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Learning lessons from accidents

*Key points and conclusions for inspectors of
major chemical hazard sites*

A Seveso inspection series publication

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Contents

Abstract.....	iii
Acknowledgements.....	iv
Preface.....	v
Executive Summary.....	1
1 Learning Lessons from Accidents: The Challenge of Moving from Theory to Practice.....	9
1.1 Challenges for inspectors in meeting lessons learned responsibilities	9
1.2 The Mutual Joint Visit Workshop for Seveso Inspectors on Lessons Learned from Accidents	11
1.3 Accident investigations and analysis for lessons learned	13
1.4 Conclusions	18
2 The accident investigation in a Seveso Directive framework.....	19
2.1 Learning lessons in a Seveso Directive framework	19
2.2 Effectiveness and competency in Seveso accident investigations	22
2.3 Conclusions	26
3 The role of lessons learned in chemical accident prevention.....	27
3.1 Sources of lessons learned	27
3.2 Dissemination and implementation of lessons learned	30
3.3 Conclusions	36
4 A learning cycle model.....	40
List of Boxes.....	Error! Bookmark not defined.
List of Figures.....	43
Annex 1 Useful references, including references in this report.....	46
Annex 2 Selection of sources of investigation reports and analyses of chemical accidents.....	51
Annex 3 Selection of publicly available databases of chemical accident data.....	53
Annex 4 Selection of conferences and symposium series that publish proceedings with lessons learned from chemical accidents.....	57
Annex 5 Inspection questionnaire – Accident and incident learning cycle.....	59
Annex 6 Participant survey questions.....	62

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Abstract

It is undisputed that learning from accidents is an essential and important part of major accident control. It is in particular an essential component in preventing future accidents, as new, hidden or underestimated potential causes are revealed, not only for those with first-hand experience. Provided that lessons learned are disseminated properly, all concerned should in theory be able to avoid similar accidents. Representatives from European Seveso inspectorates gathered in Gothenburg, Sweden, for three days in September 2013 to gain knowledge about learning from incidents, to exchange experience from inspecting the learning cycle at Seveso sites, and to learn more about finding, analysing and disseminating lessons learned. This publication presents the highlights of the exchanges during this workshop with the expectation that they will provide knowledge to support prevention and preparation for chemical accident events for competent authorities as well as the broader stakeholder community.

Acknowledgements

The European Commission is particularly grateful to the Swedish Civil Contingencies Agency (MSB - Myndigheten för samhällsskydd och beredskap) for organising this workshop on learning lessons from accidents for inspectors of EU competent authorities charged with enforcing and monitoring implementing the EU Seveso Directive. The Commission also appreciates the insights provided by all the speakers that formed important input to this document. Much appreciation also goes to all the participants whose survey responses and contributions to break-out discussions and plenary discussions gave insights into practices and challenges surrounding accident analysis from a competent authority perspective as well as opportunities and ideas for making improvements.

The European Commission is also grateful for the substantial contribution of the co-authors, Blenda Weibull, an independent consultant, and Carina Fredstrom of the Swedish Civil Contingencies Agency.

Preface

The inspection function has always been considered one of the most powerful and dynamic tools available to Member State authorities for enforcement of the Seveso Directive. For this reason, the European Commission along with competent authorities responsible for Seveso Directive implementation has long held this area as a priority for EU level technical co-operation. There is a strongly shared commitment to continuing to work together to increase the effectiveness of inspection practices and to ensure a consistent approach with respect to interpreting Seveso requirements through inspections across the Member States.

This publication, “Learning from accidents”, is one of a series of publications that form part of the Seveso Inspections Publication Series. The publication series is one of a number of initiatives currently in place or in development to support implementation of the Directive and sponsored at EU level. In particular, a prime source of content for publications in this series is the Mutual Joint Visit (MJV) Programme for Seveso Inspections. The aim of the programme is to encourage the sharing and adoption of best practices for inspections through a system of regular information exchange. The visits would be hosted by different Member States (hence, visits would be “mutual”) and targeted for working inspectors of other Member States (and thereby “joint” visits) charged with assessing compliance with the Seveso Directive in industrial installations. The MJV Programme is managed by the Major Accident Hazards Bureau in consultation with the TWG on Seveso Inspections.

The Seveso Inspections Series is intended to be a set of publications reflecting conclusions and key points from technical exchanges, research and analyses on topics relevant to the effective implementation of the inspection requirements of the Seveso Directive. These publications are intended to facilitate the sharing of information about Member States’ experiences and practices for the purpose of fostering greater effectiveness, consistency and transparency in the implementation of inspection requirements of the Directive. The series is managed by the European Commission’s Technical Working Group on Seveso Inspections (TWG 2), consisting of inspectors representing Seveso inspection programmes throughout the European Union. The Technical Working Group is co-ordinated by the Major Accident Hazards Bureau of the European Commission’s Joint Research Centre with the support of DG Environment.

