European Commission - Directorate-General Environment

Review of the monitoring system under the Seveso-III Directive, including the development of indicators

Final report

Wood Environment & Infrastructure Solutions UK Limited – July 2019

Report for

European Commission – Directorate-General Environment
Directorate C – Quality of Life
Unit ENV C.4 – Industrial emissions & Safety
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Document revisions

No.	Details	Date
1	Final interim report	12 June 2018
2	Draft final report	23 October 2018
3	Final report	8 March 2019
4	Revised final report (i2)	28 May 2019
5	Revised final report (i3)	10 July 2019

Executive summary

Purpose of this report

This report has been produced for the purpose of presenting the outcome of a project to 'Review of the monitoring system under the Seveso III Directive, including the development of indicators.

The current monitoring system has been in use for many years. The primary objective of the project was to provide support to the Commission on the review of the current monitoring system established under the Seveso-III-Directive, considering the Commission's Better Regulation Guidelines and the Commission report on actions to streamline environmental reporting. Based on this review, the project identified recommendations and an action plan for improving the monitoring system in the long-term. The work included consideration on the development of suitable monitoring indicators, including flagship indicators.

Monitoring systems under the Seveso III Directive

The monitoring system under Directive 2012/18/EU (the Seveso-III Directive) has three main components:

a) Reporting on implementation of the Directive in Member States by 30 September 2019 and every four years thereafter according to Article 21(2)). The objective of this monitoring is to gather information on national implementation of the Directive, including for example frequency of testing of the external emergency plans and inspections so as to assess the compliance of Member States with the requirements of the Directive[1].

b) Reporting on establishments (eSPIRS) according to Article 21(3). The aim of this reporting is to gather statistical information on establishments covered by the Directive, including on whether establishments are upper or lower tier and activity details.

c) Reporting on accidents (eMARS)[2] according to Article 18. The aim of this reporting is to exchange information and lessons learnt from accidents at establishments falling under the scope of the Directive.

There are other aspects of monitoring, including for example complaints and infringements.

Identification of needs

A stakeholder consultation exercise was organised in order to gather information on needs from the monitoring systems. A range of needs were identified and analysed. Options were presented to meet the need, as well as potential limitations, in particular administrative burden. The needs identified include (non-exhaustive): monitoring compliance with the requirements of the Directive; identifying number and location of establishments; finding establishments for a specific activity; identifying establishments in neighbouring countries; comparing situations with other Member States/ benchmarking; identifying actual practices in Member States; learning about implementation at EU level; obtaining information on inspectors' training; identifying and responding to new topics; obtaining lessons learned from major accidents and Information on near misses.

[1] For the review of the monitoring and reporting on implementation, the analysis has been based primarily on the reporting under the Seveso II Directive, as the first reporting under the Seveso III directive has not yet been completed.
[2] Commission Decision 2009/10/EC establishing a major accident report form pursuant to the Directive 96/82/EC (Seveso-II)

Review of the current monitoring systems

The current monitoring systems were reviewed to ascertain the extent to which they already respond to some of these needs. It is concluded that the perception of the current monitoring system is generally positive for both Member States and international bodies. Indeed, information made available through the implementation reports is considered as sufficient and valuable for two primary purposes, including the benchmarking of inspectorates' practices and the appreciation of the level of implementation of the Directive in other Member States. In addition, eSPIRS appears to be a valuable means of sharing information on existing Seveso plants with the public. Finally, eMARS is reported as being a useful tool to share lessons learned on major accidents occurring in Europe as well as a valuable accident scenarios database against which inspectorates may compare the list of accident scenarios considered in safety reports.

Limitations of the current monitoring system were also identified, in particular the ability of the monitoring system to demonstrate the real impact of the Directive on the risk levels to which EU citizens are exposed. Respondents agree to a large extent on the weak statistical representativeness of the number of major accidents making such a figure a poor estimator of risk trends. Various improvement suggestions have been made such as to: extend accidents accounts to include incidents, near misses and non-Seveso establishments; and to collate information on number of non-compliance issues identified during inspections.

Key drivers of performance

An objective of the project was to identify key drivers of performance, defined here as being any aspect, within or out of the regulatory mechanism that may have a strong impact on the final objective of the Directive being met (i.e. the reduction of risks from industrial accidents). One 'internal' set of drivers was identified, focusing on the different provisions of the Directive Member States are requested to report against. All were rated as being highly relevant and useful which allow to conclude that all the aspects currently reported against in the implementation report are worth monitoring.

A second set of drivers, "external" to the Directive has been identified. These aspects are not appropriate for monitoring but they provide a broader representation of the external factors that may foster or impede the Directive's ability to succeed in reducing industrial risks.

Socio-economic impacts of major accidents

One of the objectives of the project was to extend previous research on socio-economic impacts of major accidents. A literature review was conducted in order to identify information, in particular quantification of socio-economic impacts of major accidents, and whether specific impacts on communities and mental health are included.

The report details a review of recent studies on impacts of major accidents but also information reported as part of the eMARS database.

Indicators for monitoring the Seveso III Directive

The study included a review of existing indicators and their suitability in order to assist in monitoring the effectiveness of the Directive. A range of possible indicators was identified, including (non-exhaustive): the percentage of Member States having achieved the transposition of the Seveso III Directive; number of accidents in particular industries; risk of a citizen being exposed to a major accident; and public awareness such as the estimated (monetary) loss due to the nature of the major accident; the share of citizen population made aware of the information related to alert systems; main response measures and arrangements to cope with any off-site effects from an accident and the number of inhabitants living in endangered areas (based on consequence analysis or taking into account iso-risk curves).

Conclusions

The report presents some possible improvements identified including the modification of the reporting template, reporting of near misses and the incorporation of the EU Gravity Scale of Industrial Accidents into eMARS.

The findings of the report will be useful in order to consider the effectiveness of the Directive as part of the upcoming evaluation. It also provides ten long-term recommendations in order to improve the monitoring systems and generate further relevant data.

Contents

1. Introduction

1.1 This report

This is the draft final report for contract No 070201/2017/765428/SFRA/ENV.C.4 between the European Commission and Wood[3] in collaboration with INERIS and EU-VRi. It concerns the "Review of the monitoring system under the Seveso-III-Directive, including the development of indicators".

This report presents the outcome of the project, taking into account comments received from stakeholders during a workshop organised at DG Environment premises in July 2018.

1.2 Monitoring systems under the Seveso Directive

The monitoring system under Directive 2012/18/EU (the Seveso-III Directive) has three main components:

a) Reporting on implementation of the Directive in Member States by 30 September 2019 and every four years thereafter according to Article 21(2)). The objective of this monitoring is to gather information on national implementation of the Directive, including for example frequency of testing of the external emergency plans and inspections so as to assess the compliance of Member States with the requirements of the Directive.[4]

b) Reporting on establishments (eSPIRS) according to Article 21(3). The aim of this reporting is to gather statistical information on establishments covered by the Directive, including upper- or lower tier information and activity details.

c) Reporting on accidents (eMARS)[5] according to Article 18. The aim of this reporting is to exchange information and lessons learnt from accidents at establishments falling under the scope of the Directive.

There are other aspects of monitoring, including for example complaints and infringements.

The current monitoring system has been in use for many years. Despite being deemed appropriate, it is necessary to assess whether it can be further improved, especially in view of the deadlines for updating the relevant Commission Implementing decisions[6] for reporting during 2018 and 2019.

1.3 Project objective

The primary objective of the project was to provide support to the Commission on the review of the current monitoring system established under the Seveso-III-Directive, considering the Commission's Better Regulation Guidelines and the Commission report on actions to streamline environmental reporting.

[3] Previously Amec Foster Wheeler
[4] For the review of the monitoring and reporting on implementation, the analysis has been based primarily on the reporting under the Seveso II Directive, as the first reporting under the Seveso III directive has not yet been completed.
[5] Commission Decision 2009/10/EC establishing a major accident report form pursuant to the Directive 96/82/EC (Seveso-II)
[6] Commission Implementing Decision 2014/895/EU (establishing the format for communicating the information referred to in Article 21(3) of Directive 2012/18/EU on the control of major-accident hazards involving dangerous substances) and 2014/896/EU (establishing the format for communicating information from Member States on the implementation of Directive 2012/18/EU on the control of major-accident hazards involving dangerous substances).

Based on this review, the project identified recommendations and an action plan for improving the monitoring system in the long-term. The work included consideration on the development of suitable monitoring indicators, including flagship indicators.

In preparation for an expected future evaluation of the Seveso III Directive, the Better Regulation guidelines foresee the use of indicators to assess progress made by an EU intervention in achieving its objectives. Through a previous study[7] it was recognised that more work is required to develop optimal indicators.

This project therefore aimed to:

- Obtain a clear understanding of monitoring needs and objectives as well as the related requirements and expectations;
- Establish a meaningful set of indicators that would support proper monitoring in line with the Better Regulation Guidelines and policy needs; and
- Conduct a feasibility check and get a clear understanding of the obstacles that may be encountered in obtaining the relevant data for indicators or deploying the proposed improvements to the monitoring system (including recommendations for further improvement).

The outcome of the project will feed into new Commission Implementing Decisions on reporting and where relevant the update of electronic reporting tools. Furthermore, it will also feed into the Commission Report due under Article 29 of Directive 2012/18/EU in 2020.

Finally, the work is conducted with reference to a fully developed intervention logic, which is presented in Appendix A.

1.4 Structure of the report

The report is structured as follows:

- Section 2 presents the outcome of the stakeholder consultation undertaken to date.
- Section 3 presents the identification of needs and requirements for monitoring systems.
- Section 4 presents the review of the current monitoring system.
- Section 5 presents the key drivers for performance identified.
- Section 6 presents the review conducted of socio-economic impacts of major accidents.
- Section 7 presents initial work on development of indicators for monitoring and flagship indicators.
- Section 8 presents initial conclusions on the potential improvements to monitoring in both the short and long term.
- Section 9 presents next steps for the project.
- Appendix A presents the intervention logic.
- Appendix B presents the outcome of the literature review on the socio-economic and wider impacts of major accidents.
- Appendix C presents the workshop report.

[7] Amec Foster Wheeler, 2017

2. Outcome of the stakeholder consultations

2.1 Overview of the inputs from the online survey

The aim of the consultation was to gather feedback and insights from a range of stakeholders on the usefulness of the current monitoring system and, if appropriate, possible ways to improve it. The consultation included an online survey, a workshop and several ad-hoc communications with stakeholders.

The questionnaire focused on the monitoring and reporting requirements as described in the Directive.

The questionnaire was developed by the project team and reviewed by the Commission. Questions covered the following topics:

- Needs and requirements for monitoring;
- Analysis of the existing monitoring process;
- Understanding key drivers for performance;
- Socio-economic impacts of major accidents;
- Establishing indicators; and
- Flagship indicators.

The consultation was launched online on 9 February and ran until 29 March 2018. The questionnaire was distributed to four stakeholder groups. In order to adjust the questions to the audience and maximise the response rate, each group responded to a tailored set of questions. The groups consulted were:

- Member State competent authorities;
- Industry associations;
- European Commission and international organisations, including governments from non-EU countries; and
- NGOs, research institutions and academia.

The response rate varied depending on the stakeholder group, being relatively high among Member State authorities but rather low within the other stakeholder groups, especially industry. A summary of the number of responses is as follows:

- **Member State authorities:** 27[8] responses:
  - Belgium (Service Public de Wallonie; Federal Public Service Employment, Labour and Social Dialogue), Bulgaria, Cyprus (Department of Labour inspection), the Czech Republic (Ministry of Environment); Germany (Federal Ministry for the Environment; German Environment Agency; North Rhine-Westphalia State Agency for Nature, environment and consumer protection), Denmark (Danish EPA); Estonia (Estonian Rescue Board), Spain, (General Directorate of Civil Protection and Emergencies, Finland (Finnish Safety and Chemicals Agency - TUKES), France (Ministry of Environment), Hungary (National Directorate general for Disaster Management, Ministry of Interior), Ireland (Health & Safety Authority), Lithuania (Fire and Rescue Department under the Ministry of Interior); Luxembourg (Inspection du travail et des mines), Malta (Occupational Health and Safety Authority); the Netherlands

[8] The following Member States provided responses from more than one authority: Belgium (2), Germany (3), Poland (2) and Portugal (2),

(Ministry of Infrastructure and Water management), Poland (Chief Inspectorate of Environmental Protection; State Fire Service of Poland), Portugal (National Authority for Civil Protection – ANPC; Portuguese Environment Agency), Sweden (Swedish Contingencies Agency); Slovakia (Ministry of Environment), and the UK (Health and Safety Executive).

- **Industrial associations and companies:** 9 responses.
  - Including a chemical manufacturer, a trade association, a consultancy, an engineering company, an oil and gas company and a petrochemical company.
- **EU and other international organisations:** 13 responses.
  - European Commission (JRC, DG GROW, DG ENV, DG ECHO), Iceland (Administration of occupational safety and health), Norway (Norwegian Directorate for Civil Protection), Kosovo (Ministry of Environment and Spatial Planning), Montenegro (Ministry for Sustainable Development and Tourism), Serbia (Ministry of Environment and Spatial Planning), Organisation for the prohibition of chemical weapons (OPCW).
- **Research institutions:** 15 responses.
  - Instituto Italiano di Tecnologia (Italy), RIVM (the Netherlands), TEES Mary Kay O'Connor Process Safety Center (USA), Université de Mons (Belgium), INEGI/FEUP (Portugal), University of Florence (Italy), Jozef Stefan Institute (Slovenia), Major Risk Research Center (Belgium), Universidad de Zaragoza (Spain), University of Szeged (Hungary), NCSR DEMOKRITOS (Greece), EPFL (École Polytechnique Fédérale de Lausanne, Switzerland), North China Electric Power University (China), Journal of Structural Control & Health Monitoring, Karlsruhe Institut für Technologie (KIT) (Germany).

Note that none of the responses provided as part of the consultation are linked to specific organisations in order to respect the requirement for anonymous responses.

It is worth noting that although some stakeholders responded to all questions, other stakeholders only responded to specific questions that they considered reflecting their interests / priorities better. All responses were taken into account and the response statistics included in the sections below are based on the number of responses to that specific question, rather than on the total number of respondents to the survey.

The responses to the consultation have been used to identify whether an adaptation of the data collected might be necessary to allow the establishment of policy indicators to better monitor and communicate on the achievements of the Directive.

2.2 Overview of the inputs from the workshop

The workshop was held on 11 July 2018 in Brussels and was attended by 22 stakeholders (in addition to DG Environment and the project team). The attendees' background was split as follows: 14 Member States (64%), 7 stakeholders from industry (32%) and one researcher (5%). While several NGOs were approached, none was able to participate.

The aim of the workshop was to validate the findings of the interim report and collect additional input from stakeholders.

The key topics discussed during the workshop were:

- Overview of the study, scope clarifications and explanation of how stakeholders could contribute further;
- Possible future improvements to the current monitoring and reporting systems, including the questionnaire to report on implementation and reporting to eMARS and eSPIRS;

- Key drivers of performance;
- Presentation of initial findings on possible indicators; and
- European Gravity scale of industrial accidents (EGSIA) and its possible adaptation or improvement to be widely used at European level.

A more detailed description of the points discussed is available in Appendix C (Workshop report).

3. Identification of needs and requirements for monitoring

3.1 Overview

The aim of this section is to present our understanding of stakeholders' needs that the monitoring system should address. This is based on the feedback received from stakeholders who were requested to identify all the needs that, in an ideal world, the monitoring system could respond to. The second step is a critical review of these needs by assessing whether, if they were satisfied, they would lead to an improvement on the quality of monitoring, whether they would do so in a cost-efficient way and whether it would lead to an overall improvement in the efficiency of the Directive.

3.2 Identification of the needs

When reviewing the needs, it is important to keep in mind that the information from the monitoring system is used by a range of stakeholders with different objectives. As such, this section identifies a range of needs, reflecting the use made of the information by the different types of respondents. For example, some stakeholders are mostly providers of inputs (i.e. Member State competent authorities providing information to meet the reporting requirements) whereas others are mostly users of outputs (e.g. NGOs using information from eSPIRS and the analysis produced by the MAHB on eMARS).

The list of needs / use made of the information is presented in the table below. It includes a 'shortened' version of the needs and quotes from the responses received (non-exhaustive) to provide further context.

Table 3.1 Overview of the needs identified by stakeholders

Shortened version of the needs identified	Extracts from stakeholder's feedback related to the need
From reporting on establishments (eSPIRS)	**From reporting on establishments (eSPIRS)**
A. Identify number and location of establishments in eSPIRS [1]	1. "Seveso status need to be updated from Seveso II to Seveso III like in reporting on establishments"– CA [Note: This has been implemented since the survey took place] 2. "driving force behind a lot of the digitalisation-work in Denmark that would otherwise have struggled to get prioritized" – CA 3. "Information on EU level on establishments does not have much value on national level. It is nice to know, but not very important for policy making. "– CA 4. "Directing enquiries on location" - CA 5. "Actually, we do not use the eSPIRS data directly. For information purposes we use the statistics produced by the EC JRC MAHB" – CA 6. "Reporting to the eSPIRS seems unnecessary complicated and time-consuming. "– CA 7. "Very interesting information." – Trade association 8. "should provide insight on the "fluctuations" among the establishments/organisations entering/leaving the list" – Research Institute
B. Find establishments for a specific activity in eSPIRS	1. "we use eSPIRS to identify where to find a particular type of industry" - CA 2. "Reporting on establishments give opportunities to access very useful information about the number, type and location of establishments" – CA 3. "We do use eSPIRS-data to identify establishments at a certain location and to find other establishments for a certain type of activity." – CA 4. "At the national level, the data reported to eSPIRS are useful for the activities of inspections of these establishments." – CA

Shortened version of the needs identified	Extracts from stakeholder's feedback related to the need
	5. "It is useful to have the possibility of searching accident data per type of installation" - Industry
C. Identify establishments in neighbouring countries in eSPIRS	1. "We get information, which establishments are internationals" – CA 2. "Identification of transboundary risks." – CA 3. "understanding what establishments are located around LT in neighbouring countries" –CA
From reporting on implementation of the Directive	
D. Compare situations with other Member States / benchmarking	1. "It is important to have an overview and to compare with other Member States in order to share good practices" – CA 2. "to compare situations in different countries" – CA 3. "The implementation report is an interesting document, which shows us a certain number of indicators and which allows us to compare ourselves with the other EU member states." - CA 4. "The implementation report allows us to compare ourselves with the other EU member states and reveals eventually weak spots, where we have to improve ourselves." - CA 5. "Data can be used as an enforcement benchmark tool." – CA 6. "Basis for comparison with other member states." – CA 7. "Use it to benchmark our performance. For example, on level of testing of emergency plans or frequency of inspection." – CA 8. "to compare with other MSs" – CA 9. "for comparison between us and other countries" – CA 10. "It would be good if the full investigation of each accident could be ensured at EU level in order to collect lessons learned" - Industry
E. Identify practices of Member States	1. "Conclusions form the reports help to identify good and bad areas in the national implementation of the directive. They are also used to learn about different practices used in other Member States" – CA 2. "We are interested in solutions from other countries on how to improve safety, but policies cannot wait for another reporting round." – CA 3. "Issues and facts about the implementation of the Directive in the legislative system of each country. The information provided should be concrete and representative of the current situation in each MS." – Research Institute
F. Learn about implementation at EU level	1. "Because this has changed over the years this is the reporting that is the least clear. However, the Progress towards less 'complicated' questions from the reporting is a great improvement. I believe the part about the testing of emergency plans is the most relevant parameter to actually predict degree of implementation" – CA 2. "Interesting insights in terms of the trends on the number of establishments in other Member States and on the enforcement of the legal obligations." – CA 3. "- EU-wide control of implementation of the Seveso Directive by the Member States (based on the assessment of all reports of the Member States provided by the Commission)" – CA 4. "Overview of implementation." – CA 5. "General information on how the Directive is implemented in different Member States." –CA 6. "Here we get information on status of implementation in the different MS, interesting for us mainly for benchmarking purposes within the different areas of implementation (like for example external emergency planning)" – CA
G. Information to train inspectors	1. "[information on implementation] helps us to improve our supervisory guidance to our operational supervisory authorities" – CA 2. "Potential use for learning from accidents to shape inspection activity" – CA 3. "Main source to identify improvement opportunities. For instance, information from other MS related to testing emergency plans; guidance for coordinated joint inspections; procedures and experience of accessing to justice, are good example" – CA
H. Identifying and responding to new implementation issues through	1. "The implementation report could be a source of information about the different approaches of Member States on specific subjects. Maybe there could be, in each report, a (non- mandatory) question about a specific Seveso instrument (e.g. safety report assessment procedures, deadlines, etc.)." – CA

Shortened version of the needs identified		Extracts from stakeholder's feedback related to the need
	implementation report	2. "We want to exchange experience with other countries. Not wait for a future reporting format when everyone has its solutions in place. EU reporting information is old by the time we get it. It does not help new implementing issues." – CA
I.	**Deficiencies identified during inspections to be presented in implementation reports**	1. "Adding information on the deficiencies identified during regular inspections and emergency plan drills." – CA 2. "How often Seveso establishments are inspected in other Member States and what are the important findings of the inspections. "– CA
J.	**Deficiencies identified during testing to be presented in implementation reports**	1. "Adding information on the deficiencies identified during regular inspections and emergency plan drills." – CA
From reporting on accidents (eMARS)		
K.	**Lessons learned from major accidents in eMARS**	1. "An annual bulleting of accidents would also be useful: a summary of the accidents occurred (e.g. can any trends/similarities between accidents/industry types be found?) Summary could include graphics but also discussion to highlight the key points. Bulletin could give valuable information for benchmarking not only for authorities but also for the industry. " – CA 2. "Part of learning from accidents is that they are being investigated and the experiences are being taken." – CA 3. "It is useful to learn from accidents which have already happened and to identify suitable accident scenarios for each kind of equipment, installation or substance during the appraisal of the safety report, when preparing an inspection and when establishing emergency planning scenarios." – CA 4. "Useful, especially to the operators, that access the database to perform the historical analysis of accidents needed for the safety report's risk analysis." – CA 5. "useful for operators, inspection, authorities - lessons learned " – CA 6. "To train / inform Seveso officers / inspectors" – CA 7. "Keep up to date with lesson's learned" – CA 8. "To gain some information on accidents and present them during some workshops with authorities, operators, stakeholders." – CA 9. "Information of major accidents in extractive waste facilities is very important information for the assessment of the effectiveness of the Extractive Waste Directive." – European Commission
L.	**More advanced functions of eMARS with fully searchable database on accidents and available in other languages [2]**	1. "Because the system is not intuitive also there has been no commission checks on how often and what the different member states report. This has the effect that member states are able to not prioritise this reporting." CA 2. "Decision from 2009 is not fully in line with the new Seveso III Directive" –CA 3. "We mainly use the Bulletins and statistics produced by the EC JRC MAHB, which are based on the reported accident and establishments. Establishing more searching options would facilitate a better usefulness of the eSPIRS and eMARS." – CA 4. "The usefulness of the information would increase if the delay in publishing the accident description in eMARS wasn't so long." – CA [Note: The European Commission has highlighted that the main causal factor for the long delays mentioned are the long response times by the Member States] 5. "Polish version of the database would be added value." – CA 6. "Reports should be quicker available + more focus on lessons learned. "- CA 7. "We would like to use accident reports to complete existing information in the ARIA database. As data became more anonymous with the new version of eMARS, it's difficult to match these accidents with ours (for example the new version of eMARS does not publish the country where the accident occurred)." – CA 8. "Companies must use it when documenting their safety."– CA 9. "Many improvements needed in the eMARS form" – MAHB. 10. "eMARS hard to use in terms of following number of accidents reported per annum, and possible normalisation for interpretation of the possible trends. - Also, analysis for root

Shortened version of the needs identified	Extracts from stakeholder's feedback related to the need
	causes or similar is next to impossible. We need new approach to allow such uses." – Research Institute
M. **Number of near misses reported in implementation reports or through eMARS[3]**	1. "Reporting of near misses should be encouraged. Guidance on what is to be considered as an "interesting near miss" could help." - CA 2. "Internally, we register all the accidents and 'near misses' reported to the Competent Authority." – CA 3. "Near misses tell some story as well" – CA 4. "Information concerning accidents should include also near-misses and should come at preliminary stage (at first) and then completed when official investigation results are ready." – Research Institute 5. "There needs to be more consistency among Member States in reporting near misses" – Several CA 6. There should be more focus on lessons learned from near misses rather than in collecting statistical data, given the differences in how different Member States report near misses" – Several CA
For all reporting streams	
N. Information for public participation from all reporting streams	1. "[on eSPIRS] Useful and important only as information for the public and for public participation" – CA 2. "The establishment are visible on a map on the internet for everyone to see." – 3. "[on eSPIRS] public information" – CA 4. "[on eSPIRS] use as the database for wild public" – CA 5. "Exchange of good information and educational aid" – Industry
O. Information on Safety Management Systems and how they are deployed	1. "I think so yes but these things are bit difficult to monitor." – CA 2. "Definitely!!! MAHB has proposed this as a separate category for causes in its design improvement proposal. " – MAHB 3. "If this is to be reported, it might be reported in connection with reporting of typical findings from inspections?" – CA 4. "This is important but not possible to report the quantitative information." –CA 5. "Human and organisational aspects of safety should deserve more attention in the reporting of the Seveso Directive" – CA 6. "No, there are better ways to exchange information on improving measures. " – CA 7. "Yes, covering SMS would be important. The experiences of regular inspections would include this topic." – CA 8. "This is complex - difficult to anticipate how the questionnaire would look and how different member states would accommodate." – CA 9. "Human and organisational aspects of safety are complex to synthetise, and the reporting of these aspects would be difficult to achieve." – CA 10. "NO, I think that the process of learning from accidents should be prioritized and e-MARS is the best tool for that." – CA
P. Information on socio economic impacts of major accidents	1. "Those kind of data are difficult to obtain but of high relevance" – Research Institute, SI 2. "That usually also NOT considered in the scope of risk assessments - but should be." – Research Institute, 3. "Developing modelling that looks at some economic impacts of major accidents." – CA 4. "Planning to establish such a system." – CA 5. "We find it difficult to get all the data needed, not least the economic, but also personal injury is limited information about." – CA 6. "Difficult since the socio-economic impacts often take long time to be visible." – CA
Q. No need for some / all of the monitoring data	1. "we don't use the data as we already have the same information" – CA 2. "[on eSPIRS] There is no need for and no use." – CA 3. "[on eSPIRS] Not usually used" – CA 4. "Exchange of information on good practices on how to implement the directive is good for a workshop. Reporting is not necessary to come to that exchange and learning from each other." – CA 5. "I do not use the data reported to eSPIRS" –Several CAs

Shortened version of the needs identified	Extracts from stakeholder's feedback related to the need
	6. "I do not use the data reported to eMARS" – Several CAs 7. "[on eMARS] In practice, we do not make use of the collected data." – CA

Note 1: This change has already been implemented in eMARS in 2018
Note 2: According to the JRC, the main causal factor for the long delays mentioned are the long response times by the Member States.
Note 3: According to the JRC, reporting "near misses" should not be mandatory because it is very difficult to enforce, given the lack of an official definition of "near miss" in the Directive, and the administrative burden in countries with limited resources or a very high number of Seveso establishments. Member States should note the value of reporting them and learning from them.

The needs identified by the different categories of stakeholders are presented in the table below. The table presents the number of respondents that identified the needs or use in the first column as relevant.

Table 3.2 Number of times needs are identified by stakeholders based on their category

		Member States	Industry / Industry Association	European Commission and other international organisations	Academia, NGOs and other
A.	**Identify number and location of establishments**	4	2	1	
B.	**Find establishments for a specific activity**	4	1	1	1
C.	**Identify establishments in neighbouring countries**	4			
D.	**Compare situations with other Member States/ benchmarking**	9	2		1
E.	**Identify practices applied in Member States**	7	1		1
F.	**Learn about implementation at EU level**	11	1		3
G.	**Information to train inspectors**	3			
H.	**Identifying and responding to new topics**	1			
I.	**Deficiencies identified during inspections**	4			1
J.	**Deficiencies identified during testing**	1			1
K.	**Lessons learned from major accidents**	17	3	3	
L.	**Improvements to the eMARS database**	7		1	1
M.	**Information on near misses**	2		1	1
N.	**Information on Safety Management Systems**	12		3	
O.	**Information to be used for public information**	1	1		1
P.	**Information on socio economic impacts of major accidents**	3	1		2

	Member States	Industry / Industry Association	European Commission and other international organisations	Academia, NGOs and other
Q. No need for some / all monitoring data (depending on specific reporting stream)	10			2

3.3 Critical review of the needs

The table below provides our analysis on the needs expressed, the extent to which these are already addressed and wherever a gap appears. Our analysis also includes our general comments, possible options to meet the need and our view on potential limitations, costs and benefits in addressing these needs.

