No	No
Heat radiation lethal damage Probit A ((sec*(W/m2)^n))	-36.38	-36.38
Heat radiation lethal damage Probit B	2.56	2.56
Heat radiation damage Probit N	1.3333	1.3333
Accuracy		
Grid resolution	Low	Low
Reporting		
Reporting/receiver height (Zd) (m)	1.5	1.5
Distance from release centre (m)	200	200

Results	**D:Pool Fire**	**F:Pool Fire**
Fire Results		
Equivalent diameter of fire (m)	3.8116	3.8116
Max. diameter top flame (m)	5.1333	**4.6464**
Flame footprint dimensions D,-D,DMW,MW	4;-2;1;4	4;-2;1;4
Calculated pool fire surface area (m2)	11.41	11.41
Combustion rate of the chemical (kg/s)	0.22821	0.22821
Duration of the fire (s)	2128.8	2128.8
Surface emissive power (clear flame) (kW/m2)	70	70
Surface emissive power (sooted flame) (kW/m2)	30	30
Soot fraction used (-)	0.8	0.8
Flame tilt (deg)	47.284	**35.046**
Flame temperature (°C)	782.4	782.4
Length of the flame (m)	2.3007	2.3007
Height of clear fraction Flame (m)	1.12	**0.98422**
Weight ratio of HCl/chemical (%)	0	0
Weight ratio of NO2/chemical (%)	0	0
Weight ratio of SO2/chemical (%)	0	0
Weight ratio of CO2/chemical (%)	137.36	137.36
Weight ratio of H2O/chemical (%)	112.47	112.47
(Max) Heat radiation level at Xd (kW/m2)	0.0014461	**0.0016633**
Atmospheric transmissivity at Xd (%)	61.21	**61.195**
(Max) Viewfactor at Xd (-)	4.7916E-05	**5.7841E-05**
Heat radiation dose at Xd (s*(kW/m2)^4/3)	0.0032705	**0.0039415**
Percentage first degree burns at Xd (%)	0	0
Percentage second degree burns at Xd (%)	0	0
Percentage lethal burns at Xd (%)	0	0
Distance to clothing burning dose (m)	4.2898	**3.4408**

Contour maximum distances		
Heat radiation contours distance [m]	**D:Pool Fire**	**F:Pool Fire**
4 kW/m2 heat radiation contour	6	6
7 kW/m2 heat radiation contour	5	5
8 kW/m2 heat radiation contour	5	5

Lethality contours distance [m]	D:Pool Fire	F:Pool Fire
1 % lethality contour	5	5

Other information	
Main program	EFFECTS 11.5.2.22031 viewer
Last calculation	18/12/2022 12:33:34

Model: Pool Evaporation

version: v2022.12.74e1c74 (18/12/2022)
Reference: Yellow Book CPR14E 2nd Edition - Chapter 5: Evaporation. Trijssenaar-Buhre, I.J.M, Sterkenburg, R.P., Wijnant-Timmerman, S.I.: An advanced model for spreading and evaporation of accidentally released hazardous liquids on land. Diffusion coefficient in Schmidt number based on Fuller, Schetter and Gitting correlation, see http://www.thermopedia.com/content/696

Parameters		
Inputs	**D:Pool Evaporation**	**F:Pool Evaporation**
Process Conditions		
Chemical name	METHANOL (DIPPR)	METHANOL (DIPPR)
Calculation Method		
Use which representative rate	Second 20% average (toxic)	Second 20% average (toxic)
Evaporation from land or water	Land	Land
Type of release in pool	Semi-continuous	Semi-continuous
Maximum evaluation time for evaporation (s)	1800	1800
Source Definition		
Mass flow rate of the source (kg/s)	0.26989	0.26989
Duration of the release (s)	1800	1800
Temperature of the pool (°C)	15.4	15.4
Process Dimensions		
Type of pool growth on Land	Spreading in bunds	Spreading in bunds
Max. pool surface area (m2)	1316	1316
Meteo Definition		
Wind speed at 10 m height (m/s)	2.8	**1.36**
Environment		
Temperature of the subsoil (°C)	15.4	15.4
Ambient temperature (°C)	15.4	15.4
Ambient pressure (bar)	1.0151	1.0151
Ambient relative humidity (%)	66	66
Solar radiation flux	User defined	User defined
Solar heat radiation flux (W/m2)	120	120
North/South latitude of the location (deg)	51	51
Type of subsoil (evaporation)	Average subsoil	Average subsoil
Subsurface roughness description (pool)	flat sandy soil, concrete, tiles, plant-yard	flat sandy soil, concrete, tiles, plant-yard