All TWG 2 publications for Seveso inspectors can be found at <https://minerva.jrc.ec.europa.eu>.

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Executive Summary

Representatives from European Seveso inspectorates gathered in Gothenburg, Sweden, for three days in September 2013 to gain knowledge about learning from incidents, to exchange experience from inspecting the learning cycle at Seveso sites, and to learn more about finding, analysing and disseminating lessons learned. There were 50 participants representing 24 different countries, of which 21 were members of the European Union. The workshop consisted of a mixture of presentations, work in groups and plenary discussions. A questionnaire was distributed in beforehand to all participants. 28 answers were returned, representing 23 different countries.

The Seveso III Directive (2012/18/EU) that came into force on 1 June 2015 places more emphasis on the lessons learning aspect by including a new requirement, where operators are more specifically obliged to review past accidents and incidents with the same substances and processes used, consider lessons learned from these, explain specific measures taken to prevent such accidents and finally compile this information in their safety report. Learning from past incidents has thus become a crucial part of the implementation of the Seveso III Directive.

Challenges for Seveso inspectors

The Seveso inspector is often required to play three distinct roles associated with lessons learned:

- reviewing lessons learned to support oversight obligations, in particular, so that the inspector maintains and improves his/her ability to recognise situations that do not conform to good management practice
- analysing and generating lessons learned as part of an accident investigation team, or to critically review the accident report produced by the company
- disseminating lessons learned, by summarising investigation results for reporting to the national authority and the European Commission, and also communicating them to national stakeholder

Sometimes inspectorates, or individual inspectors, face a challenge stemming from a mismatch between level of responsibility and level of competence.

Common challenges in this regard include:

- An inspectorate has inadequate experience or competence to analyse the company's accident report to determine that it is reasonably complete and accurate
- An inspectorate has inadequate experience to play a leading role in an investigation team (where it is a direct participant)
- An inspectorate has to investigate an accident of unusual complexity or with unusual or unfamiliar processes or substances
- An inspector is assigned a leading role in an investigation with insufficient training in accident investigation
- Inspectors are randomly assigned responsibility to report an accident to the European Commission with insufficient training in causal and lessons learned analysis

The Mutual Joint Visit Workshop on learning lessons from accidents

Given the potential importance of the inspector's role in analysis and dissemination of lessons learned within the Seveso Directive, the Swedish competent authorities proposed to host a workshop on the topic in the framework of the Mutual Joint Visit (MJV) Programme for Seveso Inspections. The main objectives of the workshop were as follows:

- To improve understanding of inspectors of different investigation methods and the advantages of systematic accident investigations.
- To strengthen the inspector's ability to improve the quality of accident investigation reports

- To acquire knowledge about learning mechanisms in organisations for application in government enforcement and monitoring at major hazard sites
- To review available accident databases to explore how they might be used as both part of inspection preparation and in promoting lessons learned among operators

The workshop put accident investigations in the context of the learning cycle, where learning from accidents is one of several paths to organisational learning. Several presentations on different aspects of lessons learned and inspection of the learning cycle were presented from the perspective of both competent authorities and industry operators. Good practices concerning the learning cycle and its elements were discussed in detail as well as methods for conducting accident investigations. The importance of choosing corrective actions that can be embedded in the organisational memory was highlighted, as well as the importance of having a clear strategy for disseminating the results to different stakeholders.

Learning from accidents is a process

The Rasmussen/Svedung hierarchical model [21] describes the learning process on all levels from the individual to the society at large, where each level is tied to adjacent levels through nested loops of steering signals and feedback signals. Steering signals in the form of laws, policies, plans and resources are descending through the hierarchical levels, while feedback signals in the form of experiences from accidents, inspections and risk analysis are ascending.

The learning of lessons involves several steps starting with the investigation and the summarisation of lessons learned. If these first steps are achieved, the next phase consists of spreading the information by making the information available through databases, lessons learned exchanges, safety meetings, case study reports, and other similar mechanisms. Application so that the lessons learned become a living part of the organisation is the final phase. Both authorities and operators have a role in facilitating application. For example, inspectors can use lessons learned in the conduct of inspections while operators can make lessons learned operational in the daily practices of the organisation.

Lessons learning in a Seveso Directive framework

Since its inception, the Seveso Directive has always emphasised the importance of follow-up to major chemical accidents and near misses to acquire lessons learned that can be used to prevent major accidents. Over the years the responsibility of competent authorities for accident follow-up has progressively increased with each version of the Directive.