Table 3.3 Review of the needs identified by stakeholders and our analysis

Need Identified	Our Analysis
No need for monitoring data (depending on specific reporting stream)	Comment: One respondent indicated having no need at all for the monitoring data. A further nine respondents indicated having partial need for the monitoring data. The eSPIRS data was most often quoted as not used / needed followed by the eMARS data. However, this feedback does not cover the analysis of the data for use by the European Commission, particularly the Major Accident Hazards Bureau in monitoring chemical accident trends across the EU and industry sectors. Options to meet the need: Giving more visibility to the importance of having Seveso establishment data could help to reduce criticisms that the eSPIRS data are of "no value". EU-level reporting of establishments is valuable for tracking Seveso policy at EU level, concentrations of EU level risks, identifying accidents that have occurred in Seveso establishments immediately in case there is a need to respond, tracking changes in the composition of hazardous sites by industry sector across time that can greatly influence the EU's risk profile. The EU can take policy action if challenges are shared by Member States. This helps the Commission understand the challenges, which makes the EU Seveso policy dynamic. The challenges are represented by the location, industry sectors, as well as changes in them over time. This information is essential to show the importance and impact of Member State investments to fulfil Seveso Directive obligations. Communicating how this information is used could give stakeholders a better understanding of the value of the data.
Monitor compliance with the requirements of the Directive	Comment: The reporting on the implementation every three and now four years is used in order to gather information on the implementation of the Directive and understand the level of compliance in Member States. Such information can be used also for possible infringement proceedings. Options to meet the need: The reporting appears to meet this need, even though further details in the reporting might be suitable and support additional understanding of the implementation levels. Following comments from EU Member States, the Commission will reflect on the possibility of providing a harmonised reporting template in which contextual information and clarifying comments can be included and which could streamline the reporting by Member States.
Identify number and location of establishments	Comment: The identification of the number and location of establishments is considered to be a need by stakeholders, in particular being able to communicate basic information on Seveso establishments, for example following a media request. From the responses provided, stakeholders are not necessarily attached to the data being presented in eSPIRS. Further comments on integrating this reporting with other environmental reporting (e.g. the EU Registry on industrial sites project merging data from E-PRTR and IED[1]) and making it compatible with the INSPIRE Directive were received. Options to meet the need: The Commission has indicated its willingness to, in cooperation with the EEA, look into possible options to align or even integrate eSPIRS reporting with other environmental reporting, for example the EU Registry on industrial sites. When addressing this need it is important to take into account the current work from the European Commission on streamlining environmental reporting[2]. Information from the current 'Promotion of best practices for national environmental information systems, tools for data harvesting at EU level'[3] and feedback from implementing the European INSPIRE Directive might be useful to consider as it focuses on improving reporting websites. Potential limitations: Changes to the eSPIRS database, including merging it into other systems, would need to take into account costs and benefits. At this point in time it is not entirely clear if the systems can be combined because of the different way that Seveso sites and IED sites are regulated. Seveso sites are based on the entire establishment while IED sites are based on individual installations. Hence, not all of a Seveso site will be an IED installation and vice-versa. It is therefore not clear whether the costs of integrating reporting would outweigh the benefits. Competent authorities do not necessarily integrate registers so the value of having an integrated register may not have significant cost savings to Member States. Indeed, Seveso authorities are not necessarily the same authorities that are in charge of the

Need Identified	Our Analysis
	implementation of the other legislation. (The environment authority is the lead Seveso authority in little over half of the Member States) However, benefits could arise from better alignment of the data available , maintaining the databases in the same location, and allowing cross referencing between databases to give further context on IED coverage of installations and Seveso coverage of establishment (e.g. linking to E-PRTR emissions data). In order to assess the pros and cons of integrating these reporting systems, the Commission could prepare an inventory of possible synergies, the pros and cons and possibly also draft a roadmap outlining possible steps before taking a final decision on an eventual integration of the various reporting systems including eSPIRS.
Find establishments for a specific activity	Comment: Similar to the previous need, being able to identify establishments engaged in a particular activity was found useful by stakeholders. It was also suggested that it would assist if activity level analysis was provided, for example by showing the evolution in the number of establishments by tier and by activity. This was seen as a way of gaining an understanding of the dynamism of a specific industrial sector. It would also presumably help to understand drivers such as establishments coming within scope as other legislation changes e.g. CLP classifications. Options to meet the need: Changes made to the eSPIRS database should retain the option to search by activity so that this need continues to be addressed. In addition, some analysis at activity level could be requested as part of the regular analysis of the data on establishments that is conducted. Potential limitations: This need is largely already met. Addressing the need for additional analysis could generate some additional costs from the time required to process the data and provide the analysis. However, it would allow more information to be generated from the reported data.
Identify establishments in neighbouring countries	Comment: This need was identified despite the existing requirement in the Seveso Directive to provide information directly to neighbouring Member States in the event of establishments having the potential for creating a major accident with transboundary effects (Article 14). Options to meet the need: This need indicates that reporting to eSPIRS does not replace the notification obligation in the legislation and further questions might be included in the implementation reports to verify that this information is shared in practice and regularly updated. Potential limitations: Addressing this need would not generate additional costs apart from additional reporting time.
Compare situations with other Member States/ benchmarking	Comment: The importance of the use of the information generated for comparison / benchmarking is apparent from stakeholders' feedback. Options to meet the need: There would be value in focusing further the analysis of the implementation on comparing Member States' practices. Furthermore, stand-alone comparative analysis of Member States' practices such as inspections or testing of emergency plans (two of the most often quoted provisions of the Directive) could provide additional value to Member States from the reporting. Potential limitations: Addressing this need could result in additional costs (for example support for additional reporting) however it would also add value to the existing reporting streams.
Identify actual practices in Member States	Comment: Comments highlighted that implementation reporting can provide information on whether provisions are implemented but not how this is done. There seems to be further need for the implementation reporting to present actual practices (and possibly best practices) and solutions to practical issues encountered. Options to meet the need: It is important to understand the purpose of the different reporting streams. The implementation reporting which occurs every four years is not the best suited to exchange of information. The feedback received highlights the benefits from activities such as meetings of the Seveso Expert Group and Joint Mutual Visits organised by the MAHB. Having such events more frequently might be a more appropriate means of exchanging information. Specific events could focus on exchanging information on provisions of the Directive and Member States' practices (e.g. a workshop on testing emergency plans that would identify different practices and solutions to issues encountered). Potential limitations: Addressing this need would result in additional costs for example with the organisation of a workshop, the support for such a workshop and potentially transport for attendees. The

Need Identified	Our Analysis
	costs could be reduced by organising the workshop adjoining a Seveso Expert Group (SEG) meeting. Benefits of such events would depend on the attendance and participation of Member States. Attempting to capture such information within Member States implementation reports would likely create a substantial additional burden on member states and would likely be challenging to report upon.
Learn about implementation at EU level	Comment: There appears to be general agreement that this need is being fulfilled by the analysis of the implementation reports. Furthermore, information on transposition is presented in Eur-lex[4] including a link to all the transposing measures in each Member State. This information is transparent and readily available.
Information to train inspectors	Comment: Feedback indicated that the information from the implementation reports and the lessons learned analysis from the MAHB are used as part of the training of inspectors and Seveso officials. Options to meet the need: This need appears to be fulfilled already, however it might be useful to keep this use of the information in mind when drafting the material and try to identify examples of best practices, to which attention can be drawn to during training sessions. It might also be useful to consider whether this need can be further met, by asking in the first instance Member States whether they would like more on this aspect (e.g. training events for inspectors, training event for inspectors' trainers and guidance on inspection including a training section). Potential limitations: Training of staff is a national prerogative, as such the European Commission cannot prescribe specific training material. Addressing this need further (e.g. by organising training events for inspectors for example) would result in costs.
Identifying and responding to new topics	Comment: The feedback highlights that the reporting system lacks reactivity and fails to capture and treat new issues. Options to meet the need: Addressing this need should not be through the implementation reporting system. It could be better suited to include a recurring 'emerging issue' slot during the Seveso Expert Group discussion meetings where better reactivity can be ensured. Indeed, this would allow free discussions on new topics being identified at Member State level and not need to wait for formal reporting on the matter. An annual SEG seminar could also help to address this need. Potential limitations: Addressing this need would not result in additional costs.
Deficiencies identified during inspections	Comment: Information on inspection practices and number of inspections are included in the implementation reports. Based on feedback received it could be valuable to have more insights into the type of deficiencies identified by Member States during inspections. Options to meet the need: This could be addressed by increasing the visibility of existing initiatives such as the Mutual Joint Visits or the work of the Technical Working Group on Inspection (TWG 2) both of which are highly relevant to this topic. The TWG 2 publishes several reports a year. It recently began to publish reports directly online so that users could easily translate reports in their own language using web tools. Making these resources more visible could be a way to satisfy the needs expressed by Member States. Adding questions in the implementation questionnaire on this topic could be valuable, as the issues are not likely to vary a lot in between reporting periods. Potential limitations: Both of these options have costs and benefits. The first one (i.e. TWG 2) would allow more exchange on the topic selected and could be accompanied by an overview of inspection practices at Member State level but would require costs for the organisation of the event, support of the workshop and possible attendance of stakeholders. The JRC noted that if Member States increased their contributions to the TWG 2, it could impose more administrative burden on MAHB to manage the output. The second option (i.e. including in implementation reporting) is less costly as it would require only marginal additional time to report and analyse but would be less interactive and slower.
Deficiencies identified during testing	Comment: Information on the way emergency plans are tested and the number of plans tested during the reporting period are included in the implementation reports. Based on the feedback received it would be valuable to have information on the type of deficiencies identified during testing. Options to meet the need: The same options are identified as for the previous need. Potential limitations: The same limitations are identified as for the previous need.

Need Identified	Our Analysis
Lessons learned from major accidents	Comment: One of the main needs identified from the reporting under the Seveso III Directive, the lessons learned from major accidents, are seen as a very valuable source of information. Options to meet the need: Overall the feedback is very positive and the needs are met to some extent with only limited improvements identified (e.g. an annual overview, including trends analysis). However, based on changes to the eMARS database (see below) more improvement could be made by making the lessons learned more complete. Potential limitations: According to JRC, the majority of the needs could be met by increasing the number of MAHB lessons learned bulletin per year but this would cost more resources for MAHB. The suggestion of an annual analysis is not particularly practical because there are not enough major incidents annually reported to eMARS, or a uniformity of lessons learned across them, to justify the resources required for a formal publication. Moreover, reporting on major accidents often takes a long time and a year's reporting is not representative of what actually occurred during the year. The JRC indicate that it is far better to focus on lessons learned bulletins on specific topics and looking at global accident trends across hazard sources. In any case, annual information on new incidents reported in the eMARS database are already presented at OECD and SEG meetings and the information is freely available to all CAs. More importantly, Seveso accidents are not the only chemical accidents that have lessons learned and one can also learn from accidents occurring in other hazard sources and outside the EU. To a large extent the OECD Working Group on Chemical Accidents and the IMPEL group on industrial accidents also are important forums for sharing lessons learned and EU Member States who can already attend them as members and observers (for those who are not OECD members). An alternative would be better search functions for the database to allow Member States to do their own analysis.
Improvements to the eMARS database	Comment: A range of possible improvements to the database are included and described by both Member States and the MAHB. Some Member States appear to be aware of planned changes for the eMARS design and fully support this. Furthermore, some of the suggestions made from the MAHB (e.g. being able to use all fields as a search filter) are also echoed by Member States as valuable. Options to meet the need: A list of possible changes to the database are presented in Section 8. Potential limitations: Addressing this need would require further exchange with the MAHB to understand the range of changes that can be made and the associated costs. Addressing this need should also take into account the current work from the European Commission on streamlining environmental reporting[5].
Information on near misses	Comment: Near misses are being monitored and reported at national level in some Member States and it was suggested that this information could be shared at EU level. The feedback seemed to indicate an interpretation of the requirement of near misses that differs from the legislation. Indeed, while Annex VI also includes near misses in accidents to be notified, several stakeholders understand this reporting as voluntary. Near misses identification has a cultural component that might vary from Member State to Member State. Options to meet the need: Further reporting of near misses, draft guidance on the definition and the identification of near misses including a methodology to be used at EU level. These would not be useful for statistical purpose necessarily but would provide further lessons learned. Potential limitations: The differing interpretation on the compulsory nature (or not) of the reporting of near misses can hamper addressing this need. Furthermore, the absence of a common approach to identifying near misses at EU level would limit the comparability of the data. Consequently, there is the need for greater recognition of the potential value of reporting near misses so that this is done more widely. Both options would result in costs.
Information on Safety Management Systems	Comment: Despite their limitations, the current monitoring system already provides information regarding some provisions of the directive (internal and external emergency planning, safety reports, inspections, etc.) however, no information is available on the way Member States handle the human and organisational factors issues through safety management systems. Options to meet the need: Addressing this need could be done by adding questions to the implementation reporting questionnaire. However, feedback from Member States was quite mixed on whether this could be done, in particular due to the complexity of the issues relating to safety management systems. It is worthwhile to note that this is addressed in the TWG 2 on Seveso Inspections that has published common inspection criteria pertaining to some elements of safety management systems.

Need Identified	Our Analysis
	Potential limitations: Prior to addressing the need, it would be useful to further test the need based on the mixed feedback from Member States on the suitability of reporting such information.
Information to be used for public information	Comment: Respondents indicated that information available publicly online is useful for public information and general education of the public, for example providing information neighbouring establishments. Options to meet the need: Addressing this need would require raising awareness of material existing at EU level providing information on the Seveso Directive (e.g. leaflets, summaries of reports). A possibility could be to create a publicly available register or summary of infringements and complaints at national level. Member State Competent Authorities hold this information and it would be more convenient for citizens if they are able to access through the relevant national website or other information channels available in each Member State. Potential limitations: None identified.
Information on socio economic impacts of major accidents	Comment: There are only limited information on socio economic impacts of major accidents, and while three Member States are currently working on developing systems to monitor this, there does not seem to be a general methodology on assessing and reporting these costs. Options to meet the need: The European Commission could produce guidance on monitoring and reporting socio economic impacts of major accidents and refine the reporting of such impacts in eMARS. The European Gravity Scale for Industrial Accidents could be used to guide the monitoring and reporting of socio-economic impacts, however this might need some (minor) adjustments in order to make the current scale compatible with Annex VI of the Directive [see section 6.4]. Potential limitations: Addressing this need may require additional costs for providing guidance to Member States, on a common approach to identify and report socio economic impacts so that these can be reported (through eMARS) and then analysed and compared. For example, the incorporation of a Gravity Scale rating into the eMARS reporting system could be a very low-cost option. The benefits from addressing this need would be an increased understanding of impacts of major accidents which could benefit both Member States and the industry. The modernisation of the European Scale would require some additional work.
Information on the fluctuation of numerical values (number of establishments, establishments in each tier, etc) over the reporting period	Comment: During the stakeholder workshop, some Member States stated that it would be useful to report the annual variations within the numerical questions of the implementation questionnaire. This used to be the case in the past. Options to meet the need: An option would be to add the option of providing this information in the reporting template. Another possibility is to provide the information in percentages: year on year fluctuation, % inspected establishments, % upper-tier establishments, among others. Potential limitations: It might be an administrative burden for Member States with a large number of establishments. Therefore, it would be suitable to implement this as an option (allowing Member States to report in this format if easier).
More information exchange between Member States	Comment: The workshop highlighted the need to exchange more information between Member States on training of inspectors, resources used and deficiencies during testing of emergency plans. Discussions were held on whether additional questions in the implementation questionnaire would support the Commission or would improve the information exchange. Options to meet the need: Additional questions in the questionnaire could be an option but this was not generally favoured as the most appropriate means of information exchange. Examples of useful information are the number of inspection days on specific aspects or the level of effort of complying with certain provisions in comparison to other aspects. Several Member States at the workshop stated that any additional questions should be very well justified as they may lead to a significant burden. Another option would be to cover those topics in the TWG2 or the Seveso Experts Group meeting. In this regard, it was highlighted that the frequency of these meetings should increase. Potential limitations: As stated above, the possible additional questions in the reporting questionnaire outlined above may pose a significant administrative burden to competent authorities and would not

Need Identified	Our Analysis
	facilitate effective communication. As a result, increasing the frequency of TWG2 and/or SEG meetings was highlighted as a better solution as opposed to increasing the number of questions.

Note 1: http://cdrtest.eionet.europa.eu/help/ied_registry
Note 2: http://ec.europa.eu/environment/legal/reporting/fc_actions_en.htm
Note 3: http://www.eis-data.eu/
Note 4: http://eur-lex.europa.eu/legal-content/EN/NIM/?uri=CELEX:32012L0018
Note 5: http://ec.europa.eu/environment/legal/reporting/fc_actions_en.htm

4. Review of the current monitoring system

4.1 Overview

This section is dedicated to the review and analysis of the ability of the current monitoring system to answer the variety of needs expressed by stakeholders and capture all relevant aspects of the Directive's implementation and impacts. More precisely, the following questions were to be addressed:

- What are the strengths and weaknesses of the current monitoring system?
- To what extent does the current monitoring system comply with the Better Regulation Guidelines?
- Are actions necessary as a result of the roadmap for action included in the report by the Commission on Actions to Streamline Environmental Reporting?
- To what extent does the current monitoring system comply with other horizontal legislation or guidance on environmental reporting (e.g. INSPIRE Directive).
- To what extent does the current monitoring system comply with other relevant guidelines on monitoring and indicators (e.g. OECD[9])?
- To what extent does the current monitoring systems address other identified policy and communication needs (including those identified under task 2), not explicitly specified in the Seveso-III-Directive and subsequent Commission Implementing Decisions?
- Is there double-reporting, overlap or other unnecessary administrative burden? Does the current monitoring system collect information which is eventually not used? Can information available from other sources be used for the purposes of the monitoring system under the Seveso-III-Directive and vice-versa?
- What is the perception of stakeholders towards the current monitoring system? What suggestions exist for its improvement?
- If identified during the performance of the task: what good practices exist in Member States and in other policy areas?

In order to perform this task, we relied on the following approach:

1. Setting assessment criteria.
2. Analysis and discussion.
3. Synthesis and recommendations.

[9] https://www.oecd.org/chemicalsafety/chemical-accidents/41269639.pdf

4.2 Setting assessment criteria

The review of the monitoring system strengths and weaknesses has been considered with respect to the following criteria:

- *Perceptions by European and International industrial risk management stakeholders* including: Member States, EU industry associations and international organisations. However, since Member States are the main providers of data required by the monitoring, their appreciations and needs have been given particular scrutiny.
- *Compliance with reference guidelines*. Regulatory monitoring is a complex area that has been the subject of various standardisation (Coglianese, 2012). At the EU level, the Better Regulation Guidelines are the reference framework against which the Seveso monitoring systems are considered. We also reviewed other guidelines and regulations relating to environmental reporting, including the INSPIRE Directive and OECD reference documents.
- *Efficiency through information streamlining and avoidance of double reporting*. Every reporting system imposes a burden on the organisation(s) in charge of collecting, using and interpreting data. The issue of balancing the monitoring system costs and benefits is especially relevant in the case of the Seveso Directive as the data providers (Member States) are not the sole stakeholders using the data collected, as the data are also processed and analysed by the European Commission.

The criteria were analysed based on the inputs provided by the following sources:

- Responses to the questionnaire sent to stakeholders including representatives of Member States, industry associations and international organisations (see Section 2).
- Additional comments collected during the project workshop held on 11 July 2018 (DG Environment, Brussels). The discussions triggered during this workshop allowed the project team to present their analysis and interpretation of answers provided whilst collecting impressions on the interim conclusions and recommendations.
- An internal project workshop organised by INERIS with the objective of discussing how the current monitoring system succeeds in providing a representative picture of the reality of the Directive, its implementation and its application. Nine practitioners were involved in order to cover the variety of themes considered in the Seveso Directive including land use planning, safety reports, safety management systems and emergency planning.

4.3 Analysis and discussion

4.3.1 Feedback from questionnaire responses and stakeholder workshop

Table 4.1 and Table 4.2 provide a synthesis of the Member States' and international organisations' responses to the questions relating to the assessment of the monitoring system strengths and weaknesses.

Table 4.1 Member States' responses on questions relating to the review of the monitoring system

Member States' responses			
Questions		Responses	Comments
I.	**What is your overall perception of the current monitoring system of the Directive?**	Neutral: 7 Positive: 16 Negative: 2	Positive appreciations of the current monitoring system have been associated with the following strengths: Lot of information is made available allowing benchmarking between member states' practices. It is believed to be sufficient to appreciate the level of implementation of the directive. Complementary to the above, some positive responses also came with suggestions for improvements that are listed in the following alongside the limitations pointed out by neutral and negative responses: A lot of information is entered in the system but very [little] is useful. Reporting burden perceived as high. Double reporting. Only accident reporting is considered as useful. Difficulty to access useful information.
II.	**Do you have horizontal suggestions on how to improve the monitoring system?**	No: 9 No response: 11 Suggestions: 5	Rely on big data to combine information collected from different monitoring systems. Less information on the basis of need to know, not on the basis of nice to have. The monitoring system should also address the adequacy of the scope of the Seveso directive and in particular evaluate if increases in the number of establishments are justified in terms of major accident hazard potential. Separate information on number of installations from implementation reporting and to integrate eSPIRS (obligatory data fields) into EU-Registry reporting. Better access and better presentation of data.
III.	**Is there any good practice with regards to monitoring from your Member State you would like to share?**	No: 11 No response: 11 Suggestions: 3	Suggestions included: Publication of Seveso establishments' performance in connection with inspection activity. Elaboration of an electronic system for Seveso reporting concerning eSPIRS and eMARS including an electronic workflow from operators via local authorities to the national level. Provide detailed guidance on assessing safety reports and MAPP.
IV.	**The tri-annual reporting is structured according to Decision 2014/896/EU. Do you think the content of the reporting is appropriate, sufficient and useful? Explain why or why not.**	No: 2 Yes: 13 Unclear: 1 No response: 5 Suggestions: 3	Suggestions included: Favour information on concrete best practices rather than on "nice to know" information. It is not clear whether information is useful and for whom. Complete with the following information: Conclusions of regular inspections. Types and number of deficiencies identified in regular inspections. Experiences of internal and external emergency plan drills. Risk management measures prescribed by the authorities.

Member States' responses			
V.	**Is there any overlap or duplication of tasks due to the reporting on the implementation of the Directive? If yes, please describe.**	No: 9 Yes: 10 No response: 5 Suggestions: 2	Overlaps identified are the following: Double reporting of the number of establishments in eSPIRS and implementation reports. Some questions in the reporting system for the "Convention on the Transboundary Effects of Industrial Accidents" are very similar to those in the Seveso reporting system and partially overlap. Some suggestions were also formulated: A unified EU register for all Seveso related information. Connect national and EU registers.
VI.	**Lessons learnt shows that an important part of majority of accidents is caused by human and organisational factors. Accordingly, rooms of improvement might lay in the human and organisational aspects that are formalised through SMS (Safety management Systems). In the current reporting system, there is no reference to the way SMS are deployed. Do you think human and organisational aspects of safety should deserve more attention in the reporting of the Seveso Directive? If so, why and how?**	Yes: 18 No:4 No response:1 Suggestions: 4	A large majority of respondents agreed on the relevance of human and organisational factors in shaping safety performance. SMS are therefore believed to be a key lever to achieving the directive's objectives. However, important concerns are expressed on the way such aspects could be monitored through indicators or specific questions. We provide in the following a more detailed account of these concerns: Difficult to quantify SMS related information. Difficult to anticipate how the questions would look like and how different member states would accommodate. Difficult to get relevant details on SMS from operators. SMS related aspects should be considered exclusively in eMARS (lessons learned) but not in prevention context. The following suggestions have been formulated: SMS related aspects should better be addressed in seminars, SEG, TWGs and MJVs. Force reporters in eMARS to address lessons on SMS level. Report on aspects of the SMS addressed during inspections. Non mandatory questions in the implementation reporting.
VII.	**Assessing the number and location of establishments in the EU is vital to understand the development of the associated risk for citizens. Member States currently need to report on the number of establishments twice, in the reporting to eSPIRS under Article 21(3) and in the report on the implementation of the Directive (Article 21(2)) because the reporting of establishments to eSPIRS does not include a requirement on the frequency of data updates. Establishing an obligation for regularly updating eSPIRS could overcome this double reporting and would allow eSPIRS to achieve its objectives better. Would you favour such an integration of the reporting on the number of establishments under eSPIRS? Would you see any obstacles?**	Yes: 15 No:6 Further analysis required:1 No response: 3	Although a majority of responses are in favour of such an integration in eSPIRS, some strong resistance is observed in the negative responses, especially regarding the burden of a more frequent updating of information in eSPIRS.
VIII.	**Major accidents meeting criteria of annex VI are to be reported within a year after their occurrence. Until the data can eventually published often several years pass by. This hampers the objective of rapid**	Appropriate: 13 Inappropriate (too long): 3 Inappropriate (too short): 1 No responses: 6 Suggestions: 1	Many of the respondents consider the one year delay as appropriate regarding the technical and sometimes juridical complexity of accidents. They therefore do not suggest shortening this time scale and do not see any possibility of accelerating it. Some other contributions pointed the fact that accident reporting requirements are subtler in the sense that they already include a

Member States' responses			
	information sharing and identification of relevant trends. Do you believe this timescale is appropriate? What options do you see to accelerate the process? What obstacles exists to reporting faster?		fast reporting track that can be incrementally completed by newly available information. Suggestions go in the same direction by suggesting an incremental reporting that is periodically enriched by technical and juridical information when they become available.
IX.	**Do you believe the format requested by Decision 2009/10/EC for the reporting of major accidents is appropriate? If no, please specify what you think should be added or removed**	Yes: 13 No: 0 No response :5 Suggestions: 5	The following improvement suggestions have been formulated: Report the worst case scenario that could have occurred. Update the system with respect to Seveso III nomenclature.[10] Distinguish direct and root causes. Align eMARS reporting with other great EU databases (ARIA, ZEMA, etc.…). Simplify in a way that approaches the AIDA reporting scheme developed by JRC.
X.	**Beyond the number of major accidents, are you aware of any other indicators that could be used to monitor the effectiveness of the Directive? If yes, which ones?**	No: 7 No response: 8	The following improvement suggestions have been made: Number of non-compliance during inspections. Additional indicators can be obtained by analysing the factors identified in eMARS as causing accidents. Number of all major accidents, not only those reportable through annex VI. Indicators from OECD guidance on safety performance indicators. The extent of consequences of major accidents. Number of establishments using appropriate process safety performance indicators and the performance levels within those. Near misses.

Table 4.2 International organisations' responses on questions relating to the review of the monitoring system

International organisations			
Questions		**Responses**	**Comments**
I.	**What is your overall perception of the current monitoring system of the Directive?**	Neutral: 1 Positive: 4 Negative: 0 No response: 8	Opinions formulated here disregard implementation questionnaire to which respondents do not have access.
II.	**Does the current system deliver the information meeting your needs?**	Yes: 4 Partially: 1 No response: 8	The use of NACE categories by some countries in eSPIRS creates a problem in analysing the industry sectors associated with Seveso sites.
III.	**Do you have suggestions on how to improve the monitoring system? Please respond by distinguishing each reporting stream**	No: 4 No response: 8	
IV.	**Beyond the number of major accidents, are you aware of any other indicators that could be used to monitor the effectiveness of the Directive in reducing the disaster risk? If yes, which ones?**	Only two comprehensible response has been given	Respondents point out the following aspects: Near misses could be considered as a relevant complementary means of assessing risk levels. Major accident statistics are not representative due to their rarity.

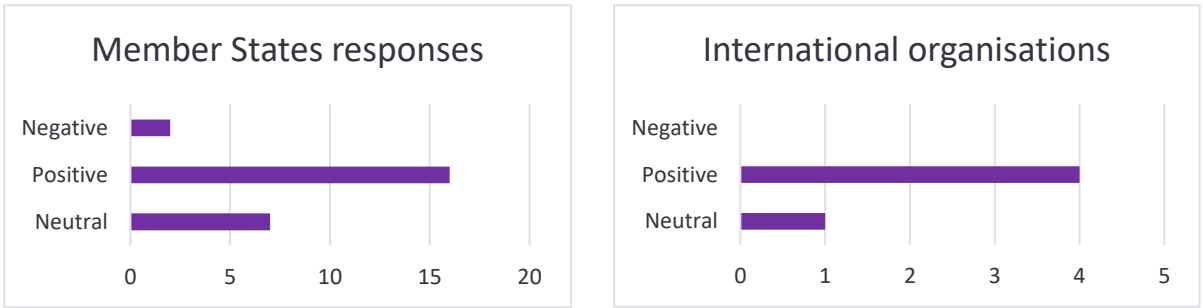
[10] Note that this has since been updated by the MAHB

International organisations			
			Look at other type of chemical accidents in non-Seveso sites (pipelines for example). Such reporting could be a requirement under the civil protection mechanism
V.	**Lessons learnt shows that an important part of majority of accidents is caused by human and organisational factors. Accordingly, rooms of improvement might lay in the human and organisational aspects that are formalised through SMS (Safety management Systems). However, in the current reporting system, there is no reference to the way SMS are deployed. Do you think human and organisational aspects of safety should deserve more attention in the reporting of the Seveso Directive? If so, why and how?**	Yes: 4 No response: 8	All respondents agreed on the relevance of integrating this aspect in the reporting. The following suggestions have been made: Report on typical inspection findings regarding SMS aspects. Already suggested as a separate category of causes by the MAHB in its design improvement proposal.
VI.	**Do you have suggestions on how to improve the monitoring systems (beyond existing reporting streams)?**		No relevant information provided here.

With respect to these elements, following are considered to be strengths:

- The perception of the current monitoring system is generally positive for both Member States and international bodies. Indeed, information made available by the implementation reports is considered as sufficient and valuable for two primary purposes, including the benchmarking of inspectorates' practices and the appreciation of the level of implementation of the Directive in other Member States.
- eSPIRS appears to be a valuable means of sharing information on existing Seveso plants with the public.
- eMARS is reported as being a useful tool to share lessons learned on major accidents occurring in Europe as well as a valuable accident scenarios database against which inspectorates may compare the list of accident scenarios considered in safety reports.

Figure 4.1 Global perception of the Seveso monitoring system



Regarding weaknesses, the following aspects have been raised by respondents:

- With respect to the ability of the current monitoring system to demonstrate the real impact of the Directive on the risk levels to which EU citizens are exposed, respondents agree to a large extent on the weak statistical representativeness of the number of major accidents making such

a figure a poor estimator of risk trends. Various improvement suggestions have been made: extend accidents accounts to include incidents, near misses and non-Seveso establishments, and collate information on number of non-compliance issues identified during inspections.

- With respect to the efficiency of the monitoring system (i.e. the ability to collect information in an optimised way), many respondents (40%) pointed to the overlap in data collection regarding:
  - Double reporting of the number of establishments in eSPIRS and the implementation questionnaire.
  - Some respondents have the feeling that not all information collected is valuable or useful (see Table 3.1 and Table 3.3).
  - Reporting under UNECE TEIA[11] overlaps in a few areas with Seveso reporting: identification and notification of hazardous activities with the potential to cause transboundary effects; steps taken to prevent major accidents; and preparedness testing and cooperation and exchange.
- The one-year, and often multi-year, delay for reporting accidents in eMARS has also raised different opinions as some respondents believe that a shorter time is not possible due to the technical and juridical complexity of accident analysis whilst others state that a faster process would allow better reactivity and integration of lessons learnt.
- Concerns over the relevance and usefulness of the information reported have been raised. Some of the respondents requested clarification that the information collected and reported is actually beneficial to the Commission or other Member States (i.e. not 'nice to know' information). On the other hand, others have suggested that there is a need to expand information collected to various aspects of inspectorates' daily practices so as? to foster benchmarking. However, discussions with Member States competent authorities at the workshop pointed out that the implementation reporting was not probably the best place for this information exchange. Seveso Expert Group meetings and more frequent gatherings of the Commission with Member State competent authorities are regarded as a better forum for these exchanges of information.
- Almost all respondents share the opinion that human and organisational aspects of safety should not be overlooked. However, important concerns are raised over the capacity of a monitoring system to capture these aspects. Some respondents are open to suggestions whereas a few others are reluctant to see any integration of these dimensions in a future evolution of the monitoring system. Other means of capturing and sharing such information may be more appropriate.
- A minority of respondents pointed to the inability of the reporting system to uncover novel or emerging issues that should deserve further attention amongst member States and greater sharing of lessons learnt and practices. However, it was also acknowledged that the reporting systems are not necessarily the best forum for this kind of exchange and that for uncovering emerging issues, the regular Seveso Expert Group meetings are considered to be better placed for these kinds of exchanges.

Considerations on the above weaknesses by the authors include:

- As mentioned earlier in this report, the monitoring system under consideration in the present study is composed of the 4 yearly implementation report, eSPIRS and eMARS. It appears that some of the weaknesses and needs expressed by Member States and others do not readily fit

[11] Working group implementation, UNECE, TEIA https://www.unece.org/env/teia/wgimplementation.html

within these monitoring processes and may therefore benefit from further consideration in other available reporting channels such as Technical Working Groups (TWG) and Mutual Joint Visits (MJV). For instance, the Seveso Expert Group appears to be a far better forum to address in a timely and more detailed manner the issue of emerging issues whereas MJVs can offer valuable opportunities for benchmarking and sharing of inspectorates' practices.

- We agree with the observation that human and organisational aspects expressed through safety management systems are complex and require careful treatment if one is looking to report on them. A possible way around this difficulty could be to not consider the Seveso monitoring system as a tool able to perfectly describe complex situations but rather as a tool that helps raising awareness and providing inputs on key topics for further discussion. In other words, the complexity of Safety Management Systems related matters should not stop the monitoring system from addressing them but should orient it towards a more modest purpose e.g. being the production of valuable inputs for workshops or working groups dedicated to this topic.

4.3.2 Feedback from additional sources

In addition to the above, a range of activities were undertaken to gather feedback. This included an internal workshop held within INERIS and further review of literature.

The internal INERIS workshop allowed for a bottom-up analysis based on individual and collective experiences at INERIS about the way the Seveso Directive's requirements are translated into practices and the ability of the monitoring system to capture these dynamics.

The workshop participants were split into three small groups in which thoughts and findings were systematically shared and discussed with all other participants.

A synthesis of the discussions organised according to the evaluation criteria described earlier is provided in the following:

- The accident reporting framework is perceived as rich as it allows people to explore technical and organisational mechanisms behind major accidents. In doing so, lessons learnt can be highly profitable for the whole EU community despite the one-year minimum delay (sometimes much longer) required to collect and organise the data.
- Regarding the conformity with the Better Regulation Guidelines, discussions raised the following points:
  - As required by the Better Regulation Guidelines, the current monitoring system provides information on implementation, application and compliance through a 4-yearly detailed questionnaire. However, no references are made to contextual information, especially regarding safety costs incurred for establishments because of the regulatory constraints.
  - A more detailed analysis of the implementation and compliance issues reveals that not all the Directive's provisions are considered. Indeed, the questionnaire items cover emergency planning, land use planning, safety information and inspections. However, this evaluation is not exhaustive as, for example, there is no reference to whether Safety Management Systems are actually deployed in establishments and inspected by the authorities. Similarly, there is no reference to whether establishments are producing (as required and on time) their safety reports and to what extent these documents provide satisfactory demonstration of knowledge of risks.
  - As already pointed out, the experts acknowledge the difficulty of encompassing such complex items in a simple questionnaire. There is also no value in requesting information that could not be further analysed and used. There could be however discussions with

Seveso experts on better monitoring these aspects by using all available fora, including working groups, so as to allow a more complete view of the Directive's implementation.