Results	D:Pool Evaporation	F:Pool Evaporation
Source Definition		
Time pool spreading ends (s)		
Time until pool has totally evaporated (s)		
Representative evaporation rate (kg/s)	0.046786	**0.034772**
Purple book representative evaporation duration (s)	1234	**1207.1**
Representative temperature (°C)	1.686	**5.5646**
Representative pool diameter (m)	10.506	**10.725**
Density after mixing with air (kg/m3)	1.2273	**1.2276**
Total evaporated mass (kg)	57.733	**41.972**
... duration evaporation time (s)	1799.5	1799.5

Pool surface area (m2)	86.688	**90.348**
Schmidt number used	0.91441	0.91441
Dispersion model strategy	Neutral gas	Neutral gas
Environment		
Heat flux from solar radiation (kW/m2)	0.12	0.12

Contour maximum distances		

Other information	
Main program	EFFECTS 11.5.2.22031 viewer
Last calculation	18/12/2022 12:33:48

Model: Dense Gas - Flammable Cloud

version: v2022.12.679beca (18/12/2022)
Reference: Yellow Book 3rd edition 1997 chapter 4; Ermak, D.L. User manual for SLAB Lawrence Livermore National Laboratory, June 1990

Parameters		
Inputs	**D:Dense Gas - Flammable Cloud**	**F:Dense Gas - Flammable Cloud**
Process Conditions		
Chemical name	METHANOL (DIPPR)	METHANOL (DIPPR)
Calculation Method		
Type of heavy gas release	Evaporating pool release	Evaporating pool release
Source Definition		
Mass flow rate of the source (kg/s)	0.046786	**0.034772**
Duration of the release (s)	1234	**1207.1**
Pool surface area (m2)	86.688	**90.348**
Temperature after release (°C)	1.686	**5.5646**
Meteo Definition		
Meteorological data	Pasquill	Pasquill
Pasquill stability class	D (Neutral)	**F (Very Stable)**
Wind speed at 10 m height (m/s)	2.8	**1.36**
Predefined wind direction	W	W
Environment		
Ambient temperature (°C)	15.4	15.4
Ambient pressure (bar)	1.0151	1.0151
Ambient relative humidity (%)	66	66
Roughness length description	Parkland, bushes; numerous obstacles, x/h < 15.	Parkland, bushes; numerous obstacles, x/h < 15.
Accuracy		
Grid resolution	Low	Low
Reporting		
Ignition time flammable cloud	Time maximum area cloud	Time maximum area cloud
Concentration averaging time (s)	20	20
Use 50% LFL for cloud contour	No	No
Use mass between LFL and UFL	No	No
Use dynamic concentration presentation	No	No

Results	**D:Dense Gas - Flammable Cloud**	**F:Dense Gas - Flammable Cloud**
Meteo Definition		
Inverse Monin-Obukhov length (1/L) used (1/m)	0	**0.04336**
Concentration Results		
Flammability threshold concentration (mg/m3)	95659	95659
Maximum distance to flammable concentration (m)		
Maximum flammable mass (kg)	0	0
Maximum area of flammable cloud (m2)	0	0
at time T (s)	0	0

Flammable mass at time t (kg)	0	0
Area flammable cloud at time t (m2)	0	0
Volume of the flammable cloud at time t (m3)		
Height to LFL at time t (m)		
Length of flammable cloud at time t (m)	0	0
Width of flammable cloud at time t (m)	0	0
Offset flammable cloud at time t (m)	0	0
Offset flammable cloud centre at time t (m)	0	0
Effective release height (m)	0	0

Contour maximum distances	

Other information	
Main program	EFFECTS 11.5.2.22031 viewer
Last calculation	18/12/2022 12:53:22

Model: Dense Gas – Toxic Vapour Cloud

Stability class D

SITE DATA:

Location: BARCELONA, SPAIN
Building Air Exchanges Per Hour: 0.5 (user specified)
Time: December 18. 2022 1237 hours ST (using computer's clock)