- The Seveso I Directive required the competent authorities "to collect, where possible, the information necessary for a full analysis of the major accident and possibly to make recommendations".
- The Seveso II Directive (96/82/EC) was more specific such that competent authorities should "collect, by inspection, investigation or other appropriate means the information necessary, etc." It also was required for the competent authority to "make recommendations on future preventive measures".
- The Seveso III Directive explicitly requires an inspection following a major accident or near miss. "Non-routine inspections shall be carried out to investigate serious complaints, serious accidents and 'near misses', incidents and occurrences of non-compliance as soon as possible".

Investigation and analysis models

The investigation of an accident is normally planned with the view to identifying both the technical causes of the accident and the underlying causes. In the case of a technical accident, the technical cause is usually the failure that directly caused the release. The underlying causes can be a variety of upstream failures that make it more likely that the release will occur. They also can include failures that condition the likelihood of failure of measures intended to mitigate the impacts of the release.

Theories on understanding what causes an industrial accident have continued to evolve from ongoing research on this topic. Recent work has uncovered potentiality causality associated with human and

organisational factors. They suggest that accident causality can often be complex and arise from systemic failures. A number of different analytical methods have been developed to examine these influences.

There has also been considerable focus on uncovering causality by diagnosing failures in terms of the difference between the expected outcome and the actual outcome (barrier analysis, deviation analysis). These methods, sometimes called *epidemiological models*, aim to identify the pathology of the accident, i.e., at what point there were opportunities to stop the sequence leading towards an accident or modify it to reduce the impact. The findings from these types of barrier and deviation analyses often are the basis of a further systemic analysis of the same incident.

The investigation

The investigation is the starting point for collecting data to enable learning lessons from an incident. The incident investigation process is sometimes divided into five steps:

- Planning
- Data collection
- Accident analysis
- Development of improvement actions
- Conclusions and reporting

The purpose of the investigation shapes all the steps in the investigation process. It is essential to define the purpose when starting the planning phase. The primary purpose of an incident investigation is to answer questions like *what, where, when* and *why* and to identify measures to prevent future incidents.

Data collection for lessons learned investigations consists of a range of activities to gain knowledge about the course of events and the conditions under which they occurred. It is very important to start this activity as early as possible, as some data may disappear very quickly and it is often not possible to reconstruct or regain afterwards. The extent of the data that are needed to understand the sequence of events is often underestimated and the importance of data collection to obtaining meaningful lessons learned can be greatly undervalued.

The results of any investigation are only as good as the investigation process. Quality is most assured when the investigation objectives are systematically followed in an unbroken chain from purpose through data collection, analysis, conclusions and recommendations. Criteria to establish a certain *confidence* level in the trustworthiness of conclusions are determined by the degree to which the following are respected:

- The purpose of the investigation is reflected in the composition and competence of the investigation team
- Objectivity in the data collection
- Logical framework of analysis and its representation
- Adequate use of appropriate methodologies
- Recommended actions are related to the accident causes
- The report is tailored to the audience with a clear and logical structure
- There is an appropriate strategy for dissemination of results

Models for accident investigation and analysis

In the analysis phase questions are asked about the data collected. Systematic accident methodologies help to ask the right questions. There are several accident models available for analysing accidents. In general, they are all simplified representations of accidents but each model emphasises different aspects of the event and its causes and contributing factors. Accident models are often divided into three categories:

- Sequential models (Example: Domino Model [7], STEP [8])
- Epidemiological models (Example: Swiss Cheese Model [22], Tripod Beta [5], Deviation Analysis)
- Systemic models (Example: Accimap [21], STAMP [13], MTO [26])

There are at least 100 different methods for accident analysis that have been published, of which around 30 are actively used. Systematic analysis can provide a strong basis for seeking data, quality control and communication of the results. The purpose, characteristics of the accident and resources available should guide the choice of method. Notably, it is not always the case that investigations will use systematic investigative techniques, even in high profile investigations where lessons learned are a primary focus. Still, these investigations produce considerable data allowing other experts to apply systematic analyses if the data are made publicly available.

A Swedish research project conducted by Strömgren of the Swedish Civil Contingencies Agency [27] aimed to evaluate nine accident investigation methodologies covered in a university course at Karlstad University in Sweden. The project concluded that none of the compared methods provided full support for all phases. Most methods concentrated on the analysis phase, and only three of them gave good support for the data collection phase. The evaluation step is often overlooked. One recommendation is therefore to combine methods so that all steps in the investigation are well-supported.

Who conducts the investigation

In the majority of cases, the company investigation is the only investigation that takes place. The operator is almost always supposed to carry out an investigation on its own or in co-operation with the authorities, even if the authorities carry out one themselves. In most cases inspection authorities do not make recommendations or place a demand on the operator on what investigation methods to use. However, in a survey of participants conducted prior to the workshop¹, it was revealed that investigating entities vary considerably across the EU. Depending on the country and the circumstances, entities with investigating roles may be operators (69%) and other government agency or agencies (52%), such as the fire brigade, the public health office and/or a national safety investigation body.