- Complementary to this, an important question when addressing implementation is the capacity of the monitoring system to capture whether Member States are making available adequate human and technical resources for the Directive to have an impact on safety. For instance, national authorities' staffing may vary in terms of number (per establishment for instance) and competence (quality and updating of training). These aspects are of particular relevance as various major accidents, including Bhopal and more recently Deep-Water Horizon[12] have pointed to a lack of authorities' supervision and staffing and information on these aspects is not monitored / reported upon.
- This point was extensively discussed during the stakeholder workshop. Participants rightfully pointed to the need to acknowledge Member States differences in terms of inspection practices and allocation of resources. Raw comparisons of such numbers may lead to misleading interpretations and even political pressure if some countries appear to have more inspectors compared to others. Accordingly, finding the right balance between addressing this important aspect of the Directive's implementation whilst acknowledging the legitimate and justified differences in Member States practices appears to be an important area of improvement for the future.

4.3.3 Linkages with the Better Regulation agenda

The Better Regulation guidelines aim at the streamlining of reporting systems in every Directive. This issue is also the subject of the 2017 EU action plan (COM(2017) 312)[13]. For the Seveso Directive, it is worth emphasising the already ongoing efforts deployed by the European Commission services to improve the monitoring system performance with regard to this aspect. Indeed, some of the actions defined in the EU action plan (COM(2017) 312) are already translated into effective initiatives as described below:

- Action 2 initiates a rolling work programme in which thematic working groups supervise streamlining of reporting obligations under environmental legislation. The Seveso reporting system is part of the 2018-2020 rolling work programme.[14]
- Action 6 has identified Seveso establishment location as one of the priority datasets for which a full implementation of the INSPIRE directive is envisioned[15]. The aspects related to the location of establishments and the data on establishments involving dangerous substances are noted as of particular interest.
- The fitness check on reporting on EU environmental policy performed in 2017[16] identifies the opportunity to streamline reporting of the European Pollutant Release and Transfer Register (E-PRTR), Seveso directive, and the Extractive Waste Directive. This possibility was discussed during the workshop and while some synergies are possible, there were also important drawbacks raised (e.g. the differences in Competent Authorities in charge of the various reporting).

[12] Please refer to this press article for the last available statements of the federal Minerals management Service on this issue. https://www.huffingtonpost.com/2010/05/16/deepwater-horizon-inspect_n_578079.html?guccounter=1

[13] Following the fitness check evaluation in June 2017, a rolling work programme has been developed with the objective of streamlining environmental reporting across different EU legislation. The EU action plan COM (2017) 312 structures the key actions defined to achieve these objectives.

[14] http://ec.europa.eu/environment/legal/reporting/pdf/FC%20Reporting%20-%20rolling%20WP%20incl%20annex%20-%20version%2002.2018.pdf

[15] https://ies-svn.jrc.ec.europa.eu/projects/2016-5/wiki

[16] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017SC0230&from=EN

Despite these initiatives, two additional items required by the action plan could be addressed more thoroughly in the next versions of the reporting system:

- *Action 8: Promote the wider use of citizen science to complement environmental reporting*. In the specific case of the Seveso Directive, this could lead to considering population awareness and understanding of risk levels in the monitoring system as well as their contextual knowledge to inform EU policy makers of the everyday reality of Seveso risks. The Commission already receives direct feedback from citizens occasionally, but this is not yet systematically recorded.
- Action 10: Strengthen cooperation with relevant international organisations, like for example the European Environment Agency and/or the UNECE, to look into possibilities to streamline reporting and information management between the EU level and the international level. We see in this action a good opportunity to provide satisfactory responses to some of the streamlining requests pointed out by the respondents in particular in relation to the overlap with the reporting under the UNECE obligations.

The Member States' four-yearly questionnaire is focused on whether some of the Seveso Directive policy levers are actually implemented rather than discussing the quality of this implementation and whether it produces tangible results. For instance, regarding inspections, the questions mainly address the issue of planning design and effective realisation leaving aside the issues of quality of inspections and tangible follow-up actions. Stakeholders at the workshop agreed that issues of inspectors training, type of inspections (planned vs unannounced) or inspection topics could benefit from sharing of experiences at the EU level. Here again, it was acknowledged that this could be through a specific experience sharing forum such as the Seveso Expert Group or dedicated working groups between Member States and the European Commission rather than the existing monitoring systems.

Similarly, to the responses gathered in the survey, workshop participants agreed on the need to further explore the way impacts on risk levels should be monitored beyond the figure of the number of major accidents. This issue is a core topic of the monitoring system review as it strongly determines whether all efforts are deployed in the right direction.

4.4 Synthesis and recommendations

Collecting stakeholders' perceptions and experts' opinions has allowed exploration of various strengths and weaknesses reflecting the diversity of stakeholders' standpoints and expectations associated with the Seveso monitoring system. Before further discussing these elements, it is important to note some of the inherent specificities of the monitoring system under consideration that make some of these weaknesses almost inevitable, not only in the way that the monitoring system is designed, but first and foremost in the way that the monitored system is functioning. These specificities are:

- The large variety of Member States practices make it difficult to adopt common criteria to appreciate their individual performances. For instance, discussions held during the stakeholders' workshop reflected the potential biases that may be introduced if a unique indicator is used to monitor and compare important implementation aspects like inspection staffing or safety management systems inspection practices. Indeed, the type of establishments inspected, the type and depth of inspections are important parameters that cannot be reduced to a simple numerical indicator.
- Input data providers (Member States) are only in partly the final users of the data (the European Commission also uses and analyses the reported data). Consequently, the issue of reducing the reporting burden and questioning the relevance of reported information appears naturally as a recurrent weakness that can be overcome when benefits are clearly explained and presented to Member States, provided that all information collected is genuinely of value.

- Finally, the current project addresses only some of the monitoring systems used for the Seveso Directive (see Section 1.2) and does not consider others such as TWGs and MJVs. Some of the reported weaknesses (in terms of understanding the successes of the directive), although acknowledged, would be better addressed through these fora, and it should not be concluded that the monitoring systems considered are not appropriate.

With respect to these elements, we summarise and discuss the set of strengths, weaknesses and suggestions collected for each of the three monitoring systems in the scope of this project.

Table 4.3 Seveso Monitoring channels considered in this study

The four yearly reporting on implementation	**Reporting on accidents - eMARS**	**Reporting on establishments - eSPIRS**
Strengths	***Strengths***	***Strengths***
▪ Implementation and compliance items required by the Better Regulation guidelines are addressed. ▪ Covers a large of set of the Directive's provisions. ▪ Provides useful information both for Member States and the Commission. ▪ Responses template considered as satisfactory by Member States.	▪ Accident reporting is considered as highly useful for Member States' sharing of lessons learnt. ▪ The accident reporting framework is perceived by experts as rich and providing insightful information on the deep causes of accidents allowing a better sharing of lessons.	▪ Valuable means of sharing information on establishments with the public.
Weaknesses	***Weaknesses***	***Weaknesses***
▪ Not all provisions of the Directive are assessed with regard to implementation and compliance criteria. ▪ Overlapping with other reporting including Convention on the Transboundary Effects of Industrial Accidents and UNECE TEIA. This is explained to some extent by the difference in objectives in the reporting streams but could be further streamlined (e.g. same reporting for some parts of the questionnaire). ▪ No references in the reporting to contextual information as required by the Better Regulation Guidelines.	▪ A (minimum) one-year reporting delay is perceived by some respondents as too long. ▪ Some presentation and search functions improvements were identified as possible improvements. ▪ Challenging to make use of the information as a measure of performance.	▪ Double reporting of the number of establishments with the implementation report. ▪ There is a lack of visibility on whether citizens, NGOs and academia/researchers are exploiting eSPIRS data. It would be beneficial to collect statistics relatively to this point. Some stakeholders lack feedback on the use of data from the eSPIRS platform by users like citizens, NGOs and academia/researchers, and are therefore under the impression that those data do not appear to be widely used.
Suggestions for improvements	***Suggestions for improvements***	***Suggestions for improvements***
▪ Explore, with Member States, how reporting through the questionnaire or any other means may be widened to include all of Directive's provisions (if appropriate).	▪ In order to improve eMARS's ability to provide DG Environment but also Member States with a better representation of risk levels, further integration of near misses and major accidents in non-Seveso establishments ((pipelines, roads, railways…) to eMARS reporting should be further investigated.	▪ Integrate eSPIRS reporting into EU registry (This has already been identified as a potential improvement and the Commission plans to discuss this with Member States). ▪ Provide activity level analysis (evolution in number by tier or activity for example). ▪ Eliminate the double reporting by asking, in the implementation report,

The four yearly reporting on implementation	Reporting on accidents - eMARS	Reporting on establishments - eSPIRS
	▪ In addition, and to better learn from past accidents, it could be highly beneficial to define a typology of causes in accident reporting that can be easily matched with Safety Management Systems items (mechanical integrity, learning from experience, working procedures…). In doing so, eMARS could help to identify information on key organisational deficits that need to be addressed at the EU level. ▪ Consider merits of aligning eMARS with other national EU databases (e.g. ZEMA and ARIA) in order to increase comparison through similar typology of accidents ▪ Regarding the issue of delays in accident reporting, it appears reasonable to accept a certain gap between accident occurrence and reporting if one is expecting an enriched and exploitable analysis of accidental mechanisms, including organisational ones. An improvement could be gained by reminding users that accident reporting requirements already include a fast reporting track that can be incrementally completed when further information becomes available**.** ▪ Reconsideration of the consequence categories in eMARS and addition of a rating //in accordance with the EU Gravity Scale for Industrial Accidents.	either for a list of establishments or the confirmation that data on eSPIRS are up to date for the reporting period. ▪ Provide more active feedback from the side of DG ENV and the MAHB to the competent authorities in the member states to better showcase the added value of the eSPIRS data.
Horizontal aspects		
Strengths ▪ Overall positive appreciation by the stakeholders of the monitoring system thanks to its ability to address implementation issues and provide Member States with a representative image, to some extent, of the variety of national practices. ▪ The Seveso directive is being considered in several streamlining initiatives at the EU level offering opportunities for real improvements on this aspect. ***Weaknesses*** ▪ Further streamlining efforts to continue to reduce the reporting burden. ▪ Reporting burden is generally perceived as high despite efforts from DG Environment to tackle this issue through several initiatives: shifting from a 3 yearly implementation questionnaire reporting to 4 yearly, several initiatives to streamline reporting as discussed earlier. ▪ Member States lack understanding to some extent on the uses and relevance for the Commission of the information asked to report. It might be valuable to make clearer in the analysis of the implementation for example, the use made of the information reported.		

The four yearly reporting on implementation	Reporting on accidents - eMARS	Reporting on establishments - eSPIRS

- Double reporting of the number of establishments in eSPIRS and implementation reports has been noted by member states (the significance of this has not been examined here).
- The Directive's main objective is to ensure a high level of protection for human health and the environment for European populations exposed to hazardous industrial activities. One of the information sources currently used to assess whether this objective is being met is data on the number of major accidents, as collected in eMARS. As pointed out by multiple responses to the questionnaire, relying exclusively on this figure to assess the directive's impacts on risk levels is insufficient. Since, major accidents are, fortunately, extremely rare, their statistical representativeness is poor. Furthermore, a lack of accidents is not synonymous with safety as proved by the large number of near misses in industrial history. Bearing this in mind, the number of accidents remains an essential piece of information to assess the performance of the Directive, since its ultimate objective is to prevent them and minimise their effects. It is noted that it needs to be assessed alongside other important information such as near misses, lessons learned from previous accidents and information on testing, planning and informing collected as part of the implementation reporting.

5. Key drivers of performance

5.1 Overview

This section focuses on the identification of key drivers of the performance of the Seveso III regulatory system. We define a key driver of performance as any aspect, within or out of the regulatory mechanism that may have a strong impact on the final objective of the Directive being met (i.e. the reduction of risks from industrial accidents). By identifying these drivers, we aim at:

- Providing the Commission with insights into the relevance of information already collected under the current monitoring system. Is each piece of information collected related to a key driver?
- Providing policymakers with an indication of where to focus their monitoring capabilities and resources to obtain the highest value.

It is unclear which measures within the Seveso Directive are considered to be most effective and efficient and which ones contribute but are less vital. This section is intended to provide a better understanding of this issue. Furthermore, in case of non-compliances, such knowledge would allow the assessment of where corrective actions by the Commission would be most effective. The section covers:

- Operator's obligations (notification, major accident prevention policy, safety management systems, safety plans, internal emergency plans);
- Competent authorities' obligations (external emergency plans, inspection, land-use planning); and
- Citizen's rights (public information, participation in decision making, access to justice).

Consideration is also given to whether there are other drivers, not included in the Seveso-III-Directive, that play a noteworthy role. Where it turns out that it is currently not possible to fully understand the drivers, solid proposals are included on how to close knowledge gaps.

In order to achieve these objectives, the project methodology relied on

- Feedback from the online survey from various categories of stakeholders, especially representatives of Member States.
- Safety experts familiar with Seveso Directive's mechanisms and their impact on risk levels.
- Literature analysis regarding technical, regulatory and more globally societal mechanisms having a significant impact on final levels of industrial risks.

5.2 Results on identification of key drivers through the questionnaire

The individual ability of the various provisions of the Seveso III Directive to impact final level of risks has been approached in the questionnaire through a quantitative scale distinguishing 5 levels (1 to 5, with 1 being the least important and 5 the most important). The respondents were asked to provide their personal assessment on the relative contribution of each provision to achieve the directive's objectives. The average scoring of each assessed disposition is given in the table below.

Table 5.1 Respondents scoring of the various Directive's provisions (indicators) with regard to their individual contribution to risk reduction and the Directive's objectives

	Notification system	MAPP[1]	SDMS[2]	Safety report	Internal emergency planning	External emergency planning	Inspection	LUP[3]	Public information	Public participation	Access to justice
Member States (22 responses)	4.1	4	4.4	4.6	4.6	4.5	4.7	4.5	3.7	3.3	3.2
International organisations and industry (6 responses)	4	3.8	5	4.3	4.7	3.8	4.6	4	3.6	4.1	2.7

Note 1: Major Accident Prevention Policy
Note 2: Seveso Directive monitoring systems
Note 3: Land use planning

Three comments can be made:

- Member States responses are quite homogeneous in the sense that all technical and organisational provisions are believed to be important whereas elements pertaining to public participation are perceived as less useful[17] in achieving the Directive's objectives. This aspect is particularly concerning if we know that important evolutions in EU and several national policies have taken the path of increasing public involvement in risk related policy making.

  These first stage responses have been further discussed during the stakeholders' workshop, see further details in Appendix C.

- Respondents from international organisations and industry have a more differentiated approach. MAPP is for instance an organisational arrangement for which impact on risk levels is perceived as low because of its administrative character whereas SMS, safety reports, emergency planning and LUP receive the highest scores. Public involvement is quite positively rated although the issue of facilitating access to justice regarding environmental matters appears to raise scepticism.

- Whether all provisions receive similar score or not is less important than the fact that almost all of them received a score higher than 4. This reflects that what is currently measured is worth measuring. Furthermore, the high scores attributed to safety management systems and safety reports reinforce some of the conclusions and recommendations discussed in the previous section regarding the need to elaborate an adequate monitoring mechanism for these two aspects (but not necessarily through the monitoring systems considered in this project which involve periodic reporting to the European Commission; other fora may be more appropriate).

5.3 Identification of key drivers through experts' discussions and literature analysis

5.3.1 Overview

This section presents a complementary analysis based on internal discussions at INERIS combined with a literature review. We distinguish two categories of driver: the first highlights within the Seveso Directive the

17 This can be nuanced by considering that stakeholders invited to the survey were technical experts, already familiar with technical provisions of the Directive.

provisions believed as having the most important impacts on the final levels of risks from major accidents. The sectors regulated under the Seveso Directive are also influenced by other drivers of different categories: technical, societal and regulatory. We therefore discuss these external drivers in a second distinct category.

5.3.2 Internal drivers of performance

High risk industrial systems are complex in the sense that they imply multiple layers – technical, human, organisational- and a large variety of stakeholders: inter alia industry, national and EU authorities, local communities, technical experts. A natural consequence of this complexity is the need for policy makers to rely for their intervention on a combination of complementary levers whose individual impacts are limited but whose combined effect is necessary to achieve required objectives.

The Seveso directive fully fits within this description as it relies on the following four complementary mechanisms:

- Improving industry's management of the risks that they generate.
- Deploying required mitigation measures including land use planning and emergency plans.
- Fostering public risk awareness and participation to decision making.
- Deploying competent and independent inspection authorities.

The following describe why each of these mechanisms is key for the directive's overall performance and how their respective impact on various aspects of the industrial system make them all of comparable importance.

Improving industry's management of the risks that they generate

No risk governance is possible without extensive knowledge of the risk scenarios generated at an establishment and the terms of their everyday management. This aspect is addressed by three provisions in the Seveso Directive:

- Safety reports identify risk scenarios and the appropriate barriers to reduce those risks to within acceptable limits. They are accordingly the first building block of every risk management process.
- The Major Accident Prevention Policy (MAPP) is a descriptive document listing the global orientations of the company regarding the issue of major risks.
- The Safety Management System structures the organisational efforts and responsibilities for addressing the list of risk scenarios and maintaining safety performance on a daily basis. The importance of SMS and associated organisational arrangements is well established in literature. For example, the JRC (Kawka and Kirchsteiger; 1999) have established that 66% of the major accidents reported to eMARS are caused by latent SMS failures and the deeper the failure the higher the consequences.

If safety reports and the Seveso Directive monitoring system are complementary in the sense that the second handles the risk scenarios identified by the first and both are of central importance, the MAPP remains a high-level document with little impact on the everyday practice of risk management. Accordingly, and with respect to this first mechanism, safety reports and the Seveso Monitoring system are considered as key drivers of the directive performance.

Deploying required mitigation measures including land use planning and emergency plans

Land use planning and emergency plans are two provisions targeted at organising the way risks can be mitigated by means of improving cooperation between the industry and stakeholders. Indeed, land use

planning aims to reduce population exposure to risks whilst emergency planning tackles the issue of optimising rescue services in case of accidents.

These mechanisms are key if one is to remember that despite all efforts, it remains out of human reach to exhaustively identify risk scenarios and prevent all possible technical, human and organisational factors from combining to produce a major accident.

Public awareness and participation to decision making

For land use planning and emergency plans to be effective, it is crucial to ensure full cooperation of local communities, including the general public but also local decision makers. For instance, reducing population concentration around Seveso establishments comes at a price as it goes against the natural tendency of intensifying economic activities and reducing daily commute of workers. In order for this policy to be accepted and costs to be shared between the various stakeholders, it is necessary to make use of participative processes where risk awareness is raised and collective decisions are made making them accepted and legitimate.

Accordingly, and in contradiction with the feedback from stakeholders that rated public participation as low as a key driver, a similar level of importance should be allocated to these aspects as we have observed the impact of this mechanism in improving stakeholders' cooperation and public acceptance of Seveso related policies. It is also worth recalling that this suggestion is in accordance with Action 8 of the streamlining action plan discussed earlier and dedicated to the importance of further considering citizen sciences in environmental reporting.

Deploy competent and independent inspection authorities

Risk governance policies are built upon the principle of industries being responsible for their risks and authorities being in charge of controlling their compliance with regulation. Maintaining this balance in interactions between these two major actors is key for the success of the Seveso directive.

We discussed earlier how endowing inspection authorities with adequate level of resources and staffing is key for the directive implementation. In addition, literature already discusses the importance of further enriching the quality of inspection-industry interactions to improve the final levels of risks. Two key mechanisms are suggested:

- Jain et al (2017) emphasise the importance of further developing leading process indicators in order to serve as a basis for discussions and priority settings for both industry efforts and inspection themes. Such a mechanism has already proved its positive impacts for workplace safety where records of incidents have started to go down after reporting of dedicated indicators have become mandatory.
- In their paper on inspectors' abilities to correctly evaluate the risk levels of Seveso establishments, Lindhout and Reniers (2017[18]) emphasise the importance of uniformity in the way inspections are conducted and the need for standard regulator appraisal methodologies. In other words, developing benchmarking on these aspects is expected to positively act on the final levels of risks.

To summarise, we agree on the equal importance of a subset of the Directive provisions being: safety reports, SMS, land use planning, public information and participation and finally inspections by authorities. We suggest considering the MAPP as a secondary priority for monitoring.

[18] https://pure.tudelft.nl/portal/en/publications/risk-validation-by-the-regulator-in-seveso-companies(fe9e3b39-04af-472e-a59b-615384616a40)/export.html

5.3.3 External drivers of performance

Complementary to the above, we discuss in the following a set of drivers that have a direct or indirect influence on the final levels of major risks in Seveso establishments.

It is worth noticing that, although this work addresses both internal and external key drivers, they are not all meant for future consideration in the Seveso Directive Monitoring System. Indeed, some aspects, especially external factors, will remain out of the directive's scope. However, it is informative to identify them so as to better understand the variety of mechanisms that can influence the final outcomes of the directive.

Evolution of external threats

Industrial systems are and will be experiencing an evolution of the external threats to which they may be exposed. A first category of emerging threats is the one resulting from climate change and the increase in intense climatic episodes. Heatwaves, storms and flooding are expected to become important triggering events for which dedicated risk assessment and management methodologies are required. A second category of emerging threats is those relating to security issues, including cyber-attacks. Here again, the security of Seveso sites is already recognised as being of increased importance and, if not treated may result in a rapid degradation of accident avoidance and mitigation performance in the EU.

Economic dynamics

Economic globalisation has the potential to produce negative effects on the management of Seveso plants. Indeed, like any other economic good, Seveso plants have become tradable goods to which formulae for rapid profitability, standardisation of practices, high personnel turnover or subcontracting are applied. Unfortunately, maintaining high levels of process safety performance requires the exact inverse: stability in personnel and practices, favouring long term profitability and investments, acknowledging specific safety cultures and valuing internal knowledge developed through experience.

These economic trends are therefore to be acknowledged as negative drivers of industrial risk levels.

Process vs occupational safety

In a recent event organised by INERIS, the head of the Environment Health and Safety department of an international company revealed that 90% of his reporting to the executive board was focused on occupational safety and only 10% on process safety[19]. This reflects the strong occupational safety regulation, the mandatory reporting of dedicated indicators (lost time or fatal accident rate), fear of litigation and certain reputation competitiveness among companies, positively enhanced by the Responsible Care commitment (Jain et al, 2017). A striking illustration of this was the BP Texas City accident revealing how the refinery EHS was managed using only occupational health indicators whilst no management attention was given to several process safety incidents. (CSB, 2007).

Accordingly, enhancing the deployment of process safety dedicated management tools, including process safety indicators, is a key driver that should help improving industry's capability to handle technical and organisational latent dynamics leading to major accidents.

Improve industrial appropriation of scientific development

The above observation calls for improving interactions between the academic and industrial worlds. Indeed, scientific papers and developments are rarely translated into operational and cost-effective tools and methodologies implemented in the industry. Reinforcing the ability of the academic world to get a better

[19] While there can be some overlap between process and occupational safety, the distinction is that occupational safety focuses on personal safety, while the process safety considers humans, the environment and the business. https://ichemeblog.org/2014/11/09/ten-differences-between-process-safety-and-occupational-safety-day-166/

grasp of industrial needs whilst inviting the European industry to further engage in research and development partnerships dedicated to all aspects of process safety should highly improve the industry capabilities to master their risks and consequently, improve their performances.

5.4 Conclusions

Two set of key drivers of performance have been emphasised in this section. The first, defined as "internal", points to the key provisions of the Directive that have a significant impact on the final levels of risks. We have seen that almost all provisions of the Directive receive high scores (from relevant stakeholders) allowing us to conclude that what is currently being monitored is worth monitoring. It also highlights the need to consider the means through which monitoring might be extended to cover all of the Directive's provisions. As mentioned previously, those aspects of the Directive's performance that are not so well covered by the current monitoring system may be better addressed through other means.

The second set of drivers is "external" to the Directive. As discussed earlier, these aspects are not necessarily appropriate for monitoring. They do, however, provide a comprehensive representation of the external factors that may foster or impede the directive's ability to succeed in reducing industrial risks. They therefore deserve to be considered as complementary axes for analysis when reviewing the successes of the Directive.

6. Review of socio-economic and environmental impacts of major accidents

6.1 Overview

While the current reporting framework for major accidents is primarily focused on the prevention of major accidents, it also has the objective of limiting the impact of major accidents should they occur. Currently, the accident reports often include limited information on the impact of an accident, and typically only information about immediate impacts such as fatalities and insured damage. Where information on environmental damage or socio-economic impacts is provided, it is often not provided in a structured or consistent manner, which makes analysis difficult.

The aim of this section is to present the information gathered following an investigation of the information available on socio-economic impacts of major accidents. Information was sought through the stakeholder consultation, but also through review of literature and alternative data sources. This section also discusses the responses received from the stakeholder consultation on the extent to which the European Gravity Scale of Industrial Accidents (EGSIA) is used by Member States to report on the socio-economic impacts of major accidents, and the obstacles in the way of its widespread use. While the primary focus is on socio-economic impacts, some relevant information on environmental impacts of major accidents is also included.

6.2 Review of available information on socio-economic and environmental impact of major accidents

A review of the literature available was undertaken to identify information on socio-economic impacts of major accidents. There is very little literature taking an overall view on socio-economic impacts of major accidents, but rather the literature mainly comprises articles focusing on specific individual accidents and incidents. Our review focused on the following aspects: whether quantification of costs was available, what costs were taken into account and what impact on communities and mental health was mentioned.

A summary of the type of costs mentioned in the reviewed reports is presented in the table below, while an extended version is presented in Appendix B[20].

Table 6.1 Summary of costs information identified in literature

Document title	Type of costs covered
a) **Handbook for Estimating the Socio-economic and Environmental Effects of Disasters, 2003, European**	• 2nd section: methods for estimating damage and losses to social sectors, with separate chapters on housing and human settlements, education and culture, and health. • 3rd section: Services and physical infrastructure, including chapters on transport and communications; energy; and water and sanitation. • 4th section: damages and losses to productive sectors, with separate chapters on agriculture and fisheries, industry, trade and tourism.

[20] Note that environmental consequences of accidents were not within the scope of the current study and so was not a primary focus. It is noted that assessment of environmental consequences of accidents is currently less developed than for health-related consequences. Examples of approaches to assessing the environmental consequences of accidents are set out in e.g. AMEC (2014), Development of an assessment methodology under Article 4 of Directive 2012/18/EU on the control of major-accident hazards involving dangerous substances (https://circabc.europa.eu/sd/a/456031f2-f713-4066-933b-08129a74dbe2/Article%204%20methodology%20-%20Task%203%20-%20Assessment%20environment.pdf).

Document title	Type of costs covered
Commission for Latin America and the Caribbean (ECLAC)[21]	• 5th section: Overall, cross-sectoral and macroeconomic effects, with separate chapters on environmental damages caused by disasters such as hurricanes, droughts, volcanic eruptions that have an impact on environmental capital and assets made up of ecosystems that provide society and economies with environmental goods and services. Examples include a hurricane covering a beach with debris and preventing its recreational use, damage caused to soils due to mudslides, lava flows from a volcanic eruption causing irreversible damage to landscape; the differential effect of the disaster on women; the impact on employment and income. The report includes a damage overview that provides a procedure for calculating total direct and indirect losses; and the effects of the disaster on the main macroeconomic aggregates.
b) **Modelling the economic impacts of an accident at major hazard sites, 2015, UK, Health and Safety Executive[22]**	• Harm to people (non-financial human costs and financial costs). • Evacuation (immediate and long-term). • Building damage (residential and non-residential). • Business disruption (loss of business and relocation). • Emergency services. • Environmental impacts resulting from, for e.g. contamination of land and rivers through pollution as a result of the loss of containment of harmful substances, are not quantified in this report. However, the report mentions that economic costs associated with environmental impacts could be realised through restrictions on the sale of food and livestock, access restrictions, countermeasures, damage to ecosystems and clean-up costs. Environmental costs were modelled in the COCO-2 model developed by PHE for nuclear site accidents based on contamination from radiation of agriculture and tourism
c) **Modelling the human and economic costs of major industrial accidents, 2016, Aldridge et al[23]**	• Causality impacts. • Disruption and temporary relocation of businesses. • Building damage. • Evacuation and emergency service requirements.
d) **The cost of reputational damage when a major accident occurs, 2015, Kyaw et al[24]**	• Cost of reputational damage following an accident (costs are monetised based on post-accident market valuation of the company).
e) **Is reputational risk quantifiable?[25]**	• Cost of reputational damage following an accident
f) **Impacts of Major Offshore Oil Spill Incidents on Petroleum Industry and Regional Economy, 2017, Taleghani et al[26]**	• Negative impact on occupations, incomes, tariffs, and profits, costs by clean-up activities. • Positive impact of economic compensation on employment and wages.

21 https://repositorio.cepal.org/bitstream/handle/11362/2782/S2003701_en.pdf;jsessionid=1EE20DF9E2F0EF091A988C4E623AF3BE?sequence=1

22 http://www.hse.gov.uk/research/rrpdf/rr1055.pdf

23 https://www.scopus.com/record/display.uri?eid=2-s2.0-84979502160&origin=resultslist&sort=r-f&src=s&st1=Industrial+accidents+impacts&nlo=&nlr=&nls=&sid=2d238d6b787fb283c60d5d0b05ac6c2d&sot=b&sdt=b&sl=43&s=TITLE-ABS-KEY%28Industrial+accidents+impacts%29&relpos=8&citeCnt=0&searchTerm=

24 https://www.scopus.com/record/display.uri?eid=2-s2.0-84958999601&origin=resultslist&sort=r-f&src=s&st1=Industrial+accidents+economic+impacts&st2=&sid=429361f08983ec7a7749b66b7f80ced6&sot=b&sdt=b&sl=52&s=TITLE-ABS-KEY%28Industrial+accidents+economic+impacts%29&relpos=12&citeCnt=5&searchTerm=

25 https://www.researchgate.net/publication/304024865_Is_Reputational_Risk_Quantifiable

26 https://www.scopus.com/record/display.uri?eid=2-s2.0-85010207334&origin=resultslist&sort=r-f&src=s&st1=Industrial+disasters+social+impacts&st2=&sid=718600bf9b6d3f560bc971a4d733d6cc&sot=b&sdt=b&sl=50&s=TITLE-ABS-KEY%28Industrial+disasters+social+impacts%29&relpos=2&citeCnt=1&searchTerm=

Document title	Type of costs covered
g) **COCO-2: A Model to Assess the Economic Impact of an Accident, 2008, Health Protection Agency**[27]	• Direct costs arising from emergency service costs; evacuation and relocation; individual and population exposure to radiation of agriculture and tourism; contamination of farmland, crops, animals and their products leading to output and GVA losses and costs for disposal of agricultural wastes; external and internal contamination of dwellings involving decontamination costs of gardens and exteriors, disposal costs of waste water, vegetation etc.; external and internal contamination of business; relocation of business; external contamination of commercial/industrial units including cost of decontaminating premises • Indirect costs arising from disruption of business; disruption of public services; disruption of networks; disruption of households; loss of tourism affecting the local economy
h) **The Buncefield Incident 11 December 2005: The final report of the Major Incident Investigation Board, Volume 1, 2005, Buncefield Major Incident Investigation Board**[28]	• Summary of the economic impact of the incident, comprising of compensation for loss, cost to the aviation sector, emergency response and the costs of the investigations. • Simple calculations of the range of costs for implementing recommendations for avoiding overfilling tanks with petrol.
i) **A Socio-Economic Cost Assessment Regarding Damages to Underground Infrastructures, 2013, Cirano**[29]	• Damage related to indirect costs to underground infrastructure, e.g. service disruption; intervention of emergency services; environmental impacts such as noise and vibration, greenhouse gas emissions resulting from overconsumption of energy during traffic congestion and dust production during repair work on damaged underground infrastructure; work delays etc.
j) **Marsh Largest loss in the hydrocarbon industry**[30]	• Review of largest business interruption claims for Business interruption insurance. • Property losses.
k) **Corrosion-related accidents in refineries, lessons learned from accidents, JRC**[31]	• Review of costs reported from accidents in refineries including environmental clean-up and restoration costs.
l) **Assessing the real cost of disasters: The need for better evidence, 2018, OECD (Organisation for Economic Co-operation and Development)**[32]	• Examples of countries' current practices in collecting ex-post data on disaster damages and loss in repositories through information in newspaper articles, data from regional competent authorities and insurance companies. • Examples of models developed to derive ex-ante loss estimations, which rely on good quality ex-post reporting on disaster damages and losses. • Section countries' current practices in collecting data on disaster risk management expenditure at the central government level, sub-national government level, NGOs, private enterprises, households, public-private infrastructure operators through surveys, expert consultations, stakeholder interviews and projects/programmes financed by national funds. • International approaches for estimating costs mentioned include: Sendai Framework indicators on measuring direct economic losses form disasters; UN ECLAC approach for calculating direct and indirect losses of disasters on the overall economy of the affected country, as well as on the household level; damage assessment for cultural heritage sites suggested by UNESCO. • Types of costs discussed include direct costs, losses due to business disruption, indirect costs, costs arising from environmental damages such as damage to assets owned by fisherman and farmers, damages to

[27] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/415529/HPA-RPD-046_for_website.pdf
[28] http://www.hse.gov.uk/comah/buncefield/miib-final-volume1.pdf
[29] https://www.scga.ca/files/2013Socio_Economic_Cost_Assessment.pdf
[30] https://www.marsh.com/us/insights/research/the-100-largest-losses-in-the-hyrdocarbon-industry-1974-2015.html
[31] https://minerva.jrc.ec.europa.eu/EN/content/minerva/51beddd7-1149-4230-928d-a225bf39471a/tr01corrosionrefineriespdf
[32] https://www.oecd-ilibrary.org/docserver/9789264298798-en.pdf?expires=1528714971&id=id&accname=id24042&checksum=0CED623EDF4466C1964B49F94186B079

Document title	Type of costs covered
	agricultural products, cattle loss, health impacts and impacts on cultural heritage, losses associated with the interruption of critical networks, government contingent liability to finance response and recovery.