CHEMICAL DATA:

Chemical Name: **METHANOL**
CAS Number: 67-56-1 Molecular Weight: 32.04 g/mol
AEGL-1 (60 min): 530 ppm AEGL-2 (60 min): 2100 ppm AEGL-3 (60 min): 7200 ppm
IDLH: 6000 ppm LEL: 71800 ppm UEL: 365000 ppm
Ambient Boiling Point: 64.7° C
Vapor Pressure at Ambient Temperature: 0.098 atm
Ambient Saturation Concentration: 98.622 ppm or 9.86%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 2.80 meters/second from W at 10 meters
Ground Roughness: urban or forest Cloud Cover: 0 tenths
Air Temperature: 15.4° C
Stability Class: D (user override)
No Inversion Height Relative Humidity: 66%

SOURCE STRENGTH:

Direct Source: 0.046786 kilograms/sec
Source Height: 0
Release Duration: 60 minutes
Release Rate: 2.81 kilograms/min
Total Amount Released: 168 kilograms

THREAT ZONE:
Model Run: Heavy Gas
Red: 20 meters --- (4000 ppm) – ZI
Orange: 54 meters --- (670 ppm) – ZA

Calculation of vulnerability

THREAT ZONE:
Model Run: Heavy Gas
Yellow: 11 meters --- (18758.5 mg/(cu m)) – DL1

SITE DATA:
Location: BARCELONA, SPAIN
Building Air Exchanges Per Hour: 0.5 (user specified)
Time: December 18. 2022 1237 hours ST (using computer's clock)

THREAT AT POINT:
Concentration Estimates at the point:
Downwind: **11 meters** Off Centerline: 0 meters
Max Concentration:
Outdoor: 30.500 mg/(cu m)
Indoor: 12.000 mg/(cu m) – DL01

SITE DATA:
Location: BARCELONA, SPAIN
Building Air Exchanges Per Hour: 1 (user specified)
Time: December 18. 2022 1237 hours ST (using computer's clock)

THREAT AT POINT:
Concentration Estimates at the point:
Downwind: **11.3 meters** Off Centerline: 0 meters
Max Concentration:
Outdoor: 18.300 mg/(cu m)
Indoor: 11.600 mg/(cu m) – DL01

Stability class F

SITE DATA:
Location: BARCELONA, SPAIN
Building Air Exchanges Per Hour: 1 (user specified)
Time: December 18. 2022 1245 hours ST (using computer's clock)

CHEMICAL DATA:

Chemical Name: **METHANOL**

CAS Number: 67-56-1 Molecular Weight: 32.04 g/mol

AEGL-1 (60 min): 530 ppm AEGL-2 (60 min): 2100 ppm AEGL-3 (60 min): 7200 ppm

IDLH: 6000 ppm LEL: 71800 ppm UEL: 365000 ppm

Ambient Boiling Point: 64.7° C

Vapor Pressure at Ambient Temperature: 0.098 atm

Ambient Saturation Concentration: 98.622 ppm or 9.86%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)

Wind: 1.36 meters/second from W at 10 meters

Ground Roughness: urban or forest Cloud Cover: 5 tenths

Air Temperature: 15.4° C

Stability Class: F (user override)

No Inversion Height Relative Humidity: 66%

SOURCE STRENGTH:

Direct Source: 0.034772 kilograms/sec

Source Height: 0

Release Duration: 60 minutes

Release Rate: 2.09 kilograms/min

Total Amount Released: 125 kilograms

THREAT ZONE:

Model Run: Heavy Gas

Red: 25 meters --- (4000 ppm) – ZI

Orange: 76 meters --- (670 ppm) – ZA

Calculation of vulnerability

THREAT ZONE:

Model Run: Heavy Gas

Yellow: 11 meters --- (18758.5 mg/(cu m)) – DL1

SITE DATA:

Location: BARCELONA, SPAIN

Building Air Exchanges Per Hour: 0.5 (user specified)

Time: December 18. 2022 1237 hours ST (using computer's clock)

THREAT AT POINT:

Concentration Estimates at the point:

Downwind: 1**1 meters** Off Centerline: 0 meters

Max Concentration:

Outdoor: 31.800 mg/(cu m)
Indoor: 12.500 mg/(cu m) – DL01

SITE DATA:
Location: BARCELONA, SPAIN
Building Air Exchanges Per Hour: 1 (user specified)
Time: December 18. 2022 1237 hours ST (using computer's clock)

THREAT AT POINT:
Concentration Estimates at the point:
Downwind: **11.4 meters** Off Centerline: 0 meters
Max Concentration:
Outdoor: 18.900 mg/(cu m)
Indoor: 11.900 mg/(cu m) – DL01

The scenarios G2, G3, G4 and G5 are calculated the same way as the scenario G1. In case of the scenario G2 as it is a catastrophic breakage there is no leak and all the content spills instantaneously.

The scenario E1 is a confined tank explosion so the method of calculation is different. This is the reason why is shown in the next page.

E1: Confined tank explosion

Model: Rupture of Vessels

version: v2022.12.274fa32 (24/12/2022)
Reference: Yellow Book 3rd edition paragraph 7.5.2 ("Rupture of Vessels")

Parameters	
Inputs	
Process Conditions	
Chemical name	ETHYLENE (DIPPR)
Initial temperature in vessel (°C)	25
Burst pressure vessel (bar)	10
Calculation Method	
Cause of vessel rupture	Internal explosion
Process Dimensions	
Vessel volume (m3)	50
Filling degree (%)	90
Vessel type	Vertical cylinder
Height cylinder (m)	7
Is the vessel elevated	No
Fragment distribution	2 equal pieces
Mass of empty vessel (kg)	1500
Environment	
Ambient temperature (°C)	15.4
Ambient pressure (bar)	1.0151
Vulnerability	
Pressure lethality based on	Treshold pressure level
Peak pressure total destruction (Indoors+Outdoors) (mbar)	300
Lethality total destruction (Indoors+Outdoors) (-)	1
Peak pressure indoors (glass) lethality (mbar)	100
Lethality indoors (glass) (-)	0.025
Reporting	
Distance from centre of vessel (Xd) (m)	50

Results	
Explosion Results	
Peak overpressure at Xd (mbar)	39.727
Pressure impulse at Xd (Pa*s)	16.064
Mass of heaviest fragment (F1) (kg)	750
Initial speed of F1 (m/s)	23.253
Maximum range of F1 (m)	49.713
Damage (general description) at Xd	Minor damage (Zone D: 3.5 - 17 kPa).
Damage to brick houses at Xd	Habitable after relatively easy repairs. Minor structural damage (3 kPa).
Damage to typical American-style houses at Xd	No damage or very minor damage
Damage to structures (empirical) at Xd	No damage or very minor damage
Damage to windows (houses before 1975) at Xd (%)	72.537
Damage to windows (houses after 1975) at Xd (%)	26.981

Contour dimensions					
Overpressure contours					
Names	**Max. dist [m]**	**Min. dist [m]**	**Dist. width [m]**	**Max. width [m]**	**Value [mbar]**
300 mbar overpressure contour	14	-14	-1	28	300
160 mbar overpressure contour	18	-18	-2	35	160
125 mbar overpressure contour	21	-21	-2	43	125
50 mbar overpressure contour	41	-41	-4	82	50
Lethality contours					
Names	**Max. dist [m]**	**Min. dist [m]**	**Dist. width [m]**	**Max. width [m]**	**Value [%]**
1 % lethality contour	14	-14	-1	28	1

Other information	
Main program	EFFECTS 11.5.2.22031 viewer

Last calculation	24/12/2022 19:02:10
Last duration	0s 32ms
Chemical database	
Chemical source	DIPPR
Chemical source date	01/05/2015

Annex G. Environmental Assessment

G6. Leakage from the tank through an equivalent hole of 10 mm in diameter

a) Sources of risk

Score according to the Annex I Part I RD 1254/1999	
Substance	**Points**
Sodium hypochlorite	10

Hazard rating

Aquatic Environment Phrase [R]	Points	*Possible Points*
R50	10	10
R50/R53	0	10
R51/R53	0	8
R52/R53	0	5
R52 y/o R53	0	5