Inspectors can play an important role in the outcome of the investigation even when they are not directly investigating the incident. Ways in which the Seveso inspector can add value to the investigation can include:

- overseeing the quality of the investigation by providing guidance on the investigation process to the investigation team, especially to small operators
- evaluating the quality of the investigation report
- engaging in dialogue with the operator to reach agreement on what corrective measures should be taken to restore safe operation and avoid a similar accident in future
- coordinating and communicating between different stakeholders and authorities involved in the investigation

The accident investigation report

The quality of an accident investigation report influences learning from accidents. In particular, some important things to look for in an accident investigation report are:

- The quality of the investigation team and its diversity of skills are aligned with the needs and purpose of the investigation
- The purpose of the investigation is well-defined

¹ The survey form distributed to the participants prior to the workshop is contained in **Annex 6**.

- All areas of investigation are identified and be included in the investigation strategy
- The investigation is of sufficient depth that potential underlying causes associated with organisational and management system failures are examined and discussed
- Recommendations are clearly linked to all causes identified in the investigation
- Recommendations include lessons learned in the safety management system and other parts of the organisational memory
- There is no strong evidence of bias, such as blaming individuals for the accident or the reports arguments consistently reflect the perspective of one stakeholder

A credible and thorough accident investigation includes proper planning and an investigation team with adequate skills, authority, objectivity and, most importantly, independence. The output from the investigation should be divided in two parts, one about causes, and one about lessons learned.

Outlining the structure of the final investigation report can also help to determine the type of data and evidence that should be collected during the investigation. This process can assist brainstorming on people that should be interviewed in the investigation, background research needs, and the types of data and evidence that would be useful to the investigation. Typical headings in an investigation report would be:

- Purpose and scope
- Information on the site, including ownership and management, site character, (e.g., age, size, historical uses), current business activities, accident history, dangerous substances present, etc.
- Accident description, that is, the sequence of events up to and including emergency response
- Human, environmental, economic, and social consequences of the accident
- Description of site operations relevant to the accident, including manufacturing, storage or handling processes at the source of the accident, as well as other operational functions (e.g., maintenance, control room) that may be relevant
- Accident analysis methodologies used
- Identification of direct causes and underlying causes, supported by an analysis of the time line and presentation of evidence
- Violations of regulations and/or standards relevant to the accident
- Recommendations and how their implementation could prevent a re-occurrence.

Inspector actions in case of an accident

The inspector should go to the site as soon as the emergency phase has ended and the site is safe to visit. Inspectors should be trained for accident follow-up if given this assignment, and if not, he or she should be accompanied by a colleague with this training. In most countries inspectors are there to learn, which should be clarified in advance training. An inspector charged with performing an investigation should have specific training on this topic in advance, to maximise chances of obtaining accurate and complete information.

Although inspector's roles may vary depending on the authority and accident circumstances, it is relatively common that inspectors will have some involvement in the accident in its immediate aftermath. Some typical immediate actions on-site could be, depending on the role:

- Demanding an investigation and a preliminary report
- Gathering basic information in order to understand what has happened and be able to inform the public and other authorities
- Giving advice on limiting the consequences of the accident
- Initiating or supporting a criminal investigation and securing evidence

There are many ways a Seveso inspector can influence the investigation and its findings. The actions taken by the inspector will be different depending on the role(s) that the Seveso inspector is undertaking. At minimum, before going to the site of an accident, the inspector should be well prepared as follows:

- Have a well-defined role in the accident follow-up, that may include a description of what is expected that the inspector will do as well as limitations of jurisdictions and tasks
- Have sufficient training in performing the role to which the inspector is assigned including any protocols established under the law and by the authority.
- Consider what chemicals, processes and equipment were likely to have been involved, based on information available on the incident as well as in available documentation, e.g., the safety report (if available) and past inspection reports.
- Review any information reported by the media, in preparation for the site visit but also to support preparation of communications to the public.
- Contact other authorities' involved, especially local authorities to notify them of the inspectorate's involvement and to facilitate collaboration and exchange of information that may be useful.
- Prepare an agenda for the site visit, including meeting with key persons at the site and with other authorities.
- Bring personal safety equipment and investigation and inspection checklists that could be relevant

The decision to intervene or not to intervene in the investigation has certain implications for the government. On the one hand, if the inspection authority intervenes at any level, it must assume some responsibility for the outcome of the investigation. Intervention also requires the inspectorate to have adequate expertise and confidence to make a judgement in this regard. On the other hand, by not intervening, the inspector has few alternatives for improving a flawed or incomplete investigation results after the investigation is completed.

Dissemination of lessons learned

Having knowledge about which accidents have occurred and the measures taken as a consequence are fundamental to the assessment of the safety report. Emergency planning is carried out on the basis of scenarios. Therefore, awareness of which accidents have already occurred in similar establishments may give an indication of which scenarios are relevant for the development of both the on-site and the off-site emergency plans.