A summary of the type of impacts on community and mental health in the reviewed reports is presented in the table below, while an extended version is presented in Appendix B.

Table 6.2 Summary of community and mental health impacts identified in literature

	Document title	Type of impacts covered
i.	**A study of posttraumatic disorders in children who experienced an industrial disaster in the Briey region**[33]	• Post traumatic disorders in children who were directly or indirectly involved in an industrial disaster. • Assessment of the respective impact of traumatic exposure, parental disorders and sociodemographic variables on the post traumatic disorders of children. • Anxiety, trauma.
ii.	**The aftermath of an industrial disaster**[34]	• The relationship between objective stressors, the workers' own feelings and the reaction of their families after the explosion and a review of the training, attitude to the workplace, general outlook and received crisis support. • Traumatisation, coping style and crisis support was assessed.
iii.	**Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine**[35]	• Radiation exposure. • Deaths due to acute radiation syndrome (ARS). • Cancer mortality. • Leukaemia, Solid Cancers and Circulatory Diseases. • Reproductive defects. • Persistent psychological and mental health problems resulting from rapid relocation, breakdown in social contacts, fear and anxiety about health effects. • Release and deposit of radioactive material. • Heavy deposition of radionuclides on open surfaces such as lawns, parks, streets; radioactive contamination of agricultural plants and plant-consuming animals due to surface deposits of radionuclides; rapid absorption of radionuclides in milk leading to significant thyroid doses to people consuming milk; persistent recycling of radiocaesium particularly in forest ecosystems resulting in high uptake of radiocaesium in vegetation and animals in forest and mountain areas; direct deposition of radionuclides on surface of rivers and lakes resulting in high activity concentration in drinking water and aquatic life. • Economic cost related to response and health care to affected population, radiation monitoring, radio-ecological improvement of settlements and disposal of radioactive waste. • Impact on local economy. • Impact on local communities.

[33] https://www.scopus.com/record/display.uri?eid=2-s2.0-0035057789&origin=resultslist&sort=r-f&src=s&st1=Industrial+disasters+social+impacts&st2=&sid=718600bf9b6d3f560bc971a4d733d6cc&sot=b&sdt=b&sl=50&s=TITLE-ABS-KEY%28Industrial+disasters+social+impacts%29&relpos=11&citeCnt=48&searchTerm=

[34] https://www.scopus.com/record/display.uri?eid=2-s2.0-0030629222&origin=resultslist&sort=r-f&src=s&st1=Industrial+disasters+social+impacts&nlo=&nlr=&nls=&sid=718600bf9b6d3f560bc971a4d733d6cc&sot=b&sdt=b&sl=50&s=TITLE-ABS-KEY%28Industrial+disasters+social+impacts%29&relpos=21&citeCnt=27&searchTerm=

[35] https://www.iaea.org/sites/default/files/chernobyl.pdf

	Document title	Type of impacts covered
iv.	**Psychological effects of a disastrous hydrogen fluoride spillage on the local community**[36]	• Psychological effects of hydrogen fluoride spill on members of the community and their relationships with physical symptoms and changes in psychological effects occurring as time passed after the accident. • Anxiety levels.
v.	**An industrial disaster. Disaster behaviour and posttraumatic stress reactions**[37]	• Acute, subacute, prolonged and chronic posttraumatic stress reactions to disaster trauma.
vi.	**Possible risk factors for acute stress disorder and post-traumatic stress disorder after an industrial explosion**[38]	• The prevalence of acute stress disorder (ASD) and post-traumatic stress disorder (PTSD) following an industrial explosion. • The variables which can be the risk factors for PTSD.
vii.	**Immediate psychological impact of the Deepwater horizon oil spill: Symptoms of PTSD and coping skills**[39]	• Psychological impact and coping styles of the Deepwater Horizon Oil Spill on Gulf Coast residents.
viii.	**Mental health of workers in Toulouse 2 years after the industrial AZF disaster: First results of a longitudinal follow-up of 3,000 people**[40]	• Association between various factors describing exposure to the disaster and anxiety and depressive symptoms. • Psychological distress. • The study revealed links between the industrial disaster and psychological distress 2 years afterwards. The results about risk factors differ according to sex and identify particularly vulnerable populations. It should guide preventive interventions in such situation.

The survey of stakeholders attempted to identify the categories of socio economic impacts to consider. Industry stakeholders provided the following as an indication of what could be considered: costs to the establishment compared to the gains of the industry (as a % of the turnover for example), direct damage, fatalities, injuries, reputational damage, damage propagation to external stakeholders, time/spatial damage, recovery time, lost functionality.

In a second step a review of the costs presented in databases was conducted both in the EU and beyond. The search was extended as, amongst EU Member States, it appears to be only one Member State with such information presented in a database (France). Furthermore, three Member States indicated that work is in progress in order to gather this information in a more systematic manner (Estonia, Hungary and the UK).

The following databases include information on socio-economic impacts of accidents:

[36] https://www.scopus.com/record/display.uri?eid=2-s2.0-85029361085&origin=resultslist&sort=plf-f&src=s&st1=industrial+accident+psychological+impact&st2=&sid=4698475b33ef3704506f56eda27489e3&sot=b&sdt=b&sl=55&s=TITLE-ABS-KEY%28industrial+accident+psychological+impact%29&relpos=4&citeCnt=0&searchTerm=

[37] https://www.scopus.com/record/display.uri?eid=2-s2.0-0023059805&origin=resultslist&sort=plf-f&src=s&st1=industrial+accident+psychological+impact&nlo=&nlr=&nls=&sid=4698475b33ef3704506f56eda27489e3&sot=b&sdt=b&sl=55&s=TITLE-ABS-KEY%28industrial+accident+psychological+impact%29&relpos=50&citeCnt=6&searchTerm=

[38] https://www.scopus.com/record/display.uri?eid=2-s2.0-84897050877&origin=resultslist&sort=plf-f&src=s&st1=industrial+disaster+post+traumatic+&st2=&sid=3c384830d6f4957c3f71c256083af6d4&sot=b&sdt=b&sl=50&s=TITLE-ABS-KEY%28industrial+disaster+post+traumatic+%29&relpos=6&citeCnt=1&searchTerm=

[39] https://www.scopus.com/record/display.uri?eid=2-s2.0-84865269758&origin=resultslist&sort=plf-f&src=s&st1=industrial+disaster+post+traumatic+&st2=&sid=3c384830d6f4957c3f71c256083af6d4&sot=b&sdt=b&sl=50&s=TITLE-ABS-KEY%28industrial+disaster+post+traumatic+%29&relpos=9&citeCnt=11&searchTerm=

[40] https://www.scopus.com/record/display.uri?eid=2-s2.0-69849104306&origin=resultslist&sort=plf-f&src=s&st1=industrial+disaster+post+traumatic+&st2=&sid=3c384830d6f4957c3f71c256083af6d4&sot=b&sdt=b&sl=50&s=TITLE-ABS-KEY%28industrial+disaster+post+traumatic+%29&relpos=16&citeCnt=8&searchTerm=

- eMARS: the database managed by the JRC includes information on costs in some instances; however, this is not always the case.
- ARIA[41]: French Ministry of Ecology, Energy, Sustainable Development listing the accidental events which have, or could have, damaged health or public safety, agriculture, nature or the environment. The reporting is done using the European Gravity Scale of Industrial Accidents (EGSIA) which assesses economic consequences. Some of the detailed reports include quantification of costs of accidents.
- JST Failure Knowledge database[42]: managed by the Japan Science and Technology Agency; it includes quantification of costs of some accidents, including remediation, social impacts including loss of reputation.
- ZEMA database: managed by the German Federal Environmental Agency, includes information on costs from property and environmental damages inside and outside the establishment.[43]

6.3 Review of socio-economic and environmental impacts of major accidents

6.3.1 Overview

In order to review in more detail socio-economic impacts of major accidents, a report on impacts of major accidents from corrosion in refineries was reviewed, along with the eMARS and ARIA database. The focus on refineries is opportunistic and due to the fact that an in-depth study had been done for that sector by the MAHB. While representative of a large sector of industries under the scope of the Directive, the refinery sector is not the only one and other sectors are addressed in following sections based on our analysis of databases.

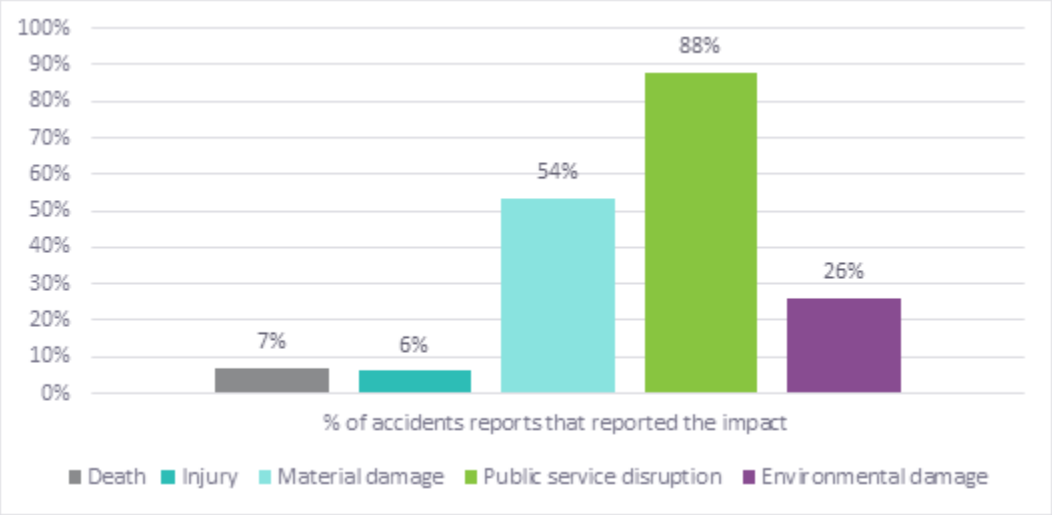
6.3.2 Joint Research Centre study (2013): Impacts of major accidents due to corrosion in refineries

Refineries form an important category of Seveso establishments. In 2014 a total of 142 Seveso establishments were categorises as 'petrochemical, refineries.

The Joint Research Centre conducted a study of corrosion-related accidents in refineries in EU and OECD countries since 1984 and based on 99 reports of important refinery accidents in which corrosion of equipment was identified as the reason leading to the accident event[44]. The study identified five main impacts resulting from an accident event, namely: deaths, injuries, material damage, environmental damage and public service disruption. Based on the data from the reports, public service disruption and material damage was the most commonly reported impact. Nearly 88% of the accident reports reviewed reported some form of public service disruption resulting from the accident, and 54% reported on resulting material damage.

[41] https://www.aria.developpement-durable.gouv.fr/the-barpi/the-aria-database/?lang=en
[42] http://www.shippai.org/fkd/en/cfen/CC1000030.html
[43] http://www.infosis.uba.de/index.php/de/site/12981/zema/index.htm
[44] https://minerva.jrc.ec.europa.eu/EN/content/minerva/51beddd7-1149-4230-928d-a225bf39471a/tr01corrosionrefineriespdf

Figure 6.1 Proportion of reviewed accident reports reporting on the five main accident impacts



To evaluate the severity of each of these impacts, the study developed a consequence ranking criteria methodology based on the European Gravity Scale of Industrial Accidents. For material and environmental damage, the level of impact was assessed using a logarithmic scale from Low to High for costs starting with < €10,000. Human consequences, production loss and public disruption was approximated using the European Gravity Scale of Industrial Accidents, condensed into 5 categories. These consequence ranking criteria developed by the JRC are shown in Table 6.3.

Table 6.3 Consequence ranking criteria developed based on the European Gravity Scale of Industrial Accidents

	Deaths	Injuries	Material Damage	Environmental Damage	Public Service Disruption
Very High	>100	>1000	>€1,000,000	€1,000,000	>1 month
High	11-100	101-1000	>€100,001-1,000,000	€1,00,001-1,000,000	1 week to 1 month
Medium	0-10	11-100	>€10,001-1,000,000	€10,001-100,000	1 day to 1 week
Low	0	1-10	>€1-10,000	>€1-10,000	>1 day
None	0	0	0	0	0

Source: JRC, 2013, Corrosion-Related Accidents in petroleum Refineries

Material damage

Material damage was reported in 54% of the reviewed accident reports. Nearly 60% of the accidents which reported on material damage, resulted in the most severe category of material damage, i.e. incurring costs greater than €1,000,000. A quarter of the reviewed accidents resulted in a "low" level of material damage, incurring costs in the range of €1-10,000. Only 2% of the reviewed accidents resulted in no material damage.

For further information on material damages following an accident, please refer to the reports listed in Table 6.1

Environmental damage

Environmental damage was reported in 26% of the reviewed accident reports. The information from accident reports was supplemented with information from literature and internet searches.

Nearly a third of the accident reports that reported on environmental damage resulted in a "very high" level of damage, i.e. greater than €1,000,000. The vast majority of the accidents (62%) that resulted in environmental damage incurred costs in the range of €1-10,000. None of the accident reports reported no environmental damage.

The total material costs of the refinery accidents since 1984 reported was €748,386,332, whereas the total environmental restoration and clean-up costs was estimated to be €698,615,706. When considering this figure, it is important to consider that this is only a partial picture as the completeness of the reporting since 1984 has varied. For comparison purposes, the Buncefield major accident has been estimated to cost €1.3 billion[45].

The major environmental impacts resulting from industrial accidents can be broadly grouped into the following categories[46]:

1. Impact on human health

   Following an accident, people may be subject to shock, trauma and confusion and in the absence of sound evacuation plans may run in the direction of the accident, increasing the risk of death and injury. If the concentration of any gaseous release is beyond the threshold limit value (TLV), it can enter the body and affect its functions.

   For instance, following the Enschede fireworks explosion (2000) and the Chemie-Park fire (2011), large amounts of toxic fumes were released into the ambient air. In the days following the Chemie-Pack fire, the common health services received 545 reports of health complaints[47].

2. Impact on terrestrial systems

   Following an industrial accident, fallout dust, gaseous clouds or dispersed toxicants can spread through the environment. Mine tailings or fly ash ponds can deposit heavy metals on soil resulting in severe soil degradation. They can also contaminate fresh water sources through surface run-off.

   For instance, the Chemie-Pack fire released large quantities of chemical substances into the air, soil and groundwater. The resulting plume contaminated crops through the deposition of toxic substances. The immediate vicinity of the fire location was seriously contaminated. The estimated damage was valued at more than €70 million . The damage consisted of, among other things, remediation of the polluted soil, other clean-up costs, health damage, water treatment costs, environmental damage, etc.[48,49]

   Of the total estimated environmental damages, the remediation costs for cleaning up the soil pollution alone amounted to €38 million. The soil around the site became so heavily polluted it had to be excavated and treated to clean up the site[50,51].

   The total environmental damage and material damage of the Enschede major-accident is estimated to amounts to around €450 million[52].

3. Impact on aquatic systems

[45] http://www.hse.gov.uk/comah/buncefield/miib-final-volume1.pdf
[46] https://www.longdom.org/articles/industrial-accidents-impact-on-environment.pdf
[47] https://de.slideshare.net/Twittercrisis/brand-bij-chemiepack-te-moerdijkonderzoeksraad-120308135755phpapp01
[48] http://www.v-smilieu.nl/upload/file/Artikel%20Chemie-Pack%20bodem%2C%20okt_%20%2712.pdf
[49] https://mens-en-samenleving.infonu.nl/diversen/66293-de-brand-bij-chemie-pack-in-moerdijk.html
[50] https://www.nu.nl/ondernemen/3727416/veel-interesse-bodemsanering-chemie-pack.html
[51] https://www.waterforum.net/acht-gegadigden-voor-bodemsanering-chemie-pack/
[52] https://mens-en-samenleving.infonu.nl/internationaal/111263-vuurwerkramp-enschede.html

Industrial effluent and accidental spills can release harmful pollutants into nearby water sources and affect their water quality and ecological balance. Aquatic organisms that are stenohaline or stenothermic may be severely impacted and vanish from the environment.

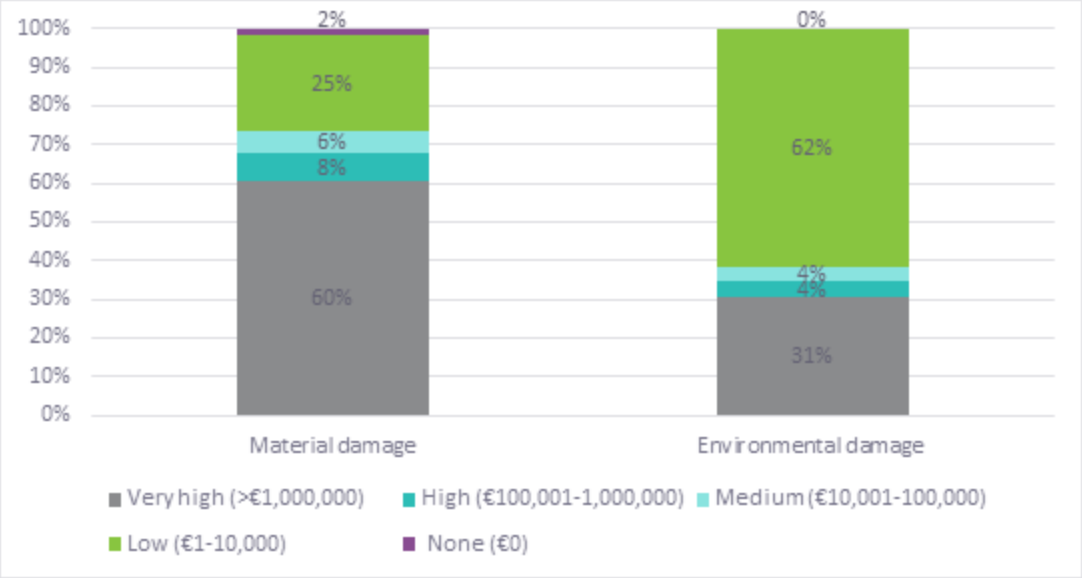
Toxic substances can also be released into the water via firefighting water, such as in the case of the Chemie-Pack fire. Measurements of the chemical composition of the firefighting water demonstrated that, shortly after the fire was extinguished, the firefighting water was heavily contaminated with organic chlorine compounds, toluene, naphthalene and xylene- some of which are known to cause cancer[53].

4. Impact on ecosystems

   Dispersed toxicants can spread through the environment and affect the local flora and fauna by interacting with living systems. Caustic gases released following an accident can lead to the formation of acid rain and can also cause necrosis, chlorosis or prohibit plants from photosynthesis.

For further information of environmental damages following an accident, please refer to reports (a), (b), (g), (i), (k) and (l) in Table 6.1.It should be noted that the primary focus of this project is the socio-economic impacts of industrial accidents. However, environmental impacts are also a significant consequence of industrial accidents, and therefore require further research and investigation.

Figure 6.2 Proportion of reviewed accident reports reporting on material and environmental damage of varying severity



Death and injury

'Death and injury' was the least reported impact, reported by only 8% and 18% of the reviewed accident reports respectively.

A total of 67 deaths and 219 injuries were reported in all the reports, with two accidents accounting for the majority of the deaths and injuries.

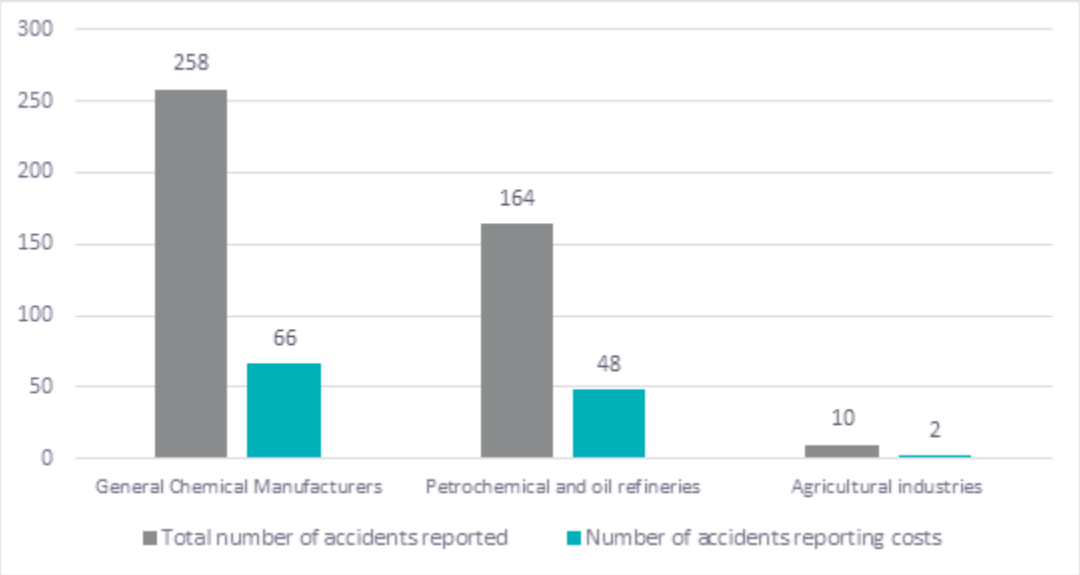
[53] https://mens-en-samenleving.infonu.nl/diversen/66293-de-brand-bij-chemie-pack-in-moerdijk.html

6.3.3 Impacts of major accidents in top 3 establishments' activities in the eMARS database

eMARS is the official reporting database for submitting accident reports to the European Commission based on the criteria set out in the Seveso III Directive. Currently, the database holds information on over 700 accidents and near misses since 1982 from across the Member States. The information contained within the database includes accident description, involved substances, causes and consequences of the accident, lessons learnt etc. although the extent of information provided varies from case to case.

A review of the accident reports submitted by general chemical manufacturers, petrochemical and oil refineries and agricultural industries[54] found that less than a third of the reports in each case reported on the costs incurred due to the accident.

Figure 6.3 Total number of accidents reported and the proportion of reports providing cost data



Out of the three industries, the most accidents were reported by general chemical manufacturers, followed by the petrochemicals industry and lastly by the agricultural industry.

General chemical manufacturers

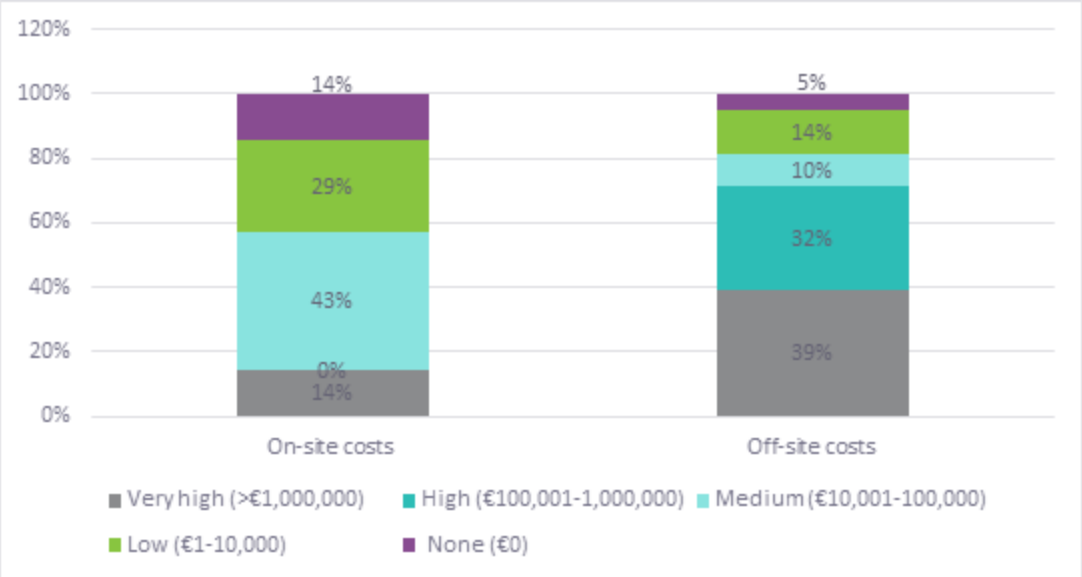
A total 258 accident reports were submitted by general chemical manufacturers, out of which only 66 provided data on costs. When inputting data on an accident event, eMARS requests operators to provide information on on-site and off-site costs incurred following the accident. These costs arise as a result of material losses, response, clean-up, restoration costs and other reasons.

Of the accident reports that included information on costs, 11% included information only on on-site costs, whereas almost 90% included information only on off-site costs. 2% included both off- and on-site costs. This could be because the bulk of the costs incurred were off-site or possibly, because there is a reluctance to divulge data for on-site costs. According to a competent authority that participated in the study, there are no criteria for reporting on-site and off-site costs. For these reasons, internal costs such as person-hours for managing the emergency, investigating the accident, loss of production etc. are not estimated by operators or at least not communicated to the authority reporting to eMARS. Therefore, these costs are usually under represented and the figures reported are therefore significantly smaller than the reported off-site costs, which are easier to identify and estimate. Furthermore, this competent authority stated that major accidents that only have on-site impacts are likely underreported.

[54] These three categories were selected as covering a large number of establishments but also representing a range of different activities.

To evaluate the severity of the costs reported, the Consequence Ranking Criteria methodology from Table 6.3 was applied.

Figure 6.4 Severity of on-site and off-site costs reported by general chemical manufacturers following an accident



Nearly 40% of the off-site costs reported within the accident reports submitted by general chemical manufacturers were of a "very high" level, i.e. greater than €1,000,000, and almost a third were of a "high" level, incurring costs in the range €100,001-1,000,000.

On the other hand, the majority of the on-site costs reported (43%) were of a "medium" level, i.e. within the range of €10,001-100,000. Only 14% of the on-site costs reported were of a "very high" level. Generally, the off-site costs incurred by general chemical manufacturers following an accident were greater than the on-site costs. It is worth mentioning that these estimates should be taken with caution, given the considerations commented above on the expected underreporting of on-site costs (in both frequency of occurrence and scale) and hence their potential underrepresentation in eMARS. The scale of such under-reporting is not known.

Petrochemicals and oil refineries

A total of 164 accidents were reported on the database by petrochemical and oil refineries, out of which only 48 reported on the costs incurred.

Similar to the case of general chemical manufacturers, the vast majority of the costs reported occurred off-site, with 89% reporting only off-site costs and only 3% reporting on-site costs only (9% reported both on- and off-site costs).

Furthermore, nearly 60% of the off-site costs reported were of a "very high" level, sustaining over €1,000,000 in damages. On the other hand, only 20% of the on-site costs reported were of a "very high" level. Most of the on-site costs reported were evenly split between the "medium" and "high" level, in the range from €10,001-1,000,000. Again, as in the case of general chemical manufactures, off-site costs were greater in number and of a higher severity than on-site costs.

Agricultural industries

Only 10 accident reports were submitted onto the database by agricultural industries, covering fertiliser leakages; and also fires and explosions in fertiliser manufacturing plants. Out of these 10 accident reports,

only 2 provided cost data. These two reports provided data on only off-site costs and no information on on-site costs was provided.

One accident report reported that no off-site costs were incurred, while the other reported off-site costs of €600,000, falling within the "high" level.

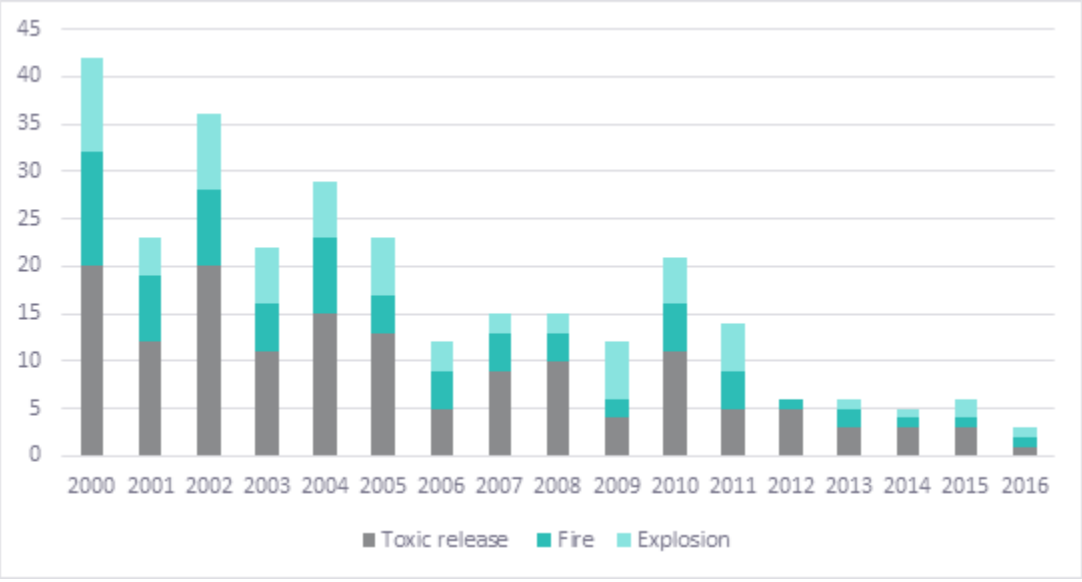
6.3.4 Impact of major accidents by type of accidents reported in the ARIA database

The Analysis, Research and Information on Accidents (ARIA) database records information on accidents in France and abroad that were, or could have been, dangerous to human health, public safety and/or the environment. This database is not exhaustive, and only contains information on those accidents for which information was provided that could be used for risk prevention and mitigation. The type of information contained includes circumstances, outcomes, accident causes and response protocols for accidents.

Based on the categories suggested in the Health and Safety Executive report from 2015[55], industrial accidents can be broadly grouped under three types of hazardous phenomena: fire, toxic release and explosion. These hazardous phenomena were mapped onto the ARIA database to assess the impact of major accidents by type of hazardous phenomena reported in the database.

The number of accident reports, falling under each of the three phenomena, submitted onto the database between the years 2000-2016 was as shown in Figure 6.5.

Figure 6.5 Number of accident reports per hazardous phenomenon submitted on the ARIA database between 2000-2016



Note: the declining trend observed is likely to be a reflexion on the time taken for major accidents and incidents to be fully reported rather than a decrease of these incidents

As can be seen from Figure 6.5, most of the accident reports submitted on the ARIA database across the years were related to toxic release of substances. This was followed by accidents related to fire for most of the years, although explosion related accidents were reported more often than fire related accidents in 2003, 2005, 2009, 2011 and 2015. It should be noted here that the number of accident reports submitted onto the ARIA database is not the same as the total number of accidents that occurred during this period.

[55] HSE, 2015, Modelling the economic impacts of an accident at major hazard sites

In order to assess how the economic impact varies for these three types of accidents, average cost data per hazardous phenomenon was derived from the HSE report (Table 6.4). This cost data covers the costs related to harm to people, evacuation, building damage, business disruption and emergency services.