Mixtures

Is there a mixture of substances (yes/no)?	no
Are there synergistic effects (yes/no)?	no

b) Primary control systems

Amount of mass involved = 222 t

Score according to the amount involved on the accident (t)		
Amount involved on the accident (t)	**Points**	***Possible Points***
> 500	0	10
50-500	7	7
5-49	0	5
0.5-4.9	3	3
< 0.5	0	1

c) Transport systems

Score according to the transport

For distances less than 10km, 2Ha or 0.180 km depending on the medium:

Enter distance affected (km)	0.006	**Points to be introduced in the following section**	1.00

Type of medium	Size affected	Puntos	*Possible points*
River, canal, stream, etc.	> 10km	1	10
Lake, pond, delta, etc.	> 2Ha		
Non-aquatic environment (including air, soil and groundwater)	> 0.180km		

Note: When the extension does not exceed the boundaries of the establishment, a value of 1 is assigned

d) Vulnerable receivers

Score according to the vulnerable receivers

Habitat	Naturalness index	Priority habitat	Comments / Recommendations	Points	*Possible points*
Code J Habitat of industrial developments and other habitat types	-	-	Code J1, Code J3, Code J4,	1	*1*
	-	-	Code J4, Code J6	0	
	-	-	Code J2, Code J5	0	*2*
Code I Agricultural, horticultural habitats regularly or recently cultivated	-	-	Code I2	0	*3*
	-	-	Code I1	0	*4*
Habitats classified under Annex I of the Habitats Directive 92/43/EEC	1	NO	-	0	*5*
	1	SI	-	0	*6*
	2	NO	-	0	*7*
	2	SI	-	0	*8*
	3	NO	-	0	*9*
	3	SI	-	0	*10*

Score according to the conditioning factors

Conditioning factor	Detail	% Increase	*% Possible increase*
Protected natural areas in the area of influence	Existent	0	*30*
	Does not existent	0	0
Species protection categories	In danger of extinction	0	*10*
	Sensitive to habitat alteration	0	8
	Vulnerable	0	5
	Of special concern	0	2
	No protection category	0	0
Historical and artistic heritage	Immovable property with the category of property of cultural interest	0	*10*
	Immovable property with any other type of protection category None of the above	0	5
Reversibility of damage / recovery	Possible permanent damage	0	0
	Recuperation time of 5 to 20 years Recuperation time of 1 to 5 years Recuperation time of weeks to 1 year	0	*10*
	Days	5	5
Socio – economic impact	Disruption of economic activity (one or more to a significant degree) AND impact on some type of infrastructure in the vicinity		
	Disruption of economic activity (one or more to a significant degree) OR impact on some form of infrastructure in the environment	0	*40*
	None of the above	0	20
	Existent	0	0

e) Global index of environmental consequences

GLOBAL INDEX OF ENVIRONMENTAL CONSEQUENCES (IGCM)	4,03

f) Likelihood / Frequency of the event

Frequency / Likelihood of the event

Frequency	Points	*Possible Points*
Between once a year and once every 5 years	0	5
Between once every 5 years and once every 25 years	0	4
Between once every 25 years and once every 50 years	0	3
Between once every 50 years and once every 100 years	0	2
Between once every 100 years and once every 500 years	0	1

Likelihood	Points	*Possible Points*
$x > 10^{-2}$	0	5
$10^{-4} < x < 10^{-2}$	0	4
$10^{-6} < x < 10^{-4}$	3	3
$10^{-8} < x < 10^{-6}$	0	2
$x < 10^{-8}$	0	1

g) Environmental Risk Index (IRM)

Partial score risk-substance sources (2-21)	*10*	
Partial score risk-substance sources (1-6)	*3.1*	
Final score risk-substance sources (1-10)		*3.1*
Final score sources of risk-amount involved (1-10)		*7*
FINAL SCORE SOURCES OF RISK (1-12)		**5.16**
Partial score for the transport System (1-10)	*1*	
FINAL SCORE FOR THE TRANSPORT SYSTEM (1-8)		**1.00**
Partial score for the vulnerable receivers (1-10)	*1*	
FINAL SCORE FOR THE VULNEABLE RECEIVERS (1-20)		**1.05**
GLOBAL INDEX OF ENVIRONMENTAL CONSEQUENCES (IGCM)		**4.03**
ENVIRONMENTAL RISK INDEX (IRM)		**12.08**

The risk assessment for the Scenarios G7 and G8 are calculated the same way as the scenario G6.