There are a number of sources of information on lessons learned from chemical accidents that operators and authorities can consult to identify potential improvements and troubleshoot risks associated with specific substances, processes and equipment. The main sources can be grouped generally as investigation reports and analyses that are directly made available online and databases of reports and information on chemical accidents. Several sources are listed in **Annexes 2, 3 and 4**.

Government and industry have developed structures and mechanisms to promote lessons learned, especially organisational learning, such that incidents continue to be actively applied and referenced in the organisation. It is in fact quite challenging to embed lessons learned in the memory of any organisation.

Disseminating lessons learned in industry

Implementing a commitment to disseminating lessons learned requires a multidimensional strategy. In the first instance, a company has to create an atmosphere where active lessons learning is clearly encouraged. Secondly, the company also has to continually work on reducing barriers to reporting and using lessons learned. Finally, it has to take every opportunity to reinforce the value of lessons learned and convince employees and contractors that they are relevant to their work. Some techniques that can create conditions for active lessons learning include:

- Presence of an open “no-blame culture”. The leadership can have a tremendous influence on whether a site has a learning culture, by actively promoting neutral exchanges on failures and potential failure scenarios. Such a trust environment is often recognisable from certain attributes, such as ample communication about past failures, co-operation on all levels to prevent failure, and extensive exchange of competence and experiences across the organisation about risks and risk management associated with known hazards.
- Promoting reporting and exchange by the company. Allocation of adequate resources and time for maintaining high safety awareness is also important. For example, companies can promote reporting through simplification of the process, and routinely giving training on the importance of prompt investigation of incidents and implementation of improvements. Regular discussion and distribution of information, such as safety alerts, lessons learned and key performance indicators, are another way of promoting reporting and exchange of information.
- Making good quality narratives available. Lessons learned is often about telling stories in a way that both the lessons are memorable and can be easily generalised for application in other contexts. Making good quality narratives available from investigation reports and in databases online may help spread *a selection* of good stories and important lessons learned.
- Making databases more readable and searchable. The use of an efficient search engine and keywords can help promote use of the database. An additional technique is to present the accidents in a list or as a result of a search as short summaries, so that the user can filter the selected accidents quickly, and only click on links to the full report of those that fit the user's criteria. Where there are language differences in the work place, a translation function may be necessary, for example, in multinational corporations or on sites where many line workers are not native speakers of the national language.
- Reinforcing the relevance of lessons learned through action. There is nothing more powerful than demonstrating the importance of lessons learned by applying them when they are relevant. Companies have several opportunities to incorporate lessons learned into routine activities, through process hazard and job analyses, in audit and control functions, review of processes and procedures, change management, discussion in safety meetings, and various other functions.
- Promoting reporting and exchange by the authority. Authorities may review, as part of inspections, the site's previous incidents over a period of time and check if all notifiable incidents, including incidents that are interesting for lessons learned, have been reported. This practice allows for a good discussion with the operator about the selection criteria and how to decide when to report border-line cases. Authorities may also advise operators to have an automatic prompt in their investigation procedure when external reporting requirements might be relevant. In general the authority should also seek to refrain from using punishment to stimulate reporting, except in extreme cases.

Dissemination of lessons learned in inspection authorities

The interaction with operators at different points of the learning cycle, in order to get lessons learned transferred into implementation among operators, was seen as a key challenge for inspectors. Many opportunities exist for spreading information from lessons learned. The most important thing is to make conclusions and lessons learned from incidents publicly available. The following are some mechanisms that can facilitate lessons learned dissemination:

- Bulletins and reports of accident case studies
- Presentation at conferences
- Inspection campaigns based on a lessons learned
- Leaflets on specific lessons learned topic
- Joint workshops between different authorities with a role in Seveso implementation
- Industry specific workshops on accident cases

- Workshops between inspectorates in different countries
- Videos and interactive tools describing the accident event and what went wrong
- Teaching packages based on lessons learned themes from specific accidents
- Professional development and training courses on specific process safety topics

Matching lessons learned sources to hazards and risk management problems associated with specific sites is also a significant challenge. Most often one needs to generalise lessons learned or transfer them into a slightly different context. This requires time, experience and knowledge. Various ways to overcome this challenge in Seveso inspectorates may include:

- Planning resources in the inspectorate and making available or assigning certain staff to be specialists on topics, e.g., corrosion, reactive hazards, etc., with up-to-date knowledge on the lessons learned available for that topic.
- Assigning lessons learned as a specialist task of one inspector or group of inspectors in the inspector.
- Basing inspection themes on a specific lessons learned topic and building awareness of lessons learned on this topic among operators.
- Checking scenarios in safety reports against past accidents both at the operator and elsewhere.
- Share inspection themes (campaigns) as well as tools with other inspectorates within the country as well as at international level, for example, through EU or OECD networks.
- Use lessons learned by one operator when inspecting others
- Include a lessons learned a discussion item in routine internal meetings.