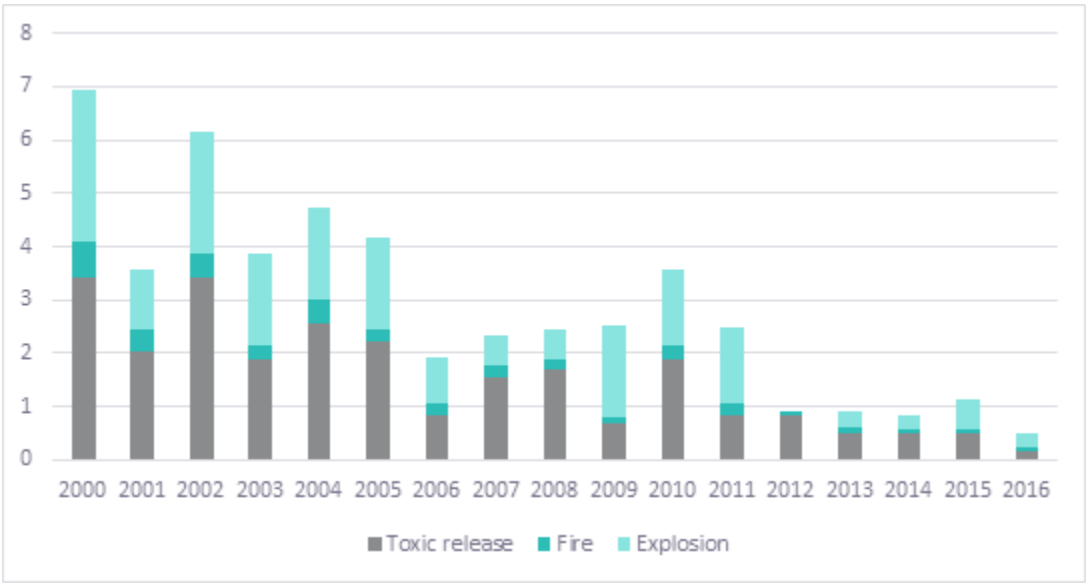
Table 6.4 Average cost data per accident type derived from data in the HSE report

Hazardous phenomenon	Toxic release	Fire	Explosion
Cost per site (€ million)	171	55	285

In most cases, the average cost incurred by a site is greatest in the case of an explosion, followed by toxic release of substances and lastly by fire. The HSE report provides further details on the elements included in order to estimate costs for each of these phenomena.

This average cost data per hazardous phenomenon was applied to the accident report numbers obtained from the ARIA database to assess how the economic impact varies by accident type. This is shown in Figure 6.6.

Figure 6.6 Total cost associated with hazardous phenomena involved in accident reported on the ARIA database (€ billion)



Across almost all the years, apart from 2009, 2011, 2015 and 2016, toxic release of substances resulted in the greatest cost. This is as expected because accidents related to toxic release were the most commonly reported in the ARIA database. For all the years, the cost incurred due to fire related accidents is the lowest. Here again, the decreasing trend in costs since 2010 is more of a reflection on the lag due to reporting and estimating the consequences of these accidents than an indication on the reduction of accidents. As such it is possible that the number of accidents reported will increase, once sufficient time has passed to absorb the time-lag in reporting. There might be other factors at play which would contribute to the decrease of absolute numbers.

Another angle that has been explored as part of this study is the frequency with which each cost type is reported in ARIA. From 238 accidents reported for the period 1980-2018[56], the vast majority reported internal costs (65%). This contrasts with eMARS, where external costs were generally reported more often and on-site

[56] Although the ARIA database was created later (2003), it reported accidents retrospectively

costs only reported infrequently. Table 6.5 contains a more detailed split of the types of costs from the accident reports in the ARIA database.

Table 6.5 Proportion of cost categorisation in the ARIA database* for accidents covering the 1980-2018 period

Cost category	No. of accident reports	% split
External material damages	36	12%
External operating loss	13	4%
Internal material damages	108	37%
Internal operating loss	81	28%
Total	238	100%

(*) Only accidents occurring in the EU have been reported in this table

6.4 Scalability of alternative systems reporting socio-economic impacts of major accidents and synergies with EU system

The European Gravity Scale of Industrial Accidents (EGSIA) was introduced by the Committee of Competent Authorities of the Member States in 1994 and is based on 18 technical parameters designed to characterise the effects or consequences of accidents. While not applied at EU level, it is the basis of the ARIA database managed by the French authorities.

Figure 6.7 provides a graphical representation of how the EGSIA is used in ARIA. The technical parameters include six levels. The highest level determines the accident index.

Figure 6.7 European gravity scale of industrial accidents as used by the ARIA database

The technical parameters are split into four groups[57]:

- Two parameters concern the quantities of dangerous materials involved.
- Seven parameters consider the human and social aspects.
- Five parameters cover the environmental consequences.
- Four parameters cover the economic aspects.

The following figures include all the parameters of EGSIA.

[57] https://www.aria.developpement-durable.gouv.fr/in-case-of-accident/european-scale-of-industrial-accidents/?lang=en

Figure 6.8 EGSIA: Parameters on dangerous materials

Dangerous material released		1	2	3	4	5	6
Q1	Quantity Q of substance actually lost or released in relation to the « Seveso » threshold *	Q < 0,1 %	0,1 % ≤ Q < 1 %	1 % ≤ Q < 10 %	10 % ≤ Q < 100 %	De 1 à 10 fois le seuil	≥ 10 fois le seuil
Q2	Quantity Q of explosive substance having actually participated in the explosion (equivalent in TNT)	Q < 0,1 t	0,1 t ≤ Q < 1 t	1 t ≤ Q < 5 t	5 t ≤ Q < 50 t	50 t ≤ Q < 500 t	Q ≥ 500 t

* Use the higher "Seveso" thresholds. If more than one substance are involved, the higher level should be adopted.

Source: Ministère de la Transition écologique et solidaire (2018) European scale of industrial accidents. Available at : https://www.aria.developpement-durable.gouv.fr/in-case-of-accident/european-scale-of-industrial-accidents/?lang=en

Figure 6.9 EGSIA: Parameters on human and social consequences

Human and social consequences		1	2	3	4	5	6
H3	Total number of death: including - employees - external rescue personnel - persons from the public	- - - -	1 1 - -	2 – 5 2 – 5 1 -	6 – 19 6 – 19 2 – 5 1	20 – 49 20 – 49 6 – 19 2 – 5	≥ 50 ≥ 50 ≥ 20 ≥ 6
H4	Total number of injured with hospitalisation ≥ 24 h: including - employees - external rescue personnel - persons from the public	1 1 1 -	2 – 5 2 – 5 2 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	≥ 200 ≥ 200 ≥ 200 ≥ 50
H5	Total number of slightly injured cared for on site with hospitalisation < 24 h : including - employees - external rescue personnel - persons from the public	1 – 5 1 – 5 1 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	200 – 999 200 – 999 200 – 999 50 – 199	≥ 1000 ≥ 1000 ≥ 1000 ≥ 200
H6	Total number of homeless or unable to work (outbuildings and work tools damaged)	-	1 – 5	6 – 19	20 – 99	100 – 499	≥ 500
H7	Number N of residents evacuated or confined in their home > 2 hours x nbr of hours (persons x hours)	-	N < 500	500 ≤ N < 5 000	5 000 ≤ N < 50 000	50 000 ≤ N < 500 000	N ≥ 500 000
H8	Number N of persons without drinking water, electricity, gas, telephone, public transports > 2 hours x nbr of hours (persons x hours)	-	N < 1 000	1 000 ≤ N < 10 000	10 000 ≤ N < 100 000	100 000 ≤ N < 1 million	N ≥ 1 million
H9	Number N of persons having undergone extended medical supervision (≥ 3 months after the accident)	-	N < 10	10 ≤ N < 50	50 ≤ N < 200	200 ≤ N < 1 000	N ≥ 1 000

Source: Ministère de la Transition écologique et solidaire (2018) European scale of indutrial accidents. Available at : https://www.aria.developpement-durable.gouv.fr/in-case-of-accident/european-scale-of-industrial-accidents/?lang=en

Figure 6.10 European gravity scale of industrial accidents as used by the ARIA database

Environmental consequences		1	2	3	4	5	6
Env10	Quantity of wild animals killed, injured or rendered unfit for human consumption (t)	Q < 0,1	0,1 ≤ Q < 1	1 ≤ Q < 10	10 ≤ Q < 50	50 ≤ Q < 200	Q ≥ 200
Env11	Proportion P of rare or protected animal or vegetal species destroyed (or eliminated by biotope damage) in the zone of the accident	P < 0,1 %	0,1% ≤ P < 0,5%	0,5 % ≤ P < 2 %	2 % ≤ P < 10 %	10 % ≤ P < 50 %	P ≥ 50 %
Env12	Volume V of water polluted (in m^3) *	V < 1000	1000 ≤ V < 10 000	10 000 ≤ V < 0.1	0.1 Million ≤ V< 1 Million	1 Million ≤ V< 10 Million	V ≥ 10 Million
Env13	Surface area S of soil or underground water surface requiring cleaning or specific decontamination (in ha)	0,1 ≤ S < 0,5	0,5 ≤ S < 2	2 ≤ S < 10	10 ≤ S < 50	50 ≤ S < 200	S ≥ 200
Env14	Length L of water channel requiring cleaning or specific decontamination (in km)	0,1≤ L < 0,5	0,5 ≤ L< 2	2 ≤ L< 10	10 ≤ L < 50	50 ≤ L< 200	L ≥ 200

* The volume is determined with the expression Q/C_{lim} where:

- ✓ Q is the quantity of substance released,
- ✓ C_{lim} is the maximal admissible concentration in the milieu concerned fixed by the European directives in effect.

Source: Ministère de la Transition écologique et solidaire (2018) European scale of industrial accidents. Available at : https://www.aria.developpement-durable.gouv.fr/in-case-of-accident/european-scale-of-industrial-accidents/?lang=en

Figure 6.11 European gravity scale of industrial accidents as used by the ARIA database

Economic consequences		1	2	3	4	5	6
€15	Property damage in the establishment (C expressed in millions of € - Reference 93)	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C< 10	10 ≤ C< 50	50 ≤ C < 200	C ≥ 200
€16	The establishment 's production losses (C expressed in millions of € - Reference 93)	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C< 10	10 ≤ C< 50	50 ≤ C < 200	C ≥ 200
€17	Property damage or production losses outside the establishment (C expressed in millions of € - Reference 93)	-	0,05 < C < 0,1	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C < 10	C ≥ 10
€18	Cost of cleaning, decontamination, rehabilitation of the environment (C expressed in millions of € - Reference 93)	0,01 ≤ C < 0,05	0,05 ≤ C < 0,2	0,2 ≤ C < 1	1 ≤ C < 5	5 ≤ C < 20	C ≥ 20

Source: Ministère de la Transition écologique et solidaire (2018) European gravity scale of industrial accidents. Available at : https://www.aria.developpement-durable.gouv.fr/in-case-of-accident/european-scale-of-industrial-accidents/?lang=en

As part of the stakeholder consultation, efforts were undertaken to identify obstacles to the adoption of the EGSIA. In total there were 15 responses identifying obstacles to the adoption of the EGSIA; 2 responses by EU and other international organisations; 10 responses from Member States; and 3 responses by Non-Member States. Responses were mixed with some Member States not using it (and not being aware of it), some using the EGSIA for internal studies or for communication with others organisation and finally others using it to report on socio-economic impacts of major accidents. All expressed difficulties with getting cost information and doubts in the fact that data that would be obtained would be comparable. One highlighted that when there is no data on costs (i.e. unknown) the EGSIA portrays this as no costs, which is counter intuitive. Industry representatives were more positive on the potential use of EGSIA while it was noted that adjustments would be needed (e.g. to match internal accounting systems). As such a Technical Working Group could be set up to work on preparing an extensive up-to-date guidance document enabling a consistent use of the scale.

While there seems to be mixed opinions on the use of EGSIA at European level, partly due to a lack of familiarity and knowledge with the scale, a possible development could be to develop guidance on quantifying and reporting socio-economic impacts from major accidents. There seemed to be support for such an approach at the project workshop. This could possibly be followed-up by a targeted Working Group or workshop.

Some comments highlighted general difficulties with reporting socio-economic impacts of accidents, in particular that the impacts can take a long time to be visible. It was also highlighted that Member States have different systems for accounting for these impacts which might not be directly comparable. This seems to illustrate the need for (additional) guidance. However, such an approach should not prevent efforts to further the understanding of reporting socio-economic impacts of accidents and valuable information could be obtained from the range of approaches adopted by Member States.

Exchanges were held with the representative of the insurance sector in Europe and it appears that wider socio-economic impacts of major accidents beyond likely claims for damage costs are not specifically considered by the insurance sector yet. A review of the approach presented by Lloyd's[58] seemed to indicate that pollution clean-up is not usually included in insurance policies or are covered by specific additional policies. Potential damages are estimated based on e.g. vapour cloud explosion simulation for physical damage. Environmental damages appear to be assessed separately by environmental liability underwriters[59], however the focus seems to be on legal pay-outs from the incident rather than the physical damages themselves. The Lloyd's disaster scenario specification for 2017[60] includes reference to an industrial accident of release of chlorine from an industrial site. The scenario recommends developing a physical model of the incident, assuming area and populations affected and the effects of chlorine (as an example). It does not address specific environmental aspects under this scenario. A review of literature identified only a report from 1986 on the topic[61]. This is another indication illustrating the need for (additional) guidance which should for example address this issue of the possible inclusion of clean-up costs of environmental damage in the calculations of the damage costs.

Finally, the stakeholder workshop held for this study aimed at gathering views from Member State representatives, members of industry, members of international organisations and research institutions on the possible future use of EGSIA at European level. The general view was that, although the scale had provided more structure in the way accidents had been reported and described, some (minor) modernisation would be needed to make the scale compatible with Annex VI (Criteria for the notification of a major accident to the Commission) of the Directive, among others. In general, stakeholders were not fully aware of or were not clear of the benefits of the scale and thought that if the scale is to be used at EU level, the current inconsistencies with Annex VI should be eliminated to the extent possible.

The Commission proposed slightly modernising the EGSIA, which would provide Member States with categories within which they could report efficiently. This would avoid additional time and effort to identify the data to be reported (an approximate value or range being considered sufficient to understand the scale of an accident). It was also stated that a more effective search function would be more possible with such modernised scale. This modernisation was deemed to have added value in terms of improving the knowledge on potential benefits of the Seveso legislation, given that it provides scientific information on costs that occurred in industrial accidents and that could be avoided by improved implementation of the Directive.

[58] https://www.lloyds.com/

[59] An underwriter is any party that evaluates and reviews applications for insurance claims and/or coverage and accepts or rejects an applicant based on risk analysis.

[60] https://www.lloyds.com/market-resources/underwriting/realistic-disaster-scenarios-rds/scenario-specification-2017

[61] Insuring and Managing Hazardous Risks: Seveso to Bhopal and beyond, April 1986 http://pure.iiasa.ac.at/id/eprint/2776/1/ER-86-011.pdf

7. Development of indicators for monitoring of the Seveso III Directive

7.1 Overview

The objective of this section is to present our work on indicators for monitoring the Seveso III Directive. This section consists of an overview of the indicators and their purpose, a brief description of the existing Seveso indicators followed by discussion on the suitability of different safety, composite and policy indicators towards potential future Seveso indicators, including "flagship" indicators. This section is based on the review of the literature available, the responses to the online survey sent to the different types of stakeholders between February and March 2018, which had dedicated sections on establishing monitoring indicators and flagship indicators, and the feedback received from the stakeholders during the workshop.

An indicator provides information on the state or condition of something[62]. Indicators can also make perceptible a trend or phenomenon that is not immediately detectable. Thus, an indicator's significance extends beyond what is measured to a larger phenomenon of interest[63]. Indicators are generally used for three key reasons:

- To understand how a system works and how it might be improved.
- To monitor system performance and determine if a system is performing to an agreed standard.
- For accountability.

In European policy, indicators are explicitly listed as part of the Better Regulation guidelines. Toolbox #41 indicates that 'An indicator is a quantitative or qualitative measure of how close we are to achieving a set goal (e.g. policy outcome)'. The guidelines indicate that "indicators must allow measuring to what extent the objectives of the policy have been achieved (and on potential negative impacts). Indicators on transposition, implementation and enforcement in Member States might also be useful.[64]"

Indicators are used to indicate attributes of a system and are not meant to capture the richness and complexity of a system. Indicators promote clarity about programme and system goals and often rely on quantitative measures and methods, which require a basic understanding of statistics[65]. Some of the general limitations of the indicators include[66]:

- Indicators rarely cover all aspects of a subject.
- Indicators are sometimes so complex that they require more detailed parameters (sub-indicators).
- Data quality is often insufficient, with gaps for certain sectors or areas.

[62] Sustainable Cities International. (2012). Indicators for Sustainability: How cities are monitoring and evaluating their success
[63] Hammond, A., & World Resources Institute. (1995). Environmental indicators: a systematic approach to measuring and reporting on environmental policy performance in the context of sustainable development (No. 333.7/H225). Washington, DC: World Resources Institute. r
[64] European Commission, 2017, Better Regulation guidelines SWD (2017) 350
[65] http://www.nccmt.ca/knowledge-repositories/search/73
[66] https://oshwiki.eu/wiki/OSH_Performance_Indicators_%E2%80%93_and_their_application_in_the_monitoring_and_evaluation_of_OSH-infrastructure,_OSH-policies_and_OSH_legislation

- The use of indicators in international comparisons is limited, since the indicators are based on different national systems of data collection and aggregation.

Indicators can be classified in many ways, for example in the context of Seveso III Directive, policy indicators and safety indicators pertain to policy-making and safety management system respectively. Additionally, there are also operational indicators which focus on monitoring and evaluating operational areas of a service or establishment.

Policy indicators can be used to monitor the status-quo, diagnose success and failures, improve regulatory policies, programmes and tools, and to communicate progress[67]. Analysis of a policy's effectiveness, using such indicators, can determine to what extent it is having the desired result and could lead to policy revisions to improve its performance.

Indicators of safety or safety indicators are representative of the measures and the effectiveness of risk controls and their performance judged based on their relationship with risk based on incident analysis or expert judgement[68]. Safety indicators, if used effectively, can provide early warnings, before a catastrophic failure, that critical controls have deteriorated to an unacceptable level, and potentially avoid a catastrophic failure. Safety indicators are typically applied at the level of individual establishments or sectors, whereas policy indicators (in the current context) are applied at member state and EU (and international) level.

Safety indicators are usually classified into one of two categories, i.e., "lagging indicators" and "leading indicators" which are used to measure the existing and future performance of a system, respectively. According to the CCPS[69], lagging indicators are a retrospective set of indicators that are based on the incidents that meet the threshold of severity that should be reported as part of the industry-wide process safety metric. In contrast, leading indicators are forward-looking metrics which indicate the performance of the key work processes, operating discipline, or layers of protection that prevent incidents.

Operational indicators provide analysis of key operational areas to identify and address challenges, to monitor and evaluate the efficacy of the interactions with the public and media. They also provide a platform for improving services by benchmarking.[70]

Thus, indicators enable decision-makers to assess the progress of targets and objectives, towards their intended outcomes. As such, they are an integral part of a results-based accountability system. Ideally, the Seveso indicators must be a source of essential valid and reliable factual knowledge when assessing the status and performance of the Directive.

7.2 Existing Seveso indicators

7.2.1 Overview

While the Seveso II Directive aimed at the prevention of major-accident hazards involving dangerous substances and at limiting consequences of such accidents for man and environment, the Seveso III Directive supplements the previous Directive by additions or modifications to duties including[71]:

- The list of substances covered by the Regulations has been updated and aligned to the CLP Regulation.

[67] Arndt et al. (2015). Indicators of Regulatory Policy and Governance Design, Methodology and Key Results. https://www.oecd-ilibrary.org/governance/2015-indicators-of-regulatory-policy-and-governance_5jrnwqm3zp43-en
[68] Bellamy, L. J., & Sol, V. M. (2012). A literature review on safety performance indicators supporting the control of major hazards.
[69] CCPS (2011) Process Safety Leading Indicators Industry Survey
[70] http://www.durban.gov.za/City_Government/Administration/city_manager/performance_management_unit/Pages/Operation-Indicators.aspx
[71] http://www.hse.gov.uk/seveso/changes.htm

- Some definitions have been changed.
- There are transition arrangements for safety reports.
- For emergency planning, there is a new requirement for co-operation by designated authorities in tests of the external emergency plan.
- There are stronger requirements for the provision of public information, including a duty for lower-tier establishments to provide public information. There are provisions for electronic access to up-to-date public information.
- The domino effects duty is broader.

This section provides a brief description of some of the existing Seveso indicators and discusses their merits and limitations with regards to their selection as potential flagship indicators. The existing indicators and the data presented here are from the analysis of the status of Member States' implementation of Directive 96/82/EC (the Seveso II Directive) during the 2012-2014 period and a comparison with previous reporting periods.[72]

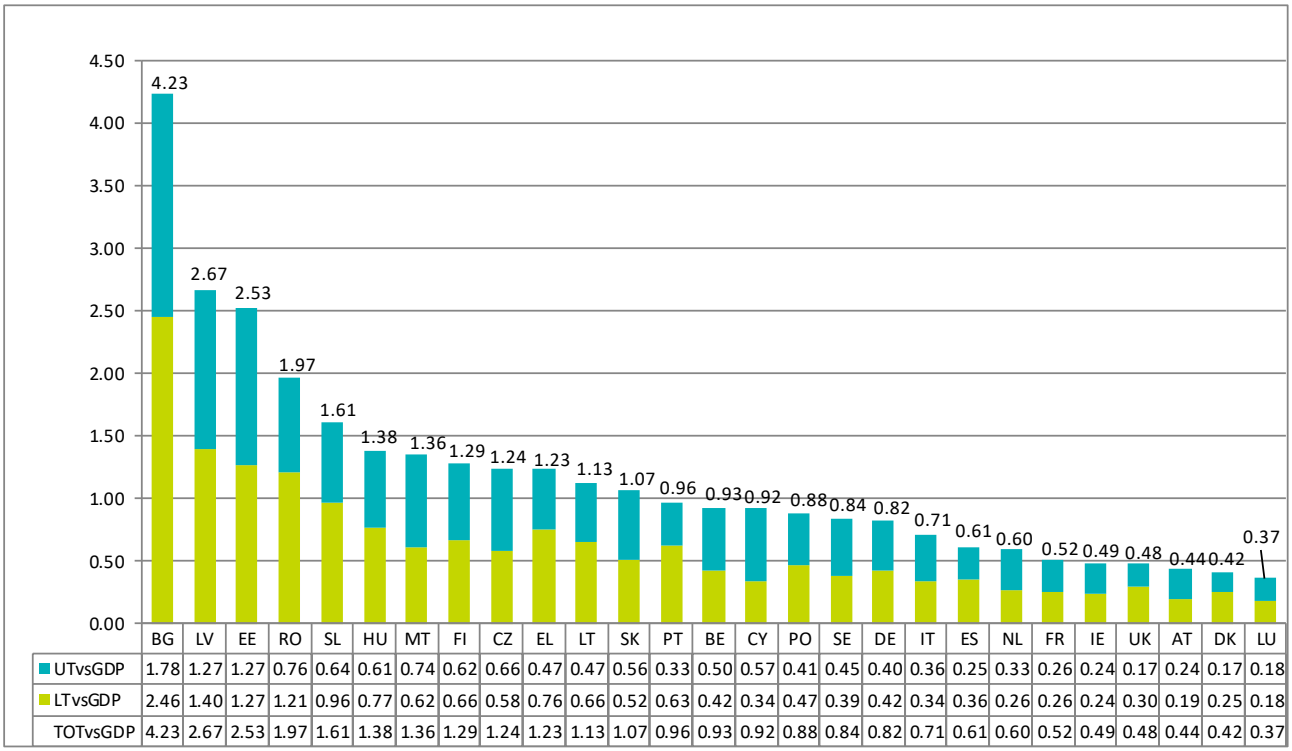
7.2.2 Number of establishments

The indicators include:

- Total number of Seveso establishments per Member State.
- Total number of Seveso establishments per million inhabitants.
- Total number of Seveso establishments per regional area (in 1000 km^2).
- Total number of Seveso establishments per unit GDP.

[72] Amec Foster Wheeler Environment & Infrastructure UK Limited (2017). Analysis and summary of Member States' reports on the implementation of Directive 96/82/EC on the control of major accident hazards involving dangerous substances

Figure 7.1 Number of Seveso establishments (Upper and Lower tier) in the EU-28 per billion € GDP



	BG	LV	EE	RO	SL	HU	MT	FI	CZ	EL	LT	SK	PT	BE	CY	PO	SE	DE	IT	ES	NL	FR	IE	UK	AT	DK	LU
UTvsGDP	1.78	1.27	1.27	0.76	0.64	0.61	0.74	0.62	0.66	0.47	0.47	0.56	0.33	0.50	0.57	0.41	0.45	0.40	0.36	0.25	0.33	0.26	0.24	0.17	0.24	0.17	0.18
LTvsGDP	2.46	1.40	1.27	1.21	0.96	0.77	0.62	0.66	0.58	0.76	0.66	0.52	0.63	0.42	0.34	0.47	0.39	0.42	0.34	0.36	0.26	0.26	0.24	0.30	0.19	0.25	0.18
TOTvsGDP	4.23	2.67	2.53	1.97	1.61	1.38	1.36	1.29	1.24	1.23	1.13	1.07	0.96	0.93	0.92	0.88	0.84	0.82	0.71	0.61	0.60	0.52	0.49	0.48	0.44	0.42	0.37

Source: Amec Foster Wheeler Environment & Infrastructure UK Limited (2017)

An increase in the number of Seveso establishments might reflect growth in terms of increased industrial activities or an expanding economy, but it can also be due to better compliance of the Directive among establishments or an increase in the number of EU Member states or even related to changes in classification system for Seveso establishments (i.e. through the link to the Global Harmonised System of Classification and Labelling of chemical substances).

The normalised metrics, such as the total number of Seveso establishments per million inhabitants or 1,000 km^2 or unit GDP (shown in Figure 7.1), can be useful in drawing comparison between the countries but care must be taken while interpreting the results. For example, a Member State with a very low GDP can be ranked higher in terms of establishments per GDP when compared to a country with a higher GDP even if the later country has significantly higher numbers of establishments compared to the former.

Similarly, for the total number of Seveso establishments per million inhabitants which might indicate where people are most exposed to risk, is difficult to interpret and would require a deeper analysis with a Geographic Information System (GIS) looking at the population in the hazard zones around Seveso establishments in order to obtain reliable information on actual scale of exposure.

7.2.3 Operator compliance regarding safety reports and internal emergency plans

The indicators reflecting compliance with the Directive include:

- % of operators which submitted (or had not submitted) a safety report to the competent authorities.
- % of operators which submitted internal emergency plans to the competent authorities.

While such indicators can reflect the overall compliance of the operators regarding drawing up safety reports and internal emergency plans, they do not provide information regarding any updates (by the operator) of the submitted safety report and the examination of the reports by competent authorities nor the quality of

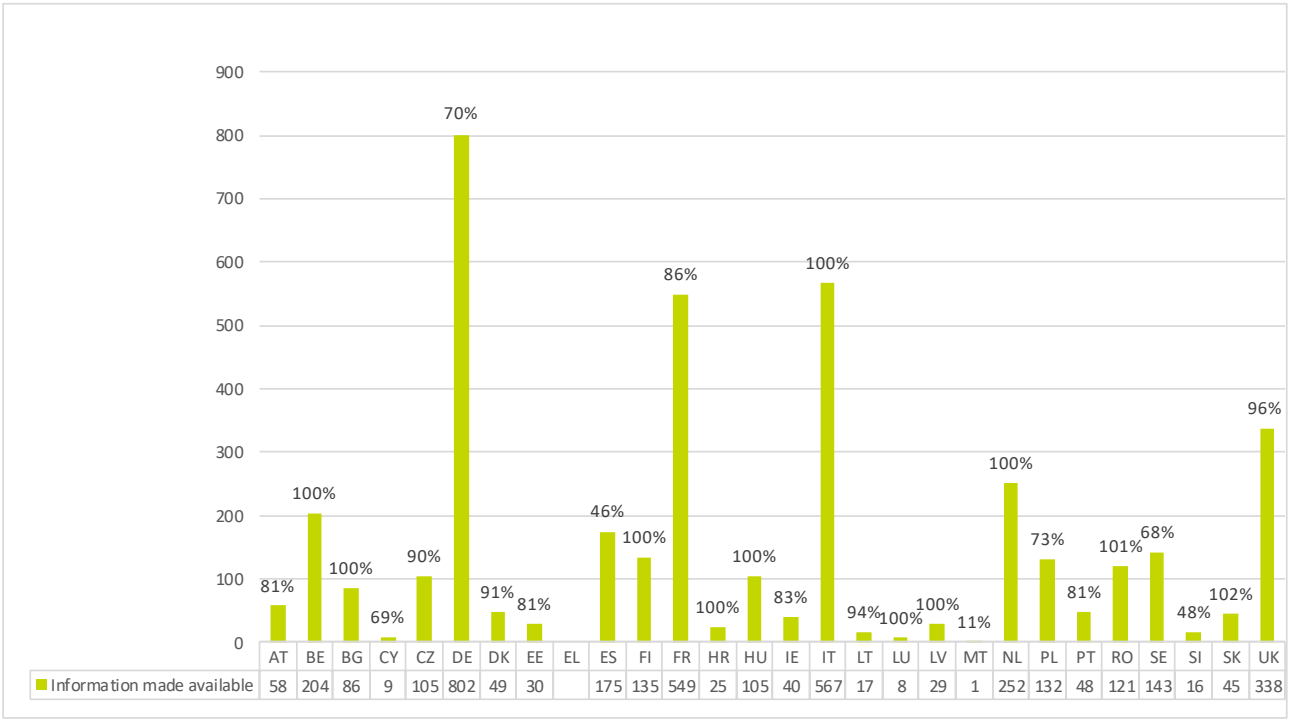
information in the safety reports. Furthermore, due to the differences in provisions of MAPP for upper and lower tier establishments it can be difficult to compare the level of compliance for the establishments. For example, under Article 8, the MAPP is implemented by appropriate means, structures and by a safety management system in accordance with Annex III, proportionate to the major-accident hazards, and the complexity of the organisation or the activities. However, the lower-tier establishments can fulfil the MAPP obligations by other appropriate means, structures and management systems, proportionate to major-accident hazards, which may be heterogeneous.

7.2.4 Role of competent authorities on examination of the safety report, drawing external emergency plans, and giving information to the public

The indicators related to this category include:

- Elaboration of external emergency plans: % of External Emergency Plans drawn up (for upper-tier establishments).
- Testing and review of external emergency plans: % of the existing External Emergency Plans tested.
- Information provided to the public: % (of upper-tier) establishments for which information is given to the public per Member State.
- Inspections: % of inspected (upper-tier) establishments.
- Use of coercive instruments (such as improvement/compliance notices, written/compliance orders, administrative fines, infringement proceedings, verbal warnings, prohibition of use, criminal proceedings): number of cases per Member State/ category of Member States.

Figure 7.2 Information made available for upper tier establishments in 2014



Note 1: The percentage indicates the share of upper tier establishments that made information available, some are over 100% (Romania and Slovakia) due to variations in the number of upper tier establishments during the reporting period.
Note 2: Greece (EL) reported that no data was available
Source: Amec Foster Wheeler Environment & Infrastructure UK Limited (2017)

As the emergency plans are required to be reviewed and tested at intervals of no longer than 3 years, there are variations in the frequency of the test conducted among different establishments which may not be reflected in the indicator.

Under the Seveso III Directive, Member States were asked to provide information on their arrangements for providing the public with information related to alert systems, main response measures and arrangements to cope with any off-site effects from an accident. Member States were requested to provide the number of upper tier establishments for which information was made actively available to the public at least once during the last five years. Regarding the implementation of the provisions, there were wide variations across the Member States with regards to methodology and reporting frequency on how the public and persons liable to be affected by a Seveso accident are informed. While most member States reported that information was made available to the public (Figure 7.2), and the tools used for doing so, there is less to no information regarding the number of citizens (in the vicinity of the establishments) who actually were made aware of the provisions.