Inspection of industry to promote a learning organisation

The Seveso Directive explicitly promotes the use of lessons learned. Through its various requirements, e.g., the safety report, the safety management system, accident investigation and reporting, the Directive gives opportunities for the authorities to intervene with operators regarding investigation, reporting, consultation and application of lessons learned. For this purpose, participants shared several suggestions on how the information can be applied in inspection:

- Ask operators how they broadcast and apply their own lessons learned. Inspections can include checking dissemination within a company, for example, by interviewing maintenance personnel.
- Verify with multinationals that they are drawing experience from incidents from other branches or from sites in the company.
- Check, as part of inspections, implementation of measures and how well lessons learned are embedded in the organisational memory. Check that safety report updates are part of measures where relevant.
- Check that relevant incidents occurred at the operator or elsewhere are covered by the scenarios and risks presented in the safety report.
- Identify a lessons learned them relevant to safety management, e.g., management of change. Check that lessons learned on this topic are reflected in the safety management systems during an SMS inspection.
- Review whether the operator has consulted its industry sources for lessons learned relevant to site operations and substances used.

1 Learning Lessons from Accidents: The Challenge of Moving from Theory to Practice

It is undisputed that learning from accidents is an essential and important part of major accident control. It is in particular an essential component in preventing future accidents, as new, hidden or underestimated potential causes are revealed, not only for those with first-hand experience. Provided that lessons learned are disseminated properly, all concerned should in theory be able to avoid similar accidents.

The Seveso III Directive (2012/18/EU) that came into force on 1 June 2015, places more emphasis on this aspect by including a new requirement, where operators are more specifically obliged to review past accidents and incidents with the same substances and processes used, consider lessons learned from these, explain specific measures taken to prevent such accidents and finally compile this information in their safety report. Learning from past incidents has thus become a crucial part of the implementation of the Seveso III Directive.

The continued emphasis in the Directive in lessons learned for upwards of thirty years now is a reflection of the firm and long-standing belief in the underpinning philosophy, that accident lessons learned must be disseminated to prevent accidents, by the vast majority of government and industry stakeholders. Nonetheless, in practice, there is much less clarity in terms of who should be learning and how the learning activity may be effectively embedded into a structure to ensure that it becomes a sustainable activity. To illustrate, hazardous establishments are operated by companies with a wide range of size and organisational complexity. Many of these organisations do not belong to the traditional chemical manufacturing or petroleum refining industries which have a long history of not only experiencing major accidents but also developing technical and organisational systems to manage their risks. Establishments that use or handle chemicals within, but not as the main focus of, their business operations may not be fully aware of the major accident potential, and are likely to face barriers to developing organisational learning around learning from accidents.

Public authorities are a second set of organisations that are closely involved in the prevention of major accidents. The way in which authorities assess permitting applications, land-use planning issues as well as the execution of inspections, and carrying out and following up on accident investigations has a significant impact on the major accident risk landscape. Whilst inspectors are not as a rule responsible for the initiating events of a major accident, they can play a significant role in ensuring that effective risk management activities are carried out and also in communicating the lessons learned from accident investigations to a wider clientele.

Small enterprises face a greater challenge as their opportunities for learning from their own experience is severely limited. Authorities and industry organisations need to support them. The learning culture is often more effective on the technical side than on the managerial side for several reasons. This underlines the need for awareness training on higher levels in organisations. The OECD guidance “Corporate Governance for Process Safety” is one tool intended to facilitate such awareness.

Moreover, authorities need to learn systematically from accidents just as operators do. Sometimes legislation may need to change, sometimes enforcement of existing regulations, improved guidance or more systematic outreach may be relevant actions after a major accident. The learning activity needs to be embedded into a management structure to foster the development of organisational learning.

1.1 Challenges for inspectors in meeting lessons learned responsibilities

In relation to the vast majority of risk management topics, the role of the inspector falls strictly in the camp of oversight and enforcement role. Typical tasks of inspectors consist of review, verification and assessment tasks, e.g., reviewing the safety report, assessing the safety management system, verifying that what is documented about safety management is reflected in practice on site, checking functionality of various technical measures, and so on. However, the inspector has a direct role, as opposed to oversight role, in at least one risk management function, learning lessons from accidents. The Seveso Directive imposes an obligation on Member States to collect information, by whatever means necessary, from a major accident occurring in their jurisdiction in order to conduct “a full analysis of the technical, organisational and managerial aspects of the accident.” In addition, the Member State is obliged to report

the accident to the European Commission's eMARS database. In most countries, these responsibilities are assigned all or in part to the inspection authorities.

Therefore, the Seveso inspector is often required to play three distinct roles associated with lessons learned:

- reviewing lessons learned to support oversight obligations, in particular, so that the inspector maintains and improves his/her ability to recognise situations that do not conform to good management practice
- analysing and generating lessons learned as part of an accident investigation team, or to critically review the accident report produced by the company
- disseminating lessons learned, by summarising investigation results for reporting to the national authority and the European Commission, and also communicating them to national stakeholders.

In essence, lesson learned are at minimum an integral part of professional development of every inspector in order to perform their job better. Yet very often inspectors are also expected to be more than just the audience for lessons learned but they are also required to be the analysts that produce them.

The challenge of routinely reviewing lessons learned for new insights

Often the review of lessons learned is an activity well-supported by inspection authorities. Some inspectorates will use lessons learned from accidents as a focus of monthly meetings. There are also organisations, such as IMPEL and the European Commission, that create opportunities specifically for exchange of lessons learned at annual or biannual (in the case of IMPEL) workshops and meetings. Nonetheless, while these events build awareness of the need for routine exposure to lessons learned, many inspectors have very little time that they can allocate to this activity. Hence, the challenge is not in convincing the inspector that lessons learned are important but in finding ways to obtain and communicate this information efficiently, so that its relevant is obvious and the lessons are easy to absorb and apply.

The challenge of analysing and disseminating lessons learned

The Seveso inspectorates vary considerably in terms of the depth of responsibility assigned to individual inspectors for analysis of lessons learned from major accidents. Equally, the level of competence of individual authorities, and available within each inspectorate, is also highly variable. In most inspectorates, collection of information to analyse accidents is required but investigation is not. Moreover, there is a wide variation among inspectors and inspectors in terms of training and experience in both analysis and investigation.

Therefore, sometimes inspectorates, or individual inspectors, face a challenge stemming from a mismatch between level of responsibility and level of competence.

Common challenges in this regard include:

- An inspectorate has inadequate experience or competence to analyse the company's accident report to determine that it is reasonably complete and accurate
- An inspectorate has inadequate experience to play a leading role in an investigation team (where it is a direct participant)
- An inspectorate has to investigate an accident of unusual complexity or with unusual or unfamiliar processes or substances
- An inspector is assigned a leading role in an investigation with insufficient training in accident investigation
- Inspectors are randomly assigned responsibility to report an accident to the European Commission with insufficient training in causal and lessons learned analysis

By and large, most countries find the necessary competence for analysis and investigation when particularly notable accidents occur. Some countries have separate investigation agencies, and others will ensure that there is adequate funding to find experts who can breach the gaps in competence. However, for major accidents that have lower visibility, the inspectorates have solutions where there is a mismatch between competence and responsibility. Indeed, a review of the eMARS database conducted in 2010 revealed that approximately 15% of over 700 accidents reported gave no lessons learned and that many other reports gave corrective measures (e.g., the pipe was fixed, a new part was installed) instead of lessons learned.

1.2 The Mutual Joint Visit Workshop for Seveso Inspectors on Lessons Learned from Accidents

Since 1999 the Mutual Joint programme of workshops for Seveso inspections has served as a vehicle for the promoting of technical exchange among Member State Seveso inspectors on relevant topics for implementation and enforcement of the Seveso Directive. The programme is managed by the Major Accident Hazard Bureau (MAHB) of the European Commission's Joint Research Centre with the support of DG Environment and the oversight of the EU Technical Working Group for Seveso Inspections (TWG 2).² The programme offers Seveso countries the opportunity to develop together a more sophisticated understanding of what constitutes Seveso compliance and acceptable safety in an inspection context. Moreover, it is rooted in the belief that countries can learn from each other, and by doing so, increase their technical proficiency and the effectiveness of their respective inspection programmes.

Given the potential importance of the inspector's role in analysis and dissemination of lessons learned within the Seveso Directive, the Swedish competent authorities, led by the Swedish Civil Contingencies Agency in Karlstad (MSB), proposed to host a workshop on the topic of lessons learned in the framework of the MJV Programme for Seveso Inspections. The workshop took place on 11th to 13th of September 2013 in Gothenburg, Sweden. A survey was also conducted among workshop participants prior to the event.

MSB worked together with a group of representatives from other competent authorities in Sweden to form and plan the meeting. The group consisted of representatives from the County Administrative Board of Västra Götaland, the Swedish Work Environment Authority and the Swedish Environmental Protection Agency. It consisted of 50 participants representing 24 different countries, including 21 Member States and 1 European Economic Area (EEA) Country.

The main objectives of the workshop were as follows:

- To improve understanding of inspectors of different investigation methods and the advantages of systematic accident investigations.
- To strengthen the inspector's ability to improve the quality of accident investigation reports.
- To acquire knowledge about learning mechanisms in organisations for application in government enforcement and monitoring at major hazard sites
- To review available accident databases to explore how they might be used as both part of inspection preparation and in promoting lessons learned among operators.