7.2.5 Statistics on accidents drawn from eMARS

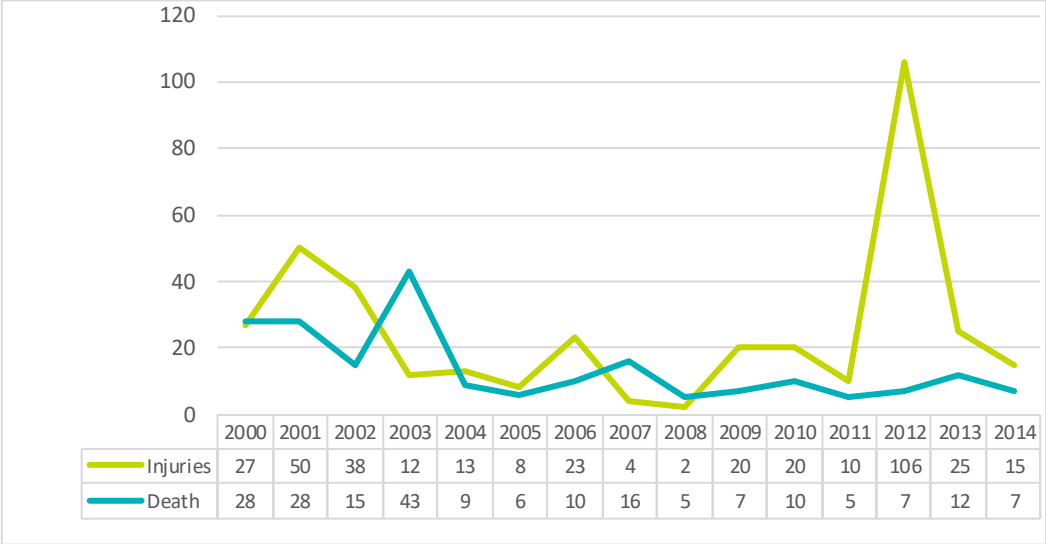
eMARS or the e-Major Accident Reporting System was established to handle information on 'major accidents' submitted by Member States to the European Commission in accordance with the Seveso Directives. Some of the indicators drawn from eMARS include:

- Number of reported major accidents.
- Number of incidents ('other' and 'near misses').
- Number of deaths and injuries on-site.

Under the Seveso III Directive, reporting of major accident events and near misses are mandatory. The number of major accidents is often used as the metric to understand the impact of the Directive. However, major accidents are unpredictable, stochastic events, and are reported in such small numbers that it is difficult to make statistical sense of the results. Similarly, the statistical significance of the values reported from the number of deaths and injuries on-site such as shown in Figure 7.3 are low and thus it is difficult to interpret trends. For example, a peak in the number of injuries in 2012 is an outlier (possibly due to 1 large incident), inclusion of which in trend analysis may lead to incorrect interpretation and can undermine the impact of Directive towards the evolution of number of injuries over time.

Data from the period covered by the Seveso I and II Directives, includes voluntary reporting of the information on 'other' incidents and near misses. Voluntary reporting of other incidents and near misses reflects more on the reporting tradition of a specific sector or a Member State rather than providing information on the level of safety. Near misses are important metrics which can act as a surrogate to the "major accident" indicator and a large number of increasing trends could be viewed as an indicator of a higher potential for a more significant event. However, feedback from the workshop highlighted that there exist differences among Member States in reporting near misses, those not reporting any and those reporting selected near misses (for example those that could have caused a major accident). Thus, there is a need for more consistency in reporting of major accidents, as well as near misses, amongst Member States as highlighted at the workshop, if this is to be a more useful indicator.

Figure 7.3 Evolution of the number of deaths and injuries on-site from 2000-2014



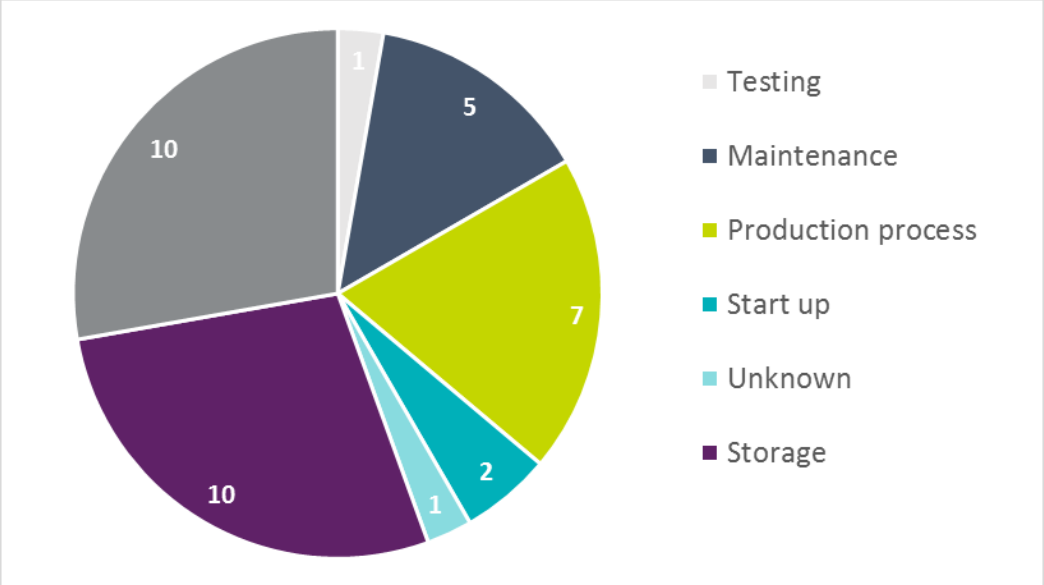
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Injuries	27	50	38	12	13	8	23	4	2	20	20	10	106	25	15
Death	28	28	15	43	9	6	10	16	5	7	10	5	7	12	7

Note: Based on published data only (total 389 reports)
Source: Amec Foster Wheeler Environment & Infrastructure UK Limited (2017)

An increase in the number of Seveso establishments with time, possibly due to expansion in industrial activities or better compliance, can lead to higher absolute numbers of major accidents but the numbers may actually be stable values when compared to the number of additional establishments. A normalised metric such as the number of major accidents over 1,000 establishments (Figure 7.5) has been used to compare the trends over time. However, given the small number of accidents overall, and uncertainties in the completeness of the underlying data, caution should be exercised in drawing any conclusion on trends over time.

A more meaningful way of looking at accidents might be by focusing on specific sector, for example presented in the figure below for LNG incidents.

Figure 7.4 LNG incidents studied by type of activity



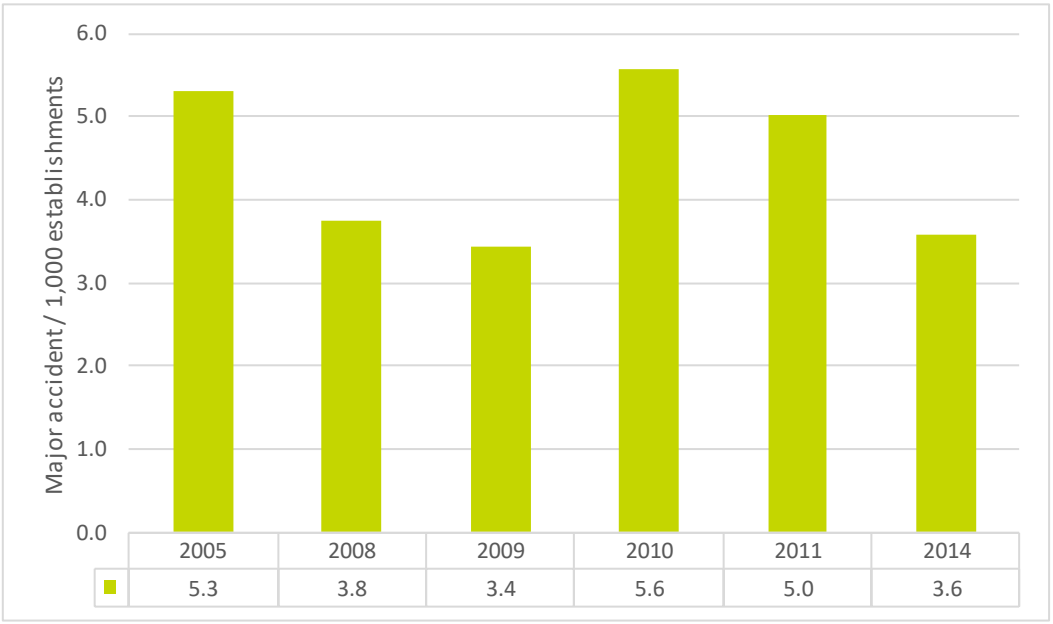
Source: JRC-MAHB, 2018[73]

[73] https://minerva.jrc.ec.europa.eu/en/shorturl/minerva/mahb_bulletin_no13lngv1201812200955pdf

The number of major accidents occurring over time per Seveso establishment is not particularly meaningful. Serious chemical accidents by nature are high impact low probability events. Hence, the years that pass without a serious chemical accident are not a sign of reduced risk, but simply evidence of the role of probability. (It should be noted that most countries consider that a chemical accident risk of 1 death in 1,000 years is unacceptable). From a purely statistical standpoint, '30 events' is far too small a number for obtaining any conclusions about trends. Moreover, chemical accidents are of a very diverse origin in terms of substance, circumstances, and the dynamics that cause harm. Hence, data aggregation produces only a very general measure that masks large variation in chemical accident causes and exposure to accident risk across industries and geographic regions.

Nonetheless, each major accident and near miss that occurs is a piece of evidence of underlying risk associated with similar risk management failures, industry activities and/or substances in locations all across the EU. While statistical analysis of the general dataset cannot provide incontrovertible evidence of a trend, analysis of cumulative accident reports associated with the same lessons learned, or with specific substances or industry sectors, can provide good evidence of common areas of weakness and concern. For this reason, the eMARS database focuses on collection of objective characteristics surrounding chemical accidents that occur and reporting of lessons learned.

Figure 7.5 Evolution of the number of major accidents per 1000 upper-tier establishments (2005-2014)



Source: Amec Foster Wheeler Environment & Infrastructure UK Limited (2017)

The same limitations on the statistical interpretation of major accidents data are applicable to the figure presented above.

7.3 Establishing indicators

7.3.1 Overview

As part of the survey circulated to stakeholders' views were requested, in particular on the suitability of the following in providing useful tools for establishing indicators for the Seveso III Directive:

- OECD Guidance on Safety Performance Indicators[74];
- Work conducted by the Disaster Risk Reduction Management Knowledge Centre on Sendai indicators and disaster loss data[75]; and
- Sustainable Development Goals Indicators[76].

The views expressed in the survey are summarised below:

- The current OECD Safety Performance Indicators[77] are largely for sites, and since they are not harmonised through the EU, they might not fit as being policy indicators directly. However, Safety Performance Indicators provide useful information which could be used to build policy indicators.
- The Sendai Indicators and the Sustainable Goals Indicator are broadly designed and most of them are not applicable to chemical accidents where progress is defined by more frequent unreported accidents with localised effects.

As such these indicators sets were not identified as directly applicable as policy-level indicators for the Seveso III Directive but may aid selecting and developing indicators useful for the purpose of this project.

Comments from stakeholders indicated that opinions were mixed: for some respondents the current Seveso related indicators used at the facility level cannot be used to measure the effectiveness of the Directive in the prevention of chemical accidents, because the current Seveso Indicators:

- are not used to understand the consequences of accidents for people and the environment;
- do not provide enough information to judge whether the levels of safety have evolved over time;
- do not provide enough information to understand the implementation of lessons learnt from previous accidents; and
- do not provide enough information to understand the implementation of the provisions on domino effects and land use planning.

Stakeholders were asked to indicate which type of Seveso related indicators they are currently using, and their answers listed the following indicators:

- Lost-time accidents / days away from work;
- Near misses and improvement suggestions;
- Serious Potential Incidents;
- French UIC indicators: Guide ICCA (International Council of Chemical Associations), March 2017[78];

[74] OECD (2008). Guidance on Developing Safety Performance Indicators related to Chemical Accident Prevention, Preparedness and Response, https://www.oecd.org/chemicalsafety/chemical-accidents/41269710.pdf
[75] http://drmkc.jrc.ec.europa.eu/
[76] United Nations (2018). Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development, https://unstats.un.org/sdgs/indicators/indicators-list/

[77] https://www.oecd.org/chemicalsafety/chemical-accidents/41269710.pdf - OECD (2008). Guidance on Safety Performance Indicators
[78] http://www.uic.fr/Actualites-et-publications/Publications/Guides-techniques/DT-118-Indicateurs-de-securite-des-procedes

- ANSI/API RP 754[79]; and
- CEFIC Responsible Care Key Performance Indicators [80].

The above are examples of indicators commonly applied at a site or sector level, rather than at e.g. EU or national level.

7.3.2 Safety performance indicators

The prevention of accidents and ensuring safety has for a long time been focused on technical issues and through the introduction and use of the safety performance indicators. To this end, different guidelines help in the identification and reporting of safety indicators, such as e.g. OECD, ANSI/API RP 754[79], CCPS[81], RNNP (Norway)[82], ICCA/ CEFIC (EU)[80], HSE (UK) [8384]and OGP[85]. However, no single authority or institution has established a set of common indicators and the adoption of indicators differ from organisation to organisation making it difficult to compare safety performance. The indicators help to measure whether an organisation is able to identify what the "adverse event" could be and what kind of measures are needed to prepare to such events.

Examples of risk indicator systems

The CCPS Process Safety Metric committee recommends the use of a process safety metric pyramid[69] (shown in Figure 7.6). The three types of metrics including lagging, leading and near misses and other internal lagging metrics can be considered as measurements at different tier levels of the "safety pyramid" including 'Process safety incidents', 'Other incidents', 'Near misses', and 'Unsafe Behaviours/insufficient operating discipline' (Figure 7.6). Reporting of low-level incidents can provide operators but also industry sectors or national associations with an "early warning system" as an increase of low-level incidents will inevitably lead to an increase in major incidents sooner or later.

[79] American Petroleum Institute, ANSI/API Recommended Practice 754, Process Safety Performance Indicators for the Refining and Petrochemical Industries, Second Edition, Washington D.C., 2016 https://www.api.org/oil-and-natural-gas/health-and-safety/refinery-and-plant-safety/process-safety/process-safety-standards/rp-754
[80] Cefic Responsible Care Key Performance Indicators, http://www.cefic.org/Responsible-Care/
[81] CCPS (2007). Guidelines for risk based process safety, 1st edition, John Wiley & Sons, Inc., Hoboken, USA. ISBN: 978-0-470-16569-2
[82] RNNP (2017). Trends in risk level in the Norwegian petroleum activity" by the Norwegian Petroleum Safety Authority, http://www.psa.no/getfile.php/1344338/PDF/RNNP%202016/ENG_summary_RNNP2016.pdf
[83] HSE. Key Process Safety Performance Indicators, http://www.hse.gov.uk/leadership/keyindicators.pdf
[84] HSE (2006). Developing process safety indicators http://www.hse.gov.uk/pUbns/priced/hsg254.pdf
[85] OGP (2011). Process Safety – Recommended Practice on Key Performance Indicators. England: International Association of Oil and Gas Producers (OGP).

Figure 7.6 Types of incidents in chemical industry – general approach (left) and the practical implementation in the guidelines (right)[69]

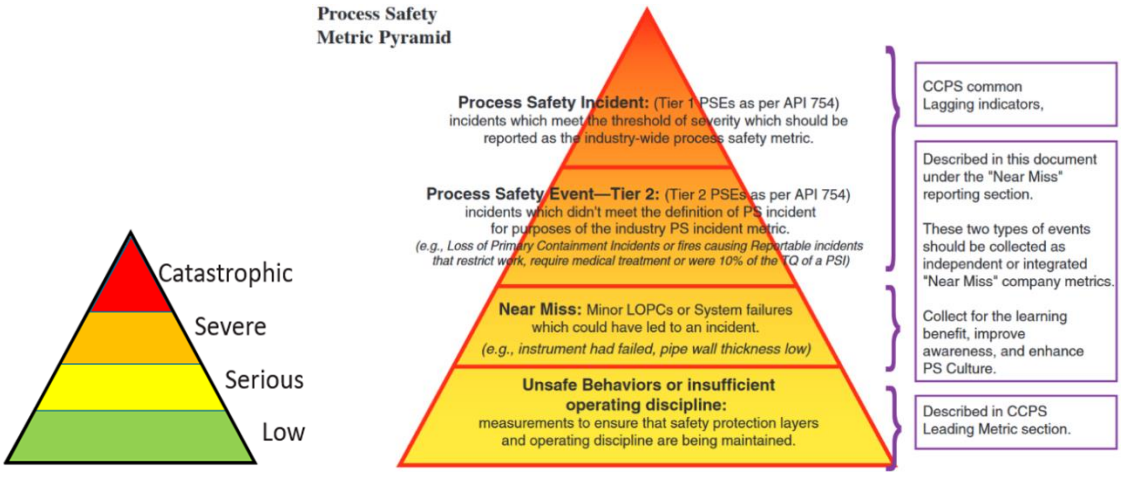


Table 7.1 presents examples of indicators as developed under the CCPS approach. The indicators are split between lagging and leading indicators.

Table 7.1 Examples of CCPS indicators

Indicator	Description	Comments
Lagging indicators related to progress with preventing major accidents and limiting their impact		
Total Count of Process Safety Incidents (PSIC)	The count of all incidents which meet the definitions of a PSI described within the CCPS.	Relying on incidents reporting prevents the European Commission from relying on weak statistical significance of extremely rare major accidents. However, due to the inclusion of all incidents, severity of the incidents is not reflected.
Process Safety Total Incident Rate (PSTIR)	The cumulative (annual) count of incidents normalised by man-hours.	Quantitative indicator contextualised by number of man-hours useful for benchmarking and comparisons.
Process Safety Incident Severity Rate (PSISR) (i.e., severity-weighted PSTIR)	The cumulative (annual) severity-weighted rate of process safety incidents.	Severity–weighted metric improves the PSIC as the severity of the accidents contextualises the propensity of the damage.
Leading indicators related to mechanical integrity		
Mechanical integrity	Ratio of number of inspections of safety critical items due during measurement period and completed on time and total number of inspections due during the measurement period.	The quantitative metric is one measure of the effectiveness of the process safety management system to ensure safety critical plant and equipment is functional.

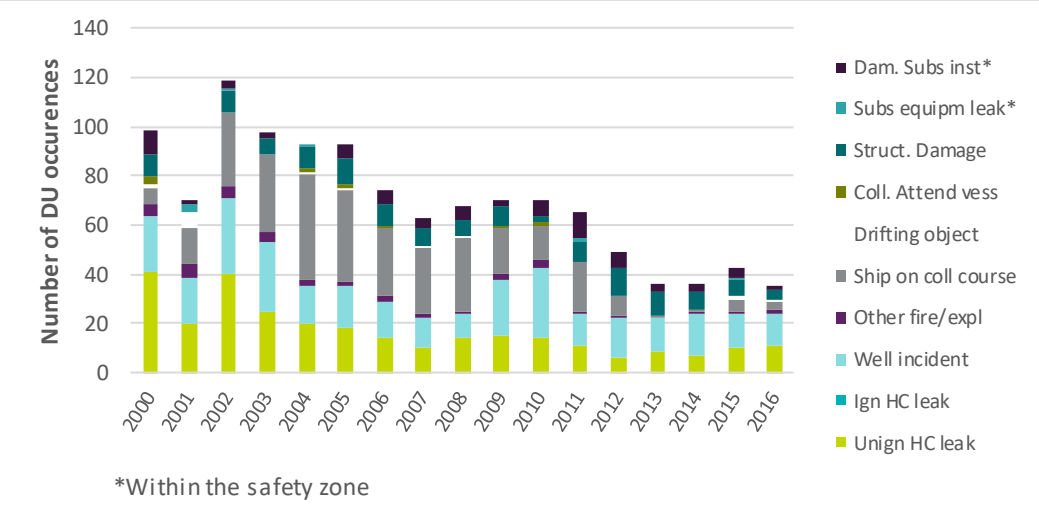
RNNP (Risiko i norsk petroleumsvirksomhet / Trends in risk level in the Norwegian petroleum activity (EN)) is performed annually by the Norwegian Petroleum Safety Authority (PSA) and is directed mainly towards offshore facilities covered by the Offshore Safety Directive. Trends in and levels of risk are presented by establishing a total indicator based on evaluation of major accident precursor event (defined hazard and accident conditions or DFUs) statistics. The RNNP system was developed with and for the Competent

Authority (CA). It emphasises the indicators for incidents and near-misses with the potential for causing a major accident (DFUs). It puts indicators into an overall group of process safety (PS).

The RNNP indicators (mentioned above) are used to evaluate the changes in major accident and occupational health and safety risk levels[86]. RNNP performs quantitative and qualitative risk analyses and applies the triangulation method which ensures that different disciplines are utilised in analysing the same phenomena i.e., major accident risk levels[87].

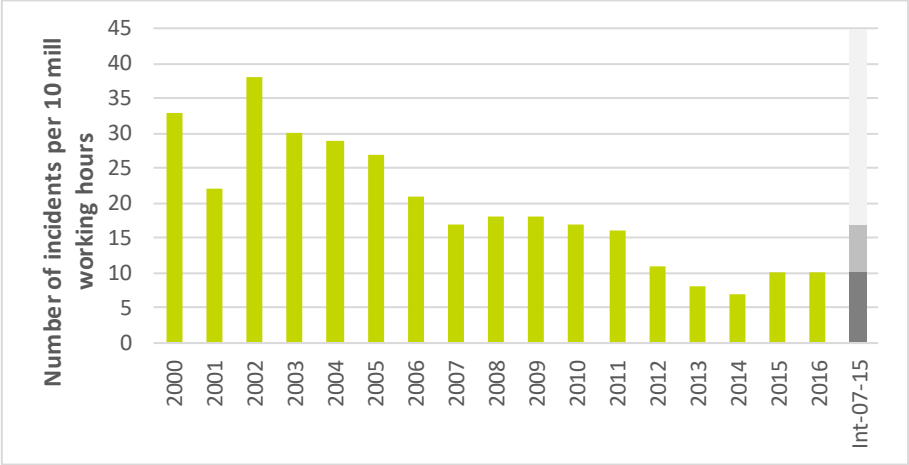
The number of reported incidents has decreased by around 65% between the years 2000 and 2016[82] (Figure 7.7a). While the reduced number of incidents is a positive sign for offshore safety, questions have been raised regarding the current RNNP methodology and its ability to portray realistic risk levels. The low number of incident reports reduces the data basis for quantitative risk assessment (QRA) considerably, where several of the DFUs have not occurred in several years, or even since the beginning of the RNNP project[87]. Furthermore, regarding the metric used in Figure 7.7b, collecting information on numbers of working hours (and uncertainties therein) was recognised at the workshop as being challenging in terms of EU-level policy indicators and may make such an indicator impractical.

Figure 7.7 (a) Number of DFUs



[86] Vinnem, Jan Erik, et al. "Major hazard risk indicators for monitoring of trends in the Norwegian offshore petroleum sector." Reliability Engineering & System Safety 91.7 (2006): 778-791.
[87] Andreassen, E. (2016). Development of a New Total Risk Indicator for the Trends in Risk Level Project (RNNP)-By utilizing DFU, Barrier Performance and Survey Results Data and incorporating Uncertainty (Master's thesis, NTNU).
https://brage.bibsys.no/xmlui/bitstream/handle/11250/2409525/14851_FULLTEXT.pdf?sequence=1

Figure 7.8 (b) DFUs normalised against working hours over a period of 2000-2016[82]



In the particular case of CEFIC and ICCA, they have adopted internationally harmonised guidance[80] in 2016. CEFIC is currently rolling out a new system for capturing key performance indicators on process safety which includes "near misses" targeting a comprehensive reporting at European level by the beginning of 2020. At the project workshop this system was discussed, with a conclusion reached that this industry-level reporting on accidents should be seen as complementary to the EU policy/regulatory level reporting (and indicators) under the three strands of the Seveso monitoring system. Under this Globally Harmonised Process Safety Metric the number of process safety events experienced by their members on an annual basis is collected, as well as total number of worker hours (employees and contractors) experienced by their members each year. The process safety event rate is the ratio of events to hours. This approach is similar to the Process Safety Total Incident Rate (PSTIR) metric proposed by CCPS (Table 7.1). The ICCA and CEFIC 'Responsible Care Leadership Group (RCLG)' recommended to their members in 2016 the phased in reporting (during a 'phase in' period of 3 years) of these data points to the RCLG.

The criteria that determine whether a process-related event qualifies as a process safety event are based on a loss of primary containment of a chemical or a release of energy triggering thresholds in any one of the following four impact areas:

1. safety/human health consequences;
2. direct cost due to damage from incident;
3. community impact; and;
4. chemical release quantity (see the flow chart showing reporting triggers).

There might be value in considering if aspects of this process safety reporting might have some relevance in the context of the implementation of the Seveso-III Directive as well.
Their combined value in better understanding performance in reducing major accidents is an area for future consideration.

7.3.3 Composite indicators

Composite indicators have been developed by the OECD (the Statistics Directorate and the Directorate for Science, Technology and Industry) and the Econometrics and Applied Statistics Unit of the Joint Research Centre (JRC) of the European Commission[88]. Composite indicators can be used to rank country performance

[88] https://composite-indicators.jrc.ec.europa.eu/

over time in areas such as industrial competitiveness, sustainable development, globalisation and innovation. Composite Indicators are a useful tool in policy analysis and communication.[89]

The OECD Glossary[90] provides the following definition: "A composite indicator is formed when individual indicators are compiled into a single index, on the basis of an underlying model of the multi-dimensional concept that is being measured". Examples of composite indicators include:

- **Environmental Sustainability Index (ESI)**: This measure provides an indication of overall progress towards environmental sustainability. The measure is a composite profile of national stewardship based on a compilation of indicators from underlying datasets.
- **Environmental Performance Index (EPI)**: This ranks 180 countries in regard to 24 performance indicators across 10 categories covering environmental health and ecosystem vitality. The metrics provide a measure at a national scale of how countries are performing in establishing environmental policy goals.

Composite indicators are mathematical combinations of a set of sub-indicators that have no common meaningful unit of measurement. As such, Composite Indicators can facilitate an interpretation of the results. However, it is important to note that these indicators can also give a misleading message or wrong policy conclusions if they are poorly constructed or misinterpreted. A critical assessment evaluating pros and cons of composite indicators has been published by the OECD[91] and is summarised in Table 7.2.

Table 7.2 Pros and cons of composite indicators

Pros of Composite Indicators	Cons of Composite Indicators
• **Allow complex or multi-dimensional issues to be summarised.** • **Illustrate a country's performance.** • **Facilitate communication with citizens.** • **Allow benchmark of countries for best performance.** • **Illustrate which countries represent a priority for improvement efforts.** • **Ability to compare complex dimensions.**	• Subjective due to different interpretation. • Often not quantitative. • Provide misleading or non-robust policy messages. • Provide simplistic conclusions. • Higher data requirements. • The outcome may reflect weak data in some dimensions. • The outcome may ignore dimensions of performance that are not measurable.

Source: OECD (2008)[91]

The suitability of the safety and composite indicators with regards to the project objectivities shows that safety indicators, albeit being useful at the establishment or sector level, do not reflect the overall objectives of the project in terms of providing indicators of the performance of the Seveso III Directive overall. On the other hand, composite indicators, due to their nature of combining a set of sub-indicators that have no common meaningful unit of measurement can lead to a misleading results or wrong policy conclusions if they are poorly constructed or misinterpreted. The feedback from the European Commission and JRC at the workshop indicated that the composite indicators are not useful for meeting the objectives of this project.

The Commission has a clear preference to look at the possibilities to use quantitative indicators over the non-quantitative ones. The use of calculable quantitative indicators based on facts/numbers/statistics are more

[89] Saltelli, A., Munda, G., Nardo, M. (2006). "From Complexity to Multi-dimensionality: the Role of Composite Indicators for Advocacy of EU Reform. " Tijdchrift vor Economie en Management.Vol. LI, 3.
[90] OCED Glossary http://stats.oecd.org/glossary/detail.asp?ID=6278
[91] OECD (2008). Handbook on Constructing Composite Indicators. Methodology and User Guide. Paris: Organisation for Economic Co-operation and Development.

suitable for policy development and objectively evaluating the implementation of the Seveso policy. Non-quantitative indicators are more indicative, more likely to trigger discussions on their interpretation and thus less suitable a policy indicator that can be used for policy evaluation purposes.

7.3.4 Policy indicators

Table 7.3 shows the possible indicators identified to monitor the implementation of the Seveso Directive, and to assess its achievements. The suggested candidate indicators for each category are organised according to the Better Regulation evaluation criteria. The proposed indicators were part of the initial groundwork on possible indicators from the analysis of the status of Member States' implementation of Directive 96/82/EC (the Seveso II Directive) during the 2012-2014 period. These should be read in conjunction with the existing indicators presented in Section 7.2.

Here these initial proposals have been reviewed and the suitability of the candidate indicators has been further assessed based on the following evaluation criteria:

- Ease of interpretation;
- Avoid misrepresentation;
- Reflect the overall benefits from the implementation of the Directive;

And in some cases:

- Reflect the progress made in preventing major accidents and limiting their impact;
- Reflect the progress made on the average risk of a citizen being exposed to a major accident.

Furthermore, and in line with the requirements from the Better Regulation guidelines[92]:

- Data should be readily available and of a good quality, ideally at national/regional level if appropriate; and
- Indicators should capture the impacts due to the policy intervention within a reasonable length of time but exclude other influences if possible.

Table 7.3 Possible indicators suggested for Seveso III Directive[72]

Possible indicators	Description	Comments
Overall degree of compliance:		
Percentage of Member States having achieved full transposition of Seveso III	Quantitative indicator based on the information from EUR-Lex and National Implementation Measures.	Easy to collect and interpret and can be used to track progress of the Directive. The quality and frequency of the data might depend on Member State reporting standards.
Percentage of safety reports updated (by the operator) and examined (by the competent authority)	Quantitative indicator to assess the amount of upper tier establishments satisfying safety reports requirements. Emergency planning.	Relatively easy to source the data from the implementation reports. Might be difficult to interpret for the general public as a flagship indicator.
Number of external emergency plan exercises performed per year divided by the number of upper tier establishments in the Member State	Quantitative indicator to assess efforts deployed by authorities to ensure that emergency plans are operational and effective.	Based on information from the implementation report, the indicator is easy to interpret and demonstrates responsibility and preparedness of the authorities.

[92] European Commission, Better regulation toolbox, #41, https://ec.europa.eu/info/better-regulation-toolbox_en

Possible indicators	Description	Comments
Share of upper tier establishments inspected annually (taking into account those Member States using systematic appraisal for defining inspection programmes)	A quantitative indicator to assess whether a core requirement of the Directive is being met.	Easily available data that can be used to effectively communicate the compliance statistics. Systematic appraisal for defining inspection programme(s) may not be shared by Member States.
Progress with preventing major accidents and limiting their impact		
Number of major accidents reported in eMARS database and evolution throughout the Directive's lifetime	Quantitative indicators for which the information can be sourced from the eMARS. They can provide another view on accident and incidents. Absolute number to be contextualised by number of establishments / sector information.	Readily available data reflecting the potential impact of the Directive. However, the metric disregards, other factors that could be responsible for major accidents including human error etc. which are difficult to measure and prevent. Due to the small number of major incidents, there is low statistical significance of the data with regards trend analysis.
Number of incidents reported in eMARS database and evolution throughout the Directive's lifetime	Same as above	Voluntary reporting of incidents reflects more on the reporting tradition of a specific sector or a Member State rather than providing information on the level of safety.
Number of near-misses reported in eMARS database and evolution throughout the Directive's lifetime	Same as above	Voluntary reporting of near misses reflects more on the reporting tradition of a specific sector or a Member State rather than providing information on the level of safety.
Risk of a citizen being exposed to a major accident		
Achievement of a high level of protection of human health	Qualitative assessment using combination of data / information to assess the achievement of the objectives of the Directive.	Difficult to find data/information and interpret the progress regarding protection of human health and environment due to the Directive.
Achievement of a high level of protection of environment		

7.4 Towards development of flagship indicators

In order to allow for effective communication with regard to the degree of compliance, progress made in prevention of major accidents and risks to which citizens are exposed, the study had a remit to consider a set of possible flagship indicators for communication. Analysis of the existing Seveso indicators (Section 7.2) shows that the indicators might not satisfy all the objectives of this project and may require modifications and additions in order to reflect the true progress of the Directive.

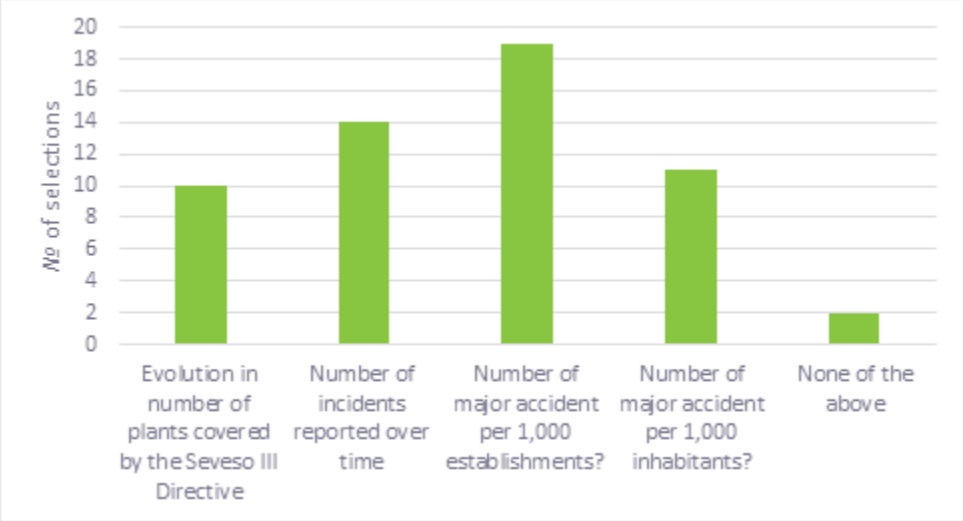
Thus, the results from the survey were reviewed to identify if one or several flagship indicators could allow the following to be depicted in a simple manner:

- The overall degree of compliance with the Directive (over all requirements);
- The progress made in preventing major accidents and limiting their impact (including the presence and performance of a process safety culture within Seveso establishments) and;
- The average risk of a citizen being exposed to a major accident.

The answers from the respondents were not homogeneous. Some of the respondents did not agree with the development of flagship indicators (30%), the main reasons stated related to the lack of relevant data about the progress made in preventing major accidents (also due to the small number of major incidents, there is low statistical significance of the data with regards trend analysis thus it is questioned whether an indicator

based on the related data is statistically meaningful). The other respondents (70%) selected one or more of the following indicators based on their suitability to communicate the effectiveness of implementation (See Figure 7.9).

Figure 7.9 Indicators best suited to communicate the effectiveness in the implementation of the Seveso Directive



The indicator reflecting the number of major accidents per 1,000 establishments was considered appropriate by the most respondents. Other respondents (2 out of 18 respondents) considered that none of the mentioned indicators are suited to monitoring the implementation of the Directive, and that while the indicators listed provide useful information to the public, they are not indicating the success or effectiveness of the Seveso III Directive. Furthermore, indicators per 1,000 inhabitants, or any normalisation on an annual basis, would be statistically meaningless, as the number of major accidents is too low and there is a large difference in industry density per region. Thus, the indicator might not be suitable to infer trends regarding the effectiveness of the Directive, but it is still a policy-relevant indicator in terms of absolute number of accidents that should be considered.

The following flagship indicators were suggested by the respondents of the survey. It is important to note that the suggestions received are listed below and to some extent all fall under the same pitfalls as other indicators, which is the limited scope for any meaningful statistical analysis due to the small number of accidents overall and the varied nature of the industries involved:

- Number of major accidents per number of Seveso establishments;
- Number of major accidents per number of inhabitants;
- The indicators such as those proposed by the Norwegian Petroleum Safety Authority[82] using risk indicators to report major accidents such as:
  - Number of hydrocarbon leaks exceeding 0.1 kg/s;
  - Number of leaks exceeding 0.1 kg/s, normalised against the number of working hours;
  - Number of serious incidents and incidents involving damage to structures (this could be normalised against the number of working hours);
  - Total indicator for the number of major accidents per year;

- Total indicator for the number of major accidents per year, normalised against working hours;
- Consequences for humans and the environment outside the establishment;
- State of compliance, deviations found in inspections;
- Total of socio-economic loss;
- Environment affected by the accidents and a quantification of the amount of damage;
- Damage to property and the environment (the former can be more readily quantified than the latter); and
- Number of inhabitants living on endangered area (based on consequence analysis or take into account the iso-risk curves[93]). An interesting aspect of this indicator is that it considers land use planning aspects and surrounding of establishments.

7.5 Possible flagship indicators

The selection of flagship indicators entails identification and analysis of different types of indicators which reflects the goals of the project. Reviewing the existing Seveso indicators and other process, safety and operational indicators showed the limitations of such indicators with regards to meeting the project criteria. Thus, one flagship indicator might not be sufficient in terms of meeting the project goals, and therefore the proposed flagship indicators are a combination of policy, process safety and operational indicators which can be visualised as a pyramid structure as shown in Figure 7.10.

Furthermore, the possible flagship indicators that allow suitable monitoring and assessment of the performance of the Seveso-III-Directive are proposed in Table 7.4.

Figure 7.10 Pyramid structure representing the nature of the possible flagship indicators

[93]Duijm, N. J., & Universitet, D. T. (2009). Acceptance criteria in Denmark and the EU. Danish Environmental Protection Agency, https://www2.mst.dk/udgiv/publications/2009/978-87-7052-920-4/pdf/978-87-7052-921-1.pdf

Table 7.4 Possible flagship indicators

Possible indicators	Description	Comments
Overall degree of compliance:		
Percentage of Member States having achieved full transposition of Seveso III	Quantitative indicator based on the information from EUR-Lex and National Implementation Measures.	Easy to collect and easy to interpret and track progress of the Directive. The quality and frequency of the data might depend on Member State reporting standards.
Progress with preventing major accidents and limiting their impact		
Number of major accidents per 1,000 establishments	Provide an overview of major accidents. The absolute numbers can possibly be contextualised using number of establishments.	Such an indicator cannot be used to reliably draw conclusions on trends but is important information to collect and communicate for policy purposes. The number per 1000 establishments provides more insight than the number of accidents alone, given the significant changes that have occurred in the total number of establishments (e.g. with new member states joining the EU). Note that, while some stakeholders supported this as an indicator, this was not unanimously supported by all stakeholders. It is also the European Commission's view is that this is not a statistically meaningful indicator.
Cumulative major accidents versus changes in GDP over time	Qualitative assessment using combination of information available making use of cumulative figures.	Due to normalisation of the absolute numbers by GDP of Member States (wide variation across Member States), and low number of accidents
Number of accidents in particular industries, substances, or associated with specific causalities over time	Evaluating number of major accidents across a common base (reference point) such as in a particular industry/sector/substance/specific causality	Having a common base considering number of accidents in a particular industry sector/substance can be useful for individual, more homogeneous, industry sectors with more confidence in data on trends likely than for Seveso establishments as a whole
Risk of a citizen being exposed to a major accident and public awareness		
Estimated (monetary) loss due to the nature of the major accident	Highlighting the potential for monetary benefits due to effective implementation of the Seveso Directive.	The estimated average cost of major accident types (explosion, toxic release or fire) such as those set out in EGSIA or by HSE (see Section 5) can be used to communicate the monetary benefits of the Directive.
% of citizen population made aware of the information related to alert systems, main response measures and arrangements to cope with any off-site effects from an accident	Information on safety measures and on requisite behaviour in the event of an accident, can be supplied regularly, and could help to monitor the progress of outreach.	Additional data required for assessing the area/population liable to be affected, i.e., in the hazard zones around Seveso establishments possibly using Geographic Information System (GIS).
Number of inhabitants living on endangered area (based on consequence analysis or taking into account iso-risk curves)	Iso risk curves show the geographic distribution of location-based (individual) risk for the chance of an accident to occur (e.g. once every 10,000 years etc.)	In combination with the number of inhabitants living within a certain curve, this objective indicator is likely to be helpful to assess and classify establishments in certain risk categories. However, the approaches to assessing risk for Seveso establishments varies across member states (not all require estimation of iso-risk curves).

7.6 Conclusion and outlook

A brief description of the different types of indicators (Section 7.1), was followed by a review of the existing Seveso indicators in Section 7.2. The results from the survey were presented in Sections 7.3 and 7.4 with regards to evaluating suitability of different safety, composite and policy indicators towards potential Seveso flagship indicators and for providing guidance for selecting flagship indicators, respectively. The survey attempted to identify if one or several flagship indicators can allow effective communication about the degree of compliance, comparison between member states (benchmarking) and to track overall progress in prevention of major accidents and manage risks.

There was no general agreement towards the development of flagship indicators with the main reason being the lack of statistically significant data regarding the number of major accidents and the progress with avoiding them. It was emphasised that objective and quantitative, (normalised) data can be useful to evaluate trends and track progress regarding the effectiveness of the Directive.
However, identifying and developing flagship indicators is a challenge due to a number of factors having different root causes: technical, political and organisational. Thus, we present possible flagship indicators which can meet the project objectives using a pyramid-style blend of policy, safety and operational indicators (Section 7.5).

Examples of technical difficulties (also mentioned by the stakeholders in the interviews in the background of this report) are:

- Difficulties related to application of the indicators established in one part of industry to other industries or scenarios.
- Broad nature and types of Seveso establishments needing their own, specific set of indicators.
- Limited communication between the plant operators (functional side) with the policy makers
- Time needed to agree the indicators among the stakeholders' groups.
- Need to include a balance of leading and the lagging metrics.

Political and organisational difficulties for the process of defining and applying common indicators are, in the EU, probably more difficult to overcome. The implementation of the Directive in member states is organized in different ways, involving not only national, but also regional differences, and, this makes defining detailed indicators in such a context, especially difficult (e.g. as highlighted previously with possible indicators such as the regulatory effort/time spent by authorities on Seveso directive implementation).

The CCPS-statement/slogan "you do not improve what you don't measure" is certainly not the whole truth but is a good reminder for all current and future discussions related to the Directive and its applications, especially in the context of:

- Constantly changing process environment (e.g.: new technologies);
- New threats to safety (e.g.: cyber, terrorism, extreme weather);
- Constantly changing social context (e.g.: risk awareness and risk aversion of the society).

8. Conclusions on improvements to monitoring of the Seveso Directive

8.1 Overview

This section presents our initial conclusions on possible improvements at short term and long term based on the feedback received by stakeholders and our analysis. For each improvement identified, an associated action plan is presented.

8.2 Short term improvements

Short term improvements are those that can be made to affect the 2019-2023 reporting period[94]. Considering the proximity of this period, any improvements that would substantively affect the way data is collected at Member State level is listed under long term improvements. One possible short-term improvement was initially identified. Feedback from stakeholders at the workshop and the Commission indicated that, although the improvement was relatively simple to apply, the 2019-2023 period was too close to allow the reporting questionnaire to be updated and allow member states to prepare for reporting. This possible improvement has now been proposed as a long-term improvement (number 1 in the table below).

8.3 Long term improvements

Most of the possible improvements identified are long term, as they either involve additional questions to be included in the implementation reporting, additional research areas or changes to the structure of the reporting. A total of 10 long term possible improvements have been identified and are described below.

Table 8.1 Overview of the long-term improvements and related actions

#	Improvement	Description	Actions
1	Modify the reporting template for numerical responses	Change the reporting templates for quantitative responses to allow numerical data (e.g. number of establishments, external emergency plans tested, establishments inspected etc.) to be reported annually, thus allowing for variation of the number of establishments and the change in tier throughout the reporting period.)	DG Environment to check with SEG that this change would be definitely welcome and not create additional burden. DG Environment to draft a new template. DG Environment to update the reporting decision to include the new template.
2	Further the reporting of near misses	Reporting of near misses is recognised as useful however many Member States do not report them. It could be through unavailability of the data but also wider misunderstanding of the possibility to do so as part of the existing framework. These differences bring the issue of "equal reporting"; the need for more consistent reporting amongst Member States. According to the Member States attending the workshop, it would be more useful to focus on the lessons learnt from near misses, rather than collecting statistical data, which is not comparable at the	DG Environment and MAHB to remind Member States that reporting of near misses is possible and encouraged through eMARS. DG Environment to set up a Technical Working Group to identify ways to define near misses, to draft guidance on identifying and reporting near misses. DG Environment to consult and share with Member States the results of the Technical Working Group work.

[94] Decision 2014/ 896/EU describes the information to be reported for the 2015-2018 period and every four year period following this. https://publications.europa.eu/en/publication-detail/-/publication/7a13c3f3-81ca-11e4-89f7-01aa75ed71a1/language-en

#	Improvement	Description	Actions
		moment due to the issue of lack of "equal reporting" mentioned above.	
3	Incorporating the EU Gravity Scale of Industrial Accidents into eMARS	Linked to the issue of understanding and identifying near misses, the modernisation of the EU Scale of Industrial Accidents would be beneficial to allow a common understanding of assessing impacts of major accidents. Currently, Member States, trade associations and research institutes do not use the scale extensively and did not see clear benefits of it as it stands.	DG Environment to propose incorporating the gravity scale into eMARS and implement minor modifications if needed (see section 6.6) to capture Member States' interest for this action, given that the current benefits of the scale are not entirely clear to them. As noted in section 6 of this report, a clear benefit of the scale is improving the knowledge on potential benefits of the Seveso legislation, given that it provides scientific information on costs that occurred in industrial accidents and that could be avoided by improved implementation of the Directive. DG Environment to set up a Technical Working Group to review ways in which the scale could be incorporated. Note should be taken of those Member States making use of it already (e.g. France). DG Environment to share with Member States the results of the Technical Working Group work. This could include a formal guidance on using the Scale.
4	Further understanding of socio- economic impacts of accidents	Further guidance and support are needed to improve the reporting of socio-economic and environmental impacts of major accidents; this requires additional work to understand the scale of the work necessary and the development of an EU wide methodology through a research project (e.g. FP 9).	DG Environment to initiate research into guidance and improvement of the reporting of socio-economic impacts of major accidents. DG Environment could set a Technical Working Group to assist in the drafting task DG Environment to identify suitable support for research (e.g. FP 9 platform)
5	Further understanding of environmental impacts of accidents	Further research is needed to understand the potential impacts on the environment of major accidents. Further research is also needed to develop guidance on the reporting of environmental impacts of major accidents. The research should also consider potential linkages of such guidance and reporting with the EU Gravity Scale of Industrial Accidents, which would require substantial amount of work (i.e. understanding the scope of the scale, exploring whether the scale can be adapted to the current needs, if not developing a stand-alone methodology)	DG Environment to initiate research into improvement of the identification of environmental impacts of major accidents and also their reporting. This could consider potential linkages with the EU Gravity Scale of Industrial Accidents. DG Environment to identify suitable support for research.
6	Shorten the time for reporting major accident	Reducing the time delay for reporting in order to improve the process of learning lessons. It is important to note here that the delays in reporting is not something in control of the MAHB, however there is scope to encourage faster reporting. Member States have recognised that there are legal and technical barriers to reporting with shorter timescales.	Member States would be required to provide on a voluntary basis an initial notification of an accident within e.g. 1 month of the accident occurring, providing basic information for rapid information sharing. This would allow the MAHB to follow up on outstanding reports and advise Member States on preparing the report if necessary; In a second stage, Member States would be required to provide any complementary information in line with Article 18 at the latest one year of the date of the accident. Then, Member States would provide on a voluntary basis any update on the impact of an accident that become apparent only after the formal submission of the report (e.g. long term impacts).

#	Improvement	Description	Actions
7	Increasing synergies with existing reporting streams – reporting on establishments	The reporting on establishments could be streamlined and combined with the reporting on installations under the IED / E-PRTR. The EEA is currently working on establishing an EU registry of industrial sites to which Seveso establishments could be reported. Exchanges with the EEA confirmed that this was technically possible but required some changes in practical ways of reporting (using EEA templates and data quality checks) that might in the first instance increase the burden at Member State level. This would diminish again once the systems are established. However, Member States have expressed concerns on the possible costs of this streamlining (and implications for quality of reporting), given that the staff in charge of the implementation of Seveso are different from the staff in charge of the other reporting streams. The importance of other non-environmental considerations such as work and industrial safety should not be disregarded as part of this streamlining and some Member States saw this as a risk.	DG Environment to consider options with the EEA on increasing synergies with reporting on IED installations and E-PRTR facilities and Seveso establishments.
8	Increasing synergies with existing reporting streams – reporting on major accidents and or the location of establishments.	The reporting on the location of establishments and the occurrence of major accidents could be put in further context by taking account other reporting mechanisms in the area of industrial emissions and chemical industry accidents from non-Seveso sites, including for example the location of installations and facilities under the Industrial Emissions Directive and the E-PRTR Regulation, as well as accidents reported under the Offshore Safety Directive and/or under the Extractive Waste Directive. These would allow a streamlining and exchanging information between various databases. The synergies between accidents reported under other legal obligations and accidents reported into the eMARS database could be investigated. Also, the synergies between the locations of establishments and the locations of IED installations and E-PRTR facilities could be investigated. This is also relevant in the context of identifying iso-risk curves etc. Member States have recognised that the staff in charge of Seveso may not always be environmental specialists but are equally or perhaps more likely to be experts in work and process safety. Given that there is only a partial overlap of establishments being covered by more than one Directive, it would be important not to lose this knowledge if reporting is streamlined with reporting for other environmental legislation.	DG Environment to engage with Member States to understand whether such reporting would be encouraged. DG Environment to engage with colleagues in charge of relevant legislation concerned to understand whether such synergies in reporting would be useful and supported. If yes, a common portal of chemical accidents from various sources could be developed. The JRC could support development of such a common portal of chemical accidents. Also, the synergies with the industrial emissions portal that is currently under development by the EEA could be relevant in this context. The accident reporting via eMARS could, in combination with information from other sources, be relevant of a common information portal or other systems to facilitate the exchange of information. As a first step, it could be considered to give access to the eMARS reporting data via in a common portal and then let everyone use them as they wish.
9	More substantive changes to the questions included in the questionnaire on implementation	A range of additional questions could be included in the implementation questionnaire including: • Additional question on training of inspectors at national level; • Additional question on deficiencies identified during inspections during the reporting period and steps taken to remedy these; • Additional question on deficiencies identified during testing of emergency plans during the reporting period and steps taken to remedy these;	DG Environment to check with SEG that the additional questions would be welcome and not create disproportionate additional burden. DG Environment to draft a new template/decision if changes are welcomed.

#	Improvement	Description	Actions
		• Additional question on safety management systems; • Additional questions related to the impact on land use planning (and hence reduction in risk); • Further questions on communication to and awareness raising of the general public; • Information on prevention efforts made versus mitigation e.g. linked to sums invested (see Section 4); • (Voluntary) include information on the number of inhabitants within certain iso-risk curves around establishments as additional indicator of the potential hazard of certain (categories of) establishments, and; • Additional question on how socio-economic impacts, e.g. by using the EU Gravity Scale of Industrial Accidents, of major accidents are being considered and recorded in the Member States.	
10	Continuous strengthening of cooperation of the Commission with relevant international organisations with the view streamlining reporting and information management between the EU level and the international level.	Feedback from stakeholders and the information gathered during the study indicated that the implementation of the Directive would benefit from enhancing the collaboration of the Commission with other organisations such as the OECD or UNECE to find synergies and promote coherence between industrial accident reporting at EU and wider international level.	DG Environment to set up meetings with relevant institutions with a view to increasing the frequency and enhancing of communication between these and the Commission.

Appendix A
Intervention logic

See Excel file appended

Appendix B
Literature review of wider impacts of major accidents

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Handbook for Estimating the Socio-economic and Environmental Effects of Disasters	The manual is a tool to assist stakeholders in identifying and quantifying damages from a disaster, through a uniform methodology and proven consistency in over three decades of implementation. It also provides the elements necessary to identify those social, economic, environmental and geographical regions that have been more concerned and that require priority in attention in the reconstruction phase.	•Deaths, injuries, response cost, cost of dealing with the injured, cost of health campaigns to prevent epidemics. •macro-economic affects, in which disaster modifies performance of the main economic variables of the affected country, effect on GDP, impact on employment. • population affected, deterioration in living standards, psychological harm such as depression, anxiety. • destruction of houses, Housing and human settlement vulnerability reduction, temporary housing, relocation.	✓	✓		✓	✓	✓	✓		✓	✓
Modelling the economic impacts of an accident at major hazard sites	This report documents the development, implementation and results of a model to estimate the economic costs of accidents at major hazard sites in Great Britain, focusing on the impacts of the accident, and taking into consideration a broad spectrum of losses. A catastrophe-modelling type approach was used to structure the work, based around model components for hazard, vulnerability and economic cost.	• Harm to people, evacuation, damage to buildings, loss of business, relocation of business, emergency services. • Costs that are closely related to the accident and can be valued via the market, costs that are not closely related to the accident but can be valued via the market, costs that are closely related to the accident and are not valued in the market, costs that are not closely related and are not valued in the market. • Accommodation and food costs, long term accommodation costs, emergency services and other public costs. • Health impacts include injuries and stress induced illness	✓	✓	✓	✓	✓	✓	✓		✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Modelling the human and economic costs of major industrial accidents	This paper presents the first attempt in Europe to model the costs of potential major accidents and produces estimates for GB via a collaborative effort between HSE and Cardiff Business School. This work will assist in continuing to ensure that the level of regulation remains proportionate for the level of risk. An innovative catastrophe modelling approach to estimate the costs of major accidents is presented. Emphasis has been placed on the novel application and re-use of available data sources and techniques. Monetised impacts comprise key direct and indirect effects including casualty impacts, disruption and temporary relocation of businesses, building damage, and evacuation and emergency service requirements.	• Monetised impacts comprise key direct and indirect effects including casualty impacts, disruption and temporary relocation of businesses, building damage, and evacuation and emergency service requirements. •Populations more vulnerable to harm were identified, such as those in hospitals, care homes and childcare facilities.	✓	✓				✓	✓			
Mapping human vulnerability to chemical accidents in the vicinity of chemical industry parks	This paper concentrates on exploring the concepts of human vulnerability and the methodology of analysing human vulnerability to chemical accidents in the vicinity of chemical industry parks. A conceptual model of human vulnerability to chemical accidents is developed, revealing the roots of human vulnerability and emphasizing its role in risk management. A geographical information system (GIS)-based methodology for mapping	• This paper concentrates on exploring the concepts of human vulnerability and the methodology of analysing human vulnerability to chemical accidents in the vicinity of chemical industry parks. • By combining physical vulnerability and social vulnerability spatially, the total vulnerability is revealed to better respond to accidents.				✓	✓				✓	

Document title	Summary of report	Summary of impacts reported	Impacts of establishment: Direct damage	Impacts of establishment: Subsequent business cost	Impacts of establishment: Image	Impacts for authorities/communities: Physical health	Impacts for authorities/communities: Psychological health	Impacts for authorities/communities: Response cost	Impacts for authorities/communities: Follow-up cost	Wide impacts: Environmental consequences	Wide impacts: Socio-economic impact	Wide impacts: Political impact
	vulnerability is proposed and applied to the Nanjing Chemical Industry Park in China. By combining physical vulnerability and social vulnerability spatially, the total vulnerability is revealed to better respond to accidents. It is proposed to improve traffic lines and allocation of medical services and include vulnerability assessment in land-use planning to reduce future risks. In other words, it seems feasible and effective to reveal physical, social and total vulnerability of residents in the vicinity of chemical risk sources.											
Relationships between impact on employment, working conditions, socio-occupational categories and symptoms of post-traumatic stress disorder after the industrial disaster in Toulouse, France	The aims of this paper were (1) to analyse the prevalence of symptoms of post-traumatic stress disorder (S-PTSD) in a population of workers 1 year after an industrial disaster; and (2) to assess the role of factors of vulnerability such as the occupational impact of a disaster and economic conditions.	• Symptoms of symptoms of post-traumatic stress disorder (S-PTSD) in workers one year after an accident • Occupational impact of a disaster and economic conditions • Impact on the workplace and socio-economic conditions were found to be associated with S-PTSD.					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Psychotropic drug use in a cohort of workers 4 years after an industrial disaster in France	Two years after the 2001 Toulouse industrial disaster, a longitudinal study was set up to evaluate the impact of the disaster. The current sub study examines the medium-term impact (5 years) the incident had on the mental health of 3,004 participants. As part of the monitoring, data relating to the psychotropic drug use of 2,494 participants were collected from administrative databases 4 years after the disaster. Use of psychotropics was higher among women for anxiolytics (10.4% for men and 15.0% for women), hypnotics (10.5% and 17.0%), and antidepressants (7.6% and 11.2%). Exposure to the disaster, especially proximity to the exposure, was significantly associated with the use of antidepressants in men, OR = 3.22, 95% CI[1.57, 6.61]. This was also the case for other exposure factors (saw dead or injury, injured, home damage, death or injury loved one, psychological disorders, exposure toxic fumes): range of OR 1.75 to 2.52 in men, 1.48 to 1.62 in women. In conclusion, this study highlights the medium-term psychological impact of an industrial disaster on psychotropic drug use and the potential for using medical records data as a means for tracking post disaster mental health.	• The mental health of participants following the Toulouse industrial disaster was studied. • Use of psychotropic drug use. • Medium term psychological impact of an industrial disaster on psychotropic drug use.					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Vulnerability analysis for two accident scenarios at an upper-tier Seveso establishment in Romania	Major accidents involving dangerous substances pose a serious threat to the health and safety of local communities and the environment, as well as to the integrity and development of infrastructure where Seveso establishments are located. In some cases, the disastrous effects may affect larger, even cross-border areas. At European level, there are continuous efforts to develop land-use planning policies and regulations to reduce consequences and to prevent future accidents from happening. Hence, research in this field comes to support the current actions and strategies of the European Commission to improve the capacity of the EU Member States to cope with and respond to the identified risks through effective prevention, preparedness and response measures. In Romania, the Seveso establishments are mostly located in or very close to urban areas. This paper analyses vulnerability in case of two different accident scenarios (explosion and toxic dispersion) in Targu-Mures, a city hosting one of the largest Seveso upper-tier establishments in Romania. The approach starts with exposure analysis - the first step in the process of vulnerability analysis - which identifies all the elements at risk, be they social	•This report identifies all the elements at risk, be they social (population, medical facilities, schools), environmental (protected areas, water bodies) or economic (transport infrastructure, buildings, utility and water supply networks, fuel or food storage facilities). • The vulnerability is assessed based on indicators selected in such way so that they cover the entire range of social, economic, environmental aspects, as well as the existing response capabilities in case of a major accident. The content of the report is not conclusive from this abstract.									✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	(population, medical facilities, schools), environmental (protected areas, water bodies) or economic (transport infrastructure, buildings, utility and water supply networks, fuel or food storage facilities).											
The employment and population impact of the boom and bust of Talvivaara mine in the context of severe environmental accidents - A CGE evaluation	There had been a mining boom in Finland before the current recession. The most ambitious investment was the Talvivaara nickel and zinc mine in Kainuu. The operation phase began in 2008, and for three years the mine produced nickel and zinc according to expectations. Then everything changed: two accidents occurred in 2012, which had severe environmental consequences. There was a failed attempt at corporate restructuring. The production company of Talvivaara is now in bankruptcy, and the national government is financing the mine. Our aim is to present an evaluation of the impact these events had on the employment and population of Kainuu region. Our results for the period 2009-2014 indicate that the Talvivaara mine still had a positive cumulative effect on the employment of Kainuu, in spite of the environmental accidents. The results for the period 2015-2022 suggest that the full	• Impact on the employment and population of the Kainuu region of the failed attempt of corporate restructuring following two accidents.		✓	✓						✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	implementation of the rejected corporate restructuring plan would have been a tolerable solution for the employment and population of Kainuu region. Considering the uncertain future of the mine, we suggest follow up studies.											
The cost of reputational damage when a major accident occurs	The occurrence of a major accident in today's industry may have several types of direct and indirect consequences. However, the most common techniques of Quantitative Risk Analysis (QRA) mainly focus on direct consequences of an accident on humans and equipment and disregard relatively secondary repercussions, such as damage to the company reputation. This type of consequence may have a serious impact on the company and lead to negative cascading events for the local community, such as the layoff of personnel and the decline of satellite companies. This paper investigates the cost of reputational damage to the industrial company where major accidents have occurred. The analysis covers the accidents occurred in 2001 in Toulouse (France) and in 2005 in Buncefield (UK).	• Cost of reputational damage. • Reputational cost is measured by the loss in the market value of the company and cumulative abnormal returns (CARs) following an accident. • Results suggested that reputational damage may exceed other economic losses and should be considered priority for the industry. • General liability policies normally do not cover the cost of decontaminating a company's own property, they only cover third-party liability costs. Nor will they protect against statutory-imposed decontamination costs. The 2011 fire at the company "Chemie-Pack" in the Netherlands however illustrated that a combination of clean-up / soil pollution remediation costs and reputational damage costs can result in bankruptcy.	✓	✓	✓							

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Is reputational risk quantifiable?	Two parameters are important when assessing risk in marine environments: the probability that an undesired event will occur and the estimated financial loss if the event occurs. The assessed risk is only as accurate as the data used to produce it. However, in the marine environment, both parameters are often difficult to assess. After a marine industrial accident such as the Deepwater Horizon explosion in the Gulf of Mexico, some losses, such as loss of product or equipment, are understood to be easily quantified. However, it is difficult to quantify loss of reputation after such an event. This paper presents a model, based on the efficient market hypothesis, for quantifying reputational losses. The efficient market hypothesis states that the stock market accurately reflects the valuation of any publicly traded company, accounting for all publicly available information. The reputational loss model introduced in this paper proposes that post-accident changes in the market valuation of a company partially reflect a quantifiable loss of reputation. The model is then applied to examine the case studies of quantified reputation loss for the companies involved in the Deepwater Horizon accident and the sinking of the Costa Concordia cruise ship. In	• Cost of reputational damage following an accident like for example: • a media grilling; • negative public opinion that is hard to reverse; • fines; • unwanted attention from pressure groups; •disastrous sales; • reduced profits and revenue. • Reputational damage is quantified using information on post-accident market valuation of company	✓	✓	✓							

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	these cases, it is concluded that the reputational losses may far exceed other losses, meaning that reputational loss should be a priority for companies in marine industries.											
Impacts of Major Offshore Oil Spill Incidents on Petroleum Industry and Regional Economy	Disasters such as offshore oil spills will have a significant negative impact on occupations, incomes, tariffs, and further profits, adding to the struggles of regional area held up in difficulty. Such a broad size of impact can more impair the functioning of the economy of the district. In addition to costs encountered by clean-up activities, industries and individuals dependent on coastal resources can experience huge economic losses. Many other related businesses and sectors can possibly hurt by disruptions and loss of earnings. To better understand different aspects of the problem, we explain the problem through a case study for recent incident in the Gulf of Mexico (GoM), the Deepwater Horizon oil spill (DWH) on April 20, 2010, the worst oil spill disaster in the history of the U.S. start off the coastline of Louisiana in the Gulf of Mexico. We have conducted study to focus on the positive impact of	• Positive impact of economic compensation on Gulf coast employment and wages. • Gross damages to economy. • Losses in the employment and earnings in Louisiana.		✓							✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	economic compensation on Gulf coast employment and wages.											
A study of posttraumatic disorders in children who experienced an industrial disaster in the Briey region	Objectives of this article are to study posttraumatic disorders in children who were directly and indirectly involved in an industrial disaster; to assess the respective impact of traumatism exposure, parental disorders and socio demographic variables on the posttraumatic disorders of the children	• Post traumatic disorders in children who were directly or indirectly involved in an industrial disaster. • Assessment of the respective impact of traumatic exposure, parental disorders and socio demographic variables on the post traumatic disorders of children. • Anxiety, trauma. • Study revealed that the younger exposed children exhibited the highest psychopathological scores.					✓				✓	
The aftermath of an industrial disaster	An explosion in a Danish super tanker under construction in 1994 caused the death of six workers and injured 15. Six months later 270 workers took part in this study, which analyses the relationships between objective stressors, the workers' own feelings and the reactions of their families after the explosion together with training, attitude to the workplace, general outlook, and received crisis help. Traumatisation, coping style and crisis support was assessed via the Impact of Event Scale (IES). The Coping Styles Questionnaire (CSQ) and the Crisis Support Scale (CSS).	• The relationship between objective stressors, the workers' own feelings and the reaction of their families after the explosion together with the training, attitude to the workplace, general outlook and received crisis help. • Traumatisation, coping style and crisis support was assessed.					✓				✓	
Assessing post-disaster	Background: A major explosion occurred in the AZF chemical factory in Toulouse in September	• The short and long-term effects of air, water and secondary soil pollution on health.				✓	✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
consequences for health at the population level: Experience from the AZF factory explosion in Toulouse	2001. A comprehensive programme of epidemiological surveillance was set up. Objectives: To present an overview of the programme and discuss the methods and potential utility of post-disaster epidemiology. The programme had three objectives: (1) to analyse comprehensively the short-term and long-term effects of air, water and secondary soil pollution on health; (2) to identify health problems needing special attention; and (3) to investigate the long-term direct and indirect effects on the population's health.	• Health problems that need special attention. • Long-term direct and indirect effects on the population's health.										
Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine	Summary of the health, environmental and socio-economic consequences of the Chernobyl Nuclear Accident. Recommendation on health care, research, environmental monitoring and economic and social policy provided for the governments of Belarus, the Russian Federation and Ukraine.	• Radiation exposure. • Deaths due to acute radiation syndrome (ARS. • Cancer mortality. • Leukaemia, Solid Cancers and Circulatory Diseases. • Reproductive defects. • Persistent psychological and mental health problems resulting from rapid relocation, breakdown in social contacts, fear and anxiety about health effects. • Release and deposit of radioactive material. • Agriculture, aquatic and forest contamination. • Economic cost related to response, social protection and health care to affected population, radiation monitoring, radioecological improvement of settlements and disposal of radioactive waste.	✓	✓		✓	✓	✓	✓	✓	✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
		• Impact on local economy. • Impact on local communities.										
COCO-2: A Model to Assess the Economic Impact of an Accident	COCO-2 is a model for assessing the potential economic costs likely to arise off-site following an accident at a nuclear reactor. COCO-2 builds on work presented in detail, and by including more sources of loss. Of particular note are: the consideration of the directly affected local economy, indirect losses that stem from the directly affected businesses, losses due to changes in tourism consumption, integration with the large body of work on recovery after an accident and a more systematic approach to health costs.	• Economic costs resulting from short-term counter measures and long-term counter measures and the impacts on the local economic. • Loss of tourism income. • Production losses. • Direct costs like emergency services, evacuation, relocation. • Indirect costs like disruption of business, public services, tourism. • Losses to agriculture sector. • Loss to the UK economy from health effects, such as direct loss of labour due to illnesses and cost for treatment. • Value of life lost, value of injury, value of labour. • Accommodation costs.	✓	✓				✓	✓	✓	✓	
The public health impact of industrial disasters	The recent Deepwater Horizon oil spill and Japanese earthquake/tsunami radiation disaster have increased public concerns regarding the public health impact of industrial disasters. Industrial disasters are known to impose a unique set of challenges for public health emergency response. There are critical gaps in scientific knowledge regarding assessment and control of public	• Review of the public health impact and unique considerations related to industrial disasters. The content of the report is not conclusive from this abstract.				✓	✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	health disasters related to industrial releases of hazardous materials. There is also a fundamental lack of familiarity regarding industrial disasters among the public health and medical communities, in general. There are few sources in the current public health literature that review this disaster phenomenon in a comprehensive manner. This article offers a review of the public health impact and unique considerations related to industrial disasters.											
The Buncefield Incident 11 December 2005: The final report of the Major Incident Investigation Board, Volume 1	This report provides an overview of the Buncefiled fuel depot in Hertfordshire, England and an account of the incident and immediate response. It also provides a summary of the economic impact of the incident, comprising of compensation for loss, cost to the aviation sector, emergency response and the costs of the investigations. Simple calculations of the range of costs for implementing recommendations for avoiding overfilling tanks with petrol and estimate, in monetary terms are also recommended.	• Infrastructural damage. • Injuries and health effects resulting from the explosion and fire. • Business disruption. • Environmental pollution. • Disruption to fuel supplies. • Economic costs related to compensation claims, costs to aviation industry, competent authority and government response, emergency response and environmental impact.	✓	✓		✓		✓	✓	✓	✓	
Market-based approximation of the cost of	Employing a market-based approach, this study provides an approximation of the total cost of non-conformance for BP and firms in	• Approximation of total cost of non-conformance for BP and firms in the oil and gas industry associated with the 2010 Gulf of Mexico oil spill.	✓	✓	✓				✓		✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
non-conformance associated with the 2010 Gulf of Mexico oil spill	the oil and gas industry associated with the 2010 Gulf of Mexico oil spill. Based on changes in market capitalisation of the firms being investigated, this study documents that, at the time the leak was sealed, the spill had resulted in a net loss of approximately $61 billion to BP, $17 billion to partners, $13 billion to the drilling sub-industry, and $19.0 billion to other integrated oil and gas firms. Results strongly support contagion effects for firms directly associated with BP and/or offshore drilling. Competition effects were also found for firms and sectors of the oil and gas industry not related with BP and/or drilling. Those benefiting from the oil spill (in relative terms) include the main rivals of BP and firms in other oil and gas sub-industries such as exploration and production, storage and transportation, and equipment and services.	• Report reveals contagion effects for firms directly associated with BP and/or offshore drilling. • Competition effects also reported for firms and sectors of the oil and gas industry not related with BP and/or drilling.										
Risks of Offshore Oil Drilling: Causes and Consequences of British Petroleum Oil Rig Explosion	The British Petroleum oil rig explosion in the Gulf of Mexico has left a legacy of environmental pollution, loss of businesses and health effects. The various stakeholders; British Petroleum, Harliburton, government regulators and Transocean Management Ltd are partly responsible for the safety of Macondo oil rig and they are accountable for	• Environmental pollution. • Loss of business and health effects. • Several species of wildlife and ecosystems were threatened. Specific health impacts assessed in the report are not conclusive from the abstract.		✓		✓	✓			✓	✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	negligence, oversight, cost-cutting and shoddy technical fixes which eventually resulted in the explosion. Several species of wildlife and ecosystems were threatened. Efforts were made to cap the well, clean the oil, and rehabilitate affected animals. In spite of the ongoing restoration efforts, there is still uncertainty regarding long-term viability of restored ecosystems											
A Socio-Economic Cost Assessment Regarding Damages to Underground Infrastructures	The research's general objective is to present a detailed study of damage related indirect costs to underground infrastructures that could be used for damage prevention and as an incentive for best practices. By providing a complete list of socio-economic costs and a realistic damage related costing, this essential step will help convince contractors of the importance of damage prevention as well as help reduce the total damage related costs for everyone (companies, population, municipalities, emergency services, etc.).	• Death and injuries. • Infrastructural damage. • Direct costs related to the cost of replacement materials, costs of materials used, labour costs and administrative costs needed to rehabilitate the damaged infrastructure. • Indirect costs include costs arising due to service disruption, administrative costs related to procedures that arise from such accidents, costs related environmental impacts, intervention of emergency services, loss of product, work delays, risk for the workers' health and life, tarnished company image, traffic disturbance, impact on business and firms, evacuations.	✓	✓	✓	✓		✓	✓	✓	✓	
Psychological effects of a disastrous	Background: On September 27, 2012, at 3:43pm, a hydrogen fluoride spill occurred in a manufacturing plant located at the 4th	• Psychological effects of hydrogen fluoride spill on members of the community and their relationships with					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
hydrogen fluoride spillage on the local community	complex of the Gumi National Industrial Complex in Gumi City, South Korea. The present study aimed to evaluate the psychological effects of the hydrogen fluoride spill on the members of the community and to investigate their relationships with physical symptoms and changes in psychological effects occurring as time passed after the accident. Methods: The 1st phase involved a survey of 1359 individuals that was conducted 1month after the spill, and the 2nd phase involved a survey of 711 individuals that was conducted 7months after the accident. The questionnaires included items for assessing demographic characteristics, hydrogen fluoride exposure level, physical symptoms, and psychological status. Physical symptoms were assessed to determine the persistence of irritations. Psychological status was assessed to investigate the impact of event level using the Impact of Event Scale - Revised Korean version (IES-R-K), and the anxiety level was assessed using the Beck Anxiety Inventory (BAI). Results: As the hydrogen fluoride exposure level increased, the impact of event and anxiety levels increased significantly both 1 and 7months after the accident ($p<0.05$). The mean score of the impact of event levels	physical symptoms and changes in psychological effects occurring as time passed after the accident. • Anxiety levels. • Study revealed that the risk of persistent physical symptoms at 7 months after the accident was higher in females and the risk of persistent physical symptoms increased significantly with age.										

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	decreased significantly from 33.33±14.64 at 1month after the accident to 28.68±11.80 at 7months after the accident ($p<0.05$). The mean score of the anxiety levels increased significantly from 5.16±6.59 at 1month after the accident to 6.79±8.41 at 7months after the accident ($p<0.05$). The risk of persistent physical symptoms at 7months after the accident was significantly higher in females. The risk of persistent physical symptoms also increased significantly, with increasing age, hydrogen fluoride exposure, and impact of event levels ($p<0.05$). Conclusions: The present study found that the impact of event level and anxiety level increased with increasing hydrogen fluoride exposure. Anxiety levels persisted even after time passed. The risk of persistent physical symptoms at 7months after the accident was higher in females, and it increased with increasing age, hydrogen fluoride exposure level, and impact of event levels.											
Associations between disaster exposures, peritraumatic distress, and	The 2011 Fukushima Daiichi Nuclear Power Plant accident was the worst nuclear disaster since Chernobyl. The nearby Daini plant also experienced substantial damage but remained intact. Workers for the both plants	• Peritraumatic distress (PD) and post-traumatic stress responses (PTSR) during and immediately after an event. • Pathway mechanism for the development of PTSR.					✓				✓	

wood.

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
posttraumatic stress responses in Fukushima nuclear plant workers following the 2011 nuclear accident: The Fukushima NEWS project study	experienced multiple stressors as disaster victims and workers, as well as the criticism from the public due to their company's post-disaster management. Little is known about the psychological pathway mechanism from nuclear disaster exposures, distress during and immediately after the event (peritraumatic distress; PD), to posttraumatic stress responses (PTSR). Methods: A self-report questionnaire was administered to 1,411 plant employees (Daiichi, n = 831; Daini, n= 580) 2-3 months post-disaster (total response rate: 80.2%). The socio-demographic characteristics and disaster-related experiences were assessed as independent variables. PD and PTSR were measured by the Japanese versions of Peritraumatic Distress Inventory and the Impact of Event Scale-Revised, respectively. The analysis was conducted separately for the two groups. Bivariate regression analyses were performed to assess the relationships between independent variables, PD, and PTSR. Significant variables were subsequently entered in the multiple regression analyses to explore the pathway mechanism for development of PTSR. Results: For both groups, PTSR highly associated with PD (Daiichi: adjusted β, 0.66; p<0.001; vs. Daini:	• It was found that PTSR highly associated with PD. PTSR was associated with discrimination/slurs experience (Fukushima and the nearby Daini plant workers faced criticism from the public due to their company's post disaster management) and presence of pre-existing illnesses.										

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	adjusted β, 0.67; p<0.001). PTSR also associated with discrimination/slurs experience (Daiichi: 0.11; p<0.001; vs. Daini, 0.09; p= 0.005) and presence of pre-existing illness(es) (Daiichi: 0.07; p = 0.005; vs. Daini: 0.15; p<.0001). Other disaster-related variables were likely to be associated with PD than PTSR. Conclusion: Among the Fukushima nuclear plant workers, disaster exposures associated with PD. PTSR was highly affected by PD along with discrimination/slurs experience.											
Suicide and disasters, Suicide from a Global Perspective: Psychosocial Approaches	Disasters of all kind are unfortunately frequent occurrences in contemporary world and, as such, cause immense human suffering. The most common natural disasters are hurricanes, floods and earthquakes, supplemented by industrial, nuclear and transportation accidents. Disasters can be analysed in a physical context as a consequence of natural catastrophe or in a social context as a consequence of human behaviour (e.g., terrorism or suicide bombers) (Lopez-Ibor, 2005). Common to all disasters is the enormous capacity to affect a huge number of people at the same time. This can lead to all sorts of stress reactions that can, subsequently, have a profound impact on personal mental	• Man-made disasters are caused by human behaviour and, thus, cause more frequent and persistent psychological distress than natural disasters (Fullerton & Ursano, 2005). • posttraumatic stress responses which can lead to additional severe secondary problems such as affective disorders, substance abuse or social and relational problems. All of these conditions lead to an increased risk of suicidal behaviour.					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	health. Intense stressors such as exposure to the dead and dying, bereavement and social and community disruption frequently lead to mental health problems (Norris, et al., 2002). Man-made disasters are caused by human behaviour and, thus, cause more frequent and persistent psychological distress than natural disasters (Fullerton & Ursano, 2005). Mass violence is, unfortunately, also common in the contemporary world in spite of a growing trend toward globalisation and unification. Violence has many faces and is manifest in wars, ethnic conflicts, terrorist acts and urban aggression. The experiences of many countries and populations in the recent past have shown that wars are often justified with "higher" causes and a "wish to initiate peace." The question "why war," which Freud and Einstein (Freud, 1933) tried to answer years ago, is still an issue of the utmost importance. Wars and terrorism in many parts of the world (e.g., September 11th, terrorist acts in Madrid, London, Turkey and Thailand, wars and conflicts in Afghanistan, the Balkans, Cambodia, Chechnya, Iraq, Israel, Lebanon, Palestine, Russia, Rwanda, Sri Lanka, Somalia and Uganda) reveal that the "malady of death" and the power of destructive forces, both											

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	outside and within the individual and society, have never appeared as frequently as they do today. Disasters may cause posttraumatic stress responses which can lead to additional severe secondary problems such as affective disorders, substance abuse or social and relational problems. All of these conditions lead to an increased risk of suicidal behaviour (Mehlum, 2006)											
Environmental aftermath of the radiation accident at Tomsk-7	An analysis is presented of the environmental effects of the most serious radiation accident recorded after Chernobyl, which occurred in the formerly secret town of Tomsk-7 in Siberia, Russia, on 6, April 1993. Fortunately, it appears not to have become a major industrial crisis or disaster. The causes of the accident are described. It is argued that a mixture of both objective and subjective prerequisites, including specific human, organisational and technological factors, were responsible for the explosion or directly facilitated it. The Tomsk-7 accident's ecological medical, social, and psychological consequences are discussed.	• Ecological, social and psychological consequences.					✓			✓	✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
An industrial disaster. Disaster behaviour and posttraumatic stress reactions	The immediate responses to disaster trauma and the acute, subacute, prolonged and chronic posttraumatic stress reactions over a four year period were studied in 246 industrial employees after a factory explosion. Among the 66 workers most severely exposed during the disaster impact, 37% demonstrated optimal disaster behaviour. High levels of disaster training/experience appeared as the single most important factor in shaping their adaptive and controlled responses. The risk of developing an acute posttraumatic stress disorder was strong in the high exposure group, 43%, and the point prevalence was down to 37% after seven months and 19% after four years. In a medium exposure group and a low exposure group, the prevalence were 23%, 17% and 2%, and 10, 4 and 3% respectively. A poor long-term prognosis was associated with severe exposure to the disaster and with premorbid personality problems. The results indicate that persons at risk of becoming ill and persons with a poor prognosis can be identified within days after a disaster.	• Acute, subacute. Prolonged and the chronic posttraumatic stress reactions to disaster trauma.					✓				✓	

wood.

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Possible risk factors for acute stress disorder and post-traumatic stress disorder after an industrial exp losion	There have been deaths and injuries after an explosion which happened in an industrial region in Ankara in February 2011. The aim of this study was to determine the prevalence of acute stress disorder (ASD) and posttraumatic stress disorder (PTSD), and to determine the variables which can be the risk factors for PTSD. Methods: In this study, we included a total of 197 subjects who were present at the factory building and at the four offices nearby when the disaster occurred. All the participants were assessed one month after the explosion and 157 of them were re-assessed six months after the explosion. Socio-demographic information forms were given and the Clinician-Administered PTSD Scale (CAPS) was administered to the participants one month after the explosion. Psychiatric assessments were done using the structured clinical interview for DSM-IV axis-I disorders (SCID-I). The CAPS was re-applied six months after the disaster. results: At the first-month assessments, ASD was detected in 37.1% of participants and PTSD in 13.7%, whereas PTSD was observed in 16.6% of subjects at the sixth month of the accident. According to the first month data, having any psychiatric disorder before the incident, physical injury,	• The prevalence of acute stress disorder (ASD) and post-traumatic stress disorder (PTSD) following an industrial explosion. • The variables which can be the risk factors for PTSD. • The study found that having a previous psychiatric disorder and being directly affected by trauma and being injured are the risk factors for PTSD.					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	acquaintances among the dead and the injured people, being involved in the incident and seeing dead people were detected as the risk factors for PTSD. At the sixth-month assessment, physical injury, acquaintances among the dead and the injured, being involved in the incident were seen as risk factors for PTSD. conclusion: ASD and PTSD can be seen after an explosion. Having a previous psychiatric disorder and being directly affected by trauma and being injured are the risk factors for PTSD. This study implies that preventive mental health care services should include the management of current psychiatric condition and employee safety issues.											
Immediate psychological impact of the Deepwater horizon oil spill: Symptoms of PTSD and coping skills	Five hundred eighty-eight participants completed the Short Post Traumatic Stress Disorder Rating Interview (SPRINT; Connor & Davidson, 2001) and the Brief COPE (Carver, 1997) to determine the psychological impacts and coping styles of the Deepwater Horizon Oil Spill on Gulf Coast residents. Participants were divided into at-risk and non-risk groups based on their occupations. Results indicated that 28% of the respondents scored above the SPRINT cut off score, indicating significant	• Psychological impact and coping styles of the Deepwater Horizon Oil Spill on Gulf Coast residents. • 28% of respondents indicated significant levels of posttraumatic stress disorder (PTSD) symptoms.					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	levels of posttraumatic stress disorder (PTSD) symptoms. Furthermore, the Brief COPE results revealed that the at-risk group showed a negative correlation between active coping and the level of PTSD-related symptoms. The at-risk respondents also showed negative correlations of PTSD-related symptoms with coping strategies such as acceptance, planning, positive reframing, humour, and religion. Future research directions are also discussed											
Course of posttraumatic stress symptoms over the 5 years following an industrial disaster: A structural equation modelling study	The present study examined individual latent changes in posttraumatic stress disorder (PTSD) symptoms over a 60-month period after an industrial disaster. Participants were recruited from survivors of a factory explosion. Participants were assessed retrospectively for peritraumatic reactions and acute stress symptoms. Posttraumatic stress disorder symptoms were then assessed at 6, 15, and 60 months. Using structural equation modelling, the authors tested 3 hypotheses of individual latent change: stability of PTSD symptoms between 6, 15, and 60 months; change between 6 and 15 months; and change between 15 and 60 months. Only one model provided a good fit suggesting that PTSD	• Latent changes in posttraumatic stress disorder (PTSD) over a 60-month period after an industrial disaster. • One model provided a good fit suggesting that PTSD symptoms evolved between 6 and 15 months after trauma exposure and remained stable at the individual level thereafter.					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	symptoms evolved between 6 and 15 months after trauma exposure and remained stable at the individual level thereafter. © 2010 International Society for Traumatic Stress Studies.											
Mental health of workers in Toulouse 2 years after the industrial AZF disaster: First results of a longitudinal follow-up of 3,000 people	On September 21, 2001, the AZF petrochemical factory near Toulouse (France) exploded. A cross-sectional survey of Toulouse workers took place in 2002 and then, a cohort follow-up began in 2003. The aim of this paper is to study the associations between various factors describing exposure to the disaster, and anxiety and depressive symptoms, assessed at cohort inclusion 2 years afterwards. Methods: In 2003, 3,006 people were included in the cohort. Psychological distress was measured by the GHQ28 at inclusion. Factors related to exposure to the disaster, such as personal distance from the site, physical injury, immediate psychological symptoms, and material and social effects, came from the 2002 cross-sectional survey. The links between mental health symptoms and exposure were studied in multivariate analyses by logistic regression. Results: The prevalence of psychological distress was 47% at inclusion in the cohort. It	• Association between various factors describing exposure to the disaster and anxiety and depressive symptoms. • Psychological distress. • The study revealed links between the industrial disaster and psychological distress 2 years afterwards. The results about risk factors differ according to sex and identify particularly vulnerable populations. It should guide preventive interventions in such situation.					✓				✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	varied according to sex and occupational class: blue-collar workers and self-employed people were most highly affected. Factors such as a history of depression, injury to a close friend or family member, sick-leaves and immediate psychological symptoms were associated with psychological distress 2 years later. These associations differed according to sex. Conclusion: This study shows links between the industrial disaster and psychological distress 2 years afterwards. The results about risk factors differ according to sex and identify particularly vulnerable populations. It should guide preventive interventions in such situation.											
Assessing the real cost of disasters: The need for better evidence, 2018, Organisation for Economic Co-operation and Development	This report provides a summary of the current practices used by some OECD countries in improving the quality and quantity of information on costs of disasters. This includes collection of ex-post data on disaster damages and disaster risk management expenditure as well as and ex-ante loss estimations	• Types of costs discussed include direct costs, losses due to business disruption, indirect costs, intangible costs like environmental impacts, health impacts and impacts on cultural heritage, losses associated with the interruption of critical network, government contingent liability to finance response and recovery.	✓	✓	✓			✓	✓	✓		

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Reputation risk – A rising C-Suite imperative	A few takeaways from the study: • 12.6% is the proportion of sudden stock price drops that are related to reputation, image, pricing, and presence in the market. • 80 weeks is the average time for the company stock price to recover after a sudden price drop • Good corporate behaviour is the best safeguard against reputational challenges. Establishing a culture that is ethical and mindful of risk requires committed leadership, as well as processes and structures that allow less tangible values to flourish. • Chief Executives should set the tone from the top in building corporate resilience to reputation risk. They must also show visible leadership in a crisis and commit the company to putting things right. • A mishandled response to a crisis can generate more reputational damage, and spur greater financial consequences, than the incident itself. This is especially true when the response appears to undermine the company's core values. • Brand development work can strengthen corporate resilience to reputation risk or	BP – oil spill (2010): The blowout on the Deepwater Horizon rig saw numerous impacts beyond the operational losses from containment and cleanup. In financial terms, this amounted to a 50% fall in the share price and a failure to pay dividends for three quarters, litigation with individuals and affected US states running to more than $42 billion of payouts, and the need for $38 billion in asset sales. In strategy terms, the company signaled an exit from solar and wind, and was banned from applying for new government contracts in the US. The firm fell from being the second to the fourth-largest oil company worldwide by market value. BP – oil spill (2010): The Deepwater Horizon incident had high media visibility from the start, with a burning rig, 11 fatalities, and an oil slick in the ocean. Irrespective of different views on the exact volumes leaked, there was significant environmental and economic damage in the five US states with a Gulf of Mexico shoreline, resulting in multiple, ongoing claims for damages. The high degree of political interest at state and federal levels ensured a robust legislative and regulatory response. The incident, set against a backdrop of the Texas City refinery explosion (2005) and the Alaska oil spill (2006), highlighted BP's difficulties in balancing its efforts to standardize and strengthen operational safety with its goal of cost leadership.	✓	✓						✓	✓	

Document title	Summary of report	Summary of impacts reported	Impacts of establishment: Direct damage	Impacts of establishment: Subsequent business cost	Impacts of establishment: Image	Impacts for authorities/communities: Physical health	Impacts for authorities/communities: Psychological health	Impacts for authorities/communities: Response cost	Impacts for authorities/communities: Follow-up cost	Wide impacts: Environmental consequences	Wide impacts: Socio-economic impact	Wide impacts: Political impact
	recovery from an incident only when communication efforts are underpinned by tangible strategic, governance, and operational commitments. **Source**: https://www.oliverwyman.com/our-expertise/insights/2014/may/reputation-risk-a-rising-c-suite-imperative.html	Oil majors – contagion management (2010): In the wake of BP's Gulf of Mexico disaster, ExxonMobil, Chevron, ConocoPhillips, and Shell agreed to pool $1 billion to set up a company that could quickly address deep-water oil spills. Given the issuance of a federal moratorium on exploratory drilling, their goal was to reassure the public and Congress of their commitment to safety and hasten the resumption of deep-water drilling.										
Putting-a-price-on-reputational-damage	Intangible factors account for 81 percent of a public company's market value, and improvement or deterioration in a company's reputation has a tangible impact on performance. A strong reputation yields 2.5 times better stock performance when compared to the overall market. A reputation event can dent a major company's market capitalization by billions of dollars, and insurers can't offer anywhere near those kinds of limits. Source: https://riskandinsurance.com/putting-a-price-on-reputational-damage/	According to the Reputation Institute — which monitors and ranks the reputation of 7,000 major organizations globally — intangible factors account for 81 percent of a public company's market value, and improvement or deterioration in a company's reputation has a tangible impact on performance. "Since 2006, a strong reputation yields 2.5 times better stock performance when compared to the overall market. And a 1-point increase in reputation yields a 2.6 percent increase in market cap," the Institute said. It added, also claiming that when a reputation improves from 'average' to 'excellent' in rating, there's a 2.7-times increase in purchase intent".		✓							✓	
The hidden costs of reputational risks – An	The quantification process consists of four steps:	The results suggested that the reputational impact is around twice as large for an institution with a strong/valuable brand as for an average institution		✓							✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
approach to quantifying reputation risk losses -	1. Identify events with the potential for risk losses. 2. Estimate the stock performance in case the event had not occurred. 3. Compare the expected stock performance to the actual stock performance. 4. Determine reputation risk impact. **Source**: https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2017/jul/Reputational%20Risk.pdf	(~100–120% greater impact from having a higher-ranked or higher-valued brand). The analysis implied that the market is more willing to dismiss events from institutions, which are perceived to already have an average reputation, while events from institutions, which are perceived to have strong/valuable reputations, lead to re-evaluations of future performance. These results highlight the fact that the management of reputation risk is not a one-time effort, but a continuous exercise, even when (and potentially especially so if) the institution already relies on a strong reputation..										
Marsh largest loss in the hydrocarbon industry	Marsh's 24th edition of the 100 Largest Losses report explores the largest property losses in the hydrocarbon industry from 1974-2015 in an attempt to identify where the risks lie in the industry and what needs to be done to manage them safely. Compiled from Marsh's energy loss database, which holds almost 10,000 records of losses spanning more than 40 years, 100 Largest Losses covers the refinery, petrochemical, gas processing, terminals and distribution, and upstream sectors.	• Review of largest business interruption claims for Business interruption insurance. • Property losses.	✓	✓							✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	In addition to examining the 100 largest loss events, the report explores the following: • The impact of the price of oil on the industry. • Business interruption. • Predominant causes of severe losses. • Largest losses of the past two years.											
Corrosion-related accidents in refineries, lessons learned from accidents	This report cites particular publications produced by the American Petroleum Institute (API), the Institute of Chemical Engineers (IChemE), the Institute of Energy (IE), the United Kingdom Health and Safety Executive (UK HSE), the French National Institute of Environment and Industrial Risk (INERIS), the U.S. Department of Energy, the U.S. Department of Transportation, the U.S. Occupational Safety and Health Administration and NACE international. This study aimed to provide insight on the collective knowledgebase from another perspective, that is, using accident data related to one particular, corrosion in refineries, to help operators and inspectors to refresh their knowledge and perhaps also focus their attention on particular aspects associated with this phenomenon. Using reports from a	Review of costs reported from accidents in refineries including death, injuries, material damage, public service disruption and environmental damage	✓	✓				✓	✓	✓	✓	

Document title	Summary of report	Summary of impacts reported	Impacts of establishment: Direct damage	Impacts of establishment: Subsequent business cost	Impacts of establishment: Image	Impacts for authorities/communities: Physical health	Impacts for authorities/communities: Psychological health	Impacts for authorities/communities: Response cost	Impacts for authorities/communities: Follow-up cost	Wide impacts: Environmental consequences	Wide impacts: Socio-economic impact	Wide impacts: Political impact
	number of open sources over the last few decades, the authors aimed to identify repeated patterns in accident occurrences both in terms of specific causal factors and failures in control strategies											
Realistic disaster Scenarios-Scenario specification	The purpose of this document is to describe the loss assumptions for each of the Lloyd's Realistic Disaster Scenarios [RDS]. For each compulsory scenario (see section 1.2.1) this document contains:- • A definition of the physical event, with a map showing the footprint or storm-track; • The assumed industry insured loss for property, split by primary class of business; • Additional lines of business that managing agents are recommended to consider; • Where applicable, a catalogue of major infrastructure (i.e. ports) that may be affected by the event; • Where applicable, supplementary information that managing agents are required to provide (i.e. offshore energy). For each de minimis scenario this document contains:- • A description of the event, or type of event;	• Industry property loss (insured losses) • Transportation disruption • Treatment of pollution • Liability risks • Political risks	✓	✓				✓				✓

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	• Additional information to the loss-return which managing agents should provide; • Where applicable, examples of scenarios - or types of scenarios - which managing agents may choose; • Where applicable, assumptions about reinsurance protections.											
Insuring and Managing Hazardous Risks: Seveso to Bhopal and beyond- An executive report on an international conference at IIASA and an overview of the conference proceedings	This executive review describes in brief the International Conference on Transportation, Storage, and Disposal of Hazardous Materials, held at the International Institute for Applied Sys tems Analysis (EEASA), and the ensuing Proceedings, Insuring and Managing Hazardous Risks. The Conference brought together representatives of academia, business, and government from East and West to discuss the nature of current problems in the area of hazardous materials. An important objective of the Conference was to suggest steps that could be undertaken by industrial firms, the insurance industry, and government agencies to improve the safety and efficiency with which hazardous materials are produced and controlled in industrialized societies.	• Direct damage • Loss of use of contaminated plants • Clean up expenses • Liability risks • Environmental impairment • Compensation •	✓					✓	✓	✓	✓	

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
	This report is a synopsis and serves as an introduction to the Conference Proceedings, Insuring and Managing Hazardous Risks.											
Industrial accidents impact on environment	This paper outlines the major environmental impacts resulting from industrial accidents and provides suggestions for protection health and environment	Environmental impacts such as: • Impact on health of biota • Impact on eco-system • Impact on terrestrial system • Impact on aquatic system								✓		
Bodemsanering Chemie-Pack Moerdijk	This paper describes the events of the major fire that occurred at the chemical storage and mixing company Chemie Pack and the ensuing environmental impacts	Soil pollution								✓		
De brand bij Chemie-Pack in Moerdijk	This paper describes the events of the major fire that occurred at the chemical storage and mixing company Chemie Pack and the ensuing impacts	• Health impacts • Environmental impacts such as release of toxic substances in air and water				✓				✓		
Veel interesse bodemsanering Chemie-Pack	This article describes the soil contamination resulting from the fire at the chemical storage and mixing company Chemie Pack	Soil pollution								✓		

			Impacts of establishment			Impacts for authorities/communities				Wide impacts		
Document title	Summary of report	Summary of impacts reported	Direct damage	Subsequent business cost	Image	Physical health	Psychological health	Response cost	Follow-up cost	Environmental consequences	Socio-economic impact	Political impact
Acht gegadigden voor bodemsanering Chemie-Pack	This article describes the soil contamination resulting from the fire at the chemical storage and mixing company Chemie Pack	Soil pollution								✓		

Appendix C
Seveso Monitoring Systems – Workshop report

Appendix D
List of Acronyms and Abbreviations Used

- **API:** American Petroleum Institute
- **ANSI:** American National Standards Institute
- **ARIA**: Analysis, Research and Information of Accidents
- **CA:** Competent Authority
- **CCPS:** Centre for Chemical Process Safety
- **CEFIC:** European Chemical Industry Council
- **CLP:** Classification, Labelling and Packaging
- **DFU:** Defined hazard and accident conditions
- **EGSIA:** European Gravity scale of industrial accidents
- **eMARS:** e-Major Accident Reporting System
- **EPI:** Environmental Performance Index
- **ESI:** Environmental Sustainability Index
- **EUR-Lex:** Official website of European Union law and other public documents of the EU
- **GDP:** Gross Domestic Product
- **GIS:** Geographic Information System
- **HSE:** Health and Safety Executive, UK
- **ICCA:** International Council of Chemical Associations
- **JRC:** Joint Research Centre
- **LUP:** Land use planning.
- **MAPP:** Major accident prevention policy.
- **OECD:** Organisation for Economic Co-operation and Development
- **OGP:** Oil & Gas Producers
- **PS:** Process Safety
- **PSA:** Petroleum Safety Authority, Norway
- **PSE:** Process Safety Events
- **PSIC:** Total Count of Process Safety Incidents
- **PSISR:** Process Safety Incident Severity Rate
- **PSTIR:** Process Safety Total Incident Rate

- **QRA:** Quantitative Risk Assessment
- **RCLG:** Responsible Care Leadership Group
- **RNNP: "**Risiko i norsk petroleumsvirksomhet (NO) / Trends in risk level in the Norwegian petroleum activity" (issued by the Norwegian Petroleum Safety Authority).
- **RP:** Recommended Practice
- **SDMS:** Seveso Directive monitoring systems.
- **UIC:** Union des Industries Chimiques, France