The workshop consisted of a mixture of several presentations, two break-out discussion groups and plenary discussion. (For break-out session topics, see **Text Boxes 1** and **2**.) The break-out sessions consisted of five groups of 6-8 participants and were assigned specific questions to discuss. After each break-out session, each group presented its results to the other participants.

² The TWG 2 consists of representatives of inspection authorities of Seveso implementing countries (EU Member States, Candidate Countries and EEA countries). The group meets once a year to discuss and develop initiatives to address common high priority topics for Seveso inspectorates in Europe.

Break-out session 1: Accident investigation

Group 1: What are the responsibilities and roles for the authorities before, during and after the investigation? What are the disadvantages and risks of not conducting a proper investigation?

Group 2: What is the role of the authorities? Do we have enough knowledge about accident investigation methodologies? How can we make sure a proper accident investigation is conducted?

Group 3: What questions should be on a checklist for accident investigation? What are the key elements to be investigated? How should an accident investigation board look and what difficulties might it encounter?

Group 4: Should we influence the selection of methods for investigation (e.g., by the operator)? Why? Why not? Who has the main responsibility for the accident investigation now, the operator or the authority, and who should have it to ensure the best results? Why?

Group 5: In what way could authorities be more active in modifying regulations and launching new recommendations based on the outcomes of accident investigations?

Text Box 1 Break-out session 1

Break-out session 2: Learning and using lessons from accidents

Group 1: How can inspectorates/inspectors use experiences from accidents in Seveso inspections? How can we put the results into a broader perspective and integrate the result in the context of the safety management system of the operator?

Group 2: What are the prerequisites to be a learning organisation? Do you have any systematic approach of inspecting the learning system part of the operator safety management system?

Group 3: Which are the most important actions for the inspectorate to perform immediately following the occurrence of a major accident? How can we prepare for this? How shall we monitor compliance with the new requirement in the Seveso III Directive, Annex II, 4c that states that performance monitoring within the safety management system should include a “review of past accidents and incidents with the same substances and processes used, consideration of lessons learned from these, and explicit reference to specific measures taken to prevent such accidents”.

Group 4: How can inspectors act to improve the learning process in a broader perspective both for the specific establishment but also for other establishments? How can learning be fostered across inspectorates, across sites, and across industries?

Group 5: How is learning from accidents influencing risk assessments and scenario selection in, e. g., the internal and external emergency plans, in revisions of risk assessments and safety reports, including the updating of old scenarios or new scenarios that can emerge from learning from accidents? Have operators described the accident investigation methodologies used in their safety reports? Should inspectors assess whether the methods are appropriate?

Text Box 2 Break-out session 2

The break-out sessions featured the topics indicated in the text boxes on this and the next page. The results contributed to several of the observations in this document regarding existing good practice or ideas for the future. (**See Text Boxes 1 and 2.**)

In addition, as preparation for the workshop, the organisers asked each participant to complete a survey on different practices related to learning from incidents in Europe (See **Annex 6**). The participant survey provided considerable information on practices and experiences in EU/EEA country in regard to investigation and analysis of major accidents, as defined in Annex VI of the Seveso Directive. There were 28 responses to

The workshop took place following the authorisation of the Seveso III Directive but prior to its effective date of 1 June 2015. The practices described in this document, therefore, reflect accident follow-up requirements of Seveso II. In large part, the workshop was designed to help competent authorities understand the implications of the revisions to obligations associated with chemical accident investigation.

the survey representing 23 EU/EEA countries³. 64% (18) of the respondents indicated that they were inspectors. It is possible that the involvement of a Seveso competent authority in accident investigation may have altered since this workshop took place due to modifications of competent authority obligations following a major accident or near miss in Seveso III.

This publication presents the highlights of the exchanges during this workshop with the expectation that they will provide knowledge to improve emergency planning practices to competent authorities in all Seveso countries as well as the broader stakeholder community.

1.3 Accident investigations and analysis for lessons learned

There has been considerable research conducted and from these findings, analytical models have been elaborated to guide accident investigation and for generally extracting information from accident reports about causality and lessons learned. Reliability models, such as Fault Tree and Event Tree analyses, Failure and Effects Mode analysis, largely drove the first set of analytical models that were adapted and refined in particular for predicting and analysing nuclear and chemical incidents by industry. The bow tie model and Layers of Protection Analysis (LOPA) evolved out of the earlier analyses and arguably have become two of the most popular analytical tools because of their ability to diagnose and explain technical strengths and weaknesses of a risk management strategy to many different audiences. These models, that largely focus on barrier failure, play a strong role in predictive risk assessment as well as post-incident analysis.

In the last few decades, it has also become important to understand the significant and diverse contribution of the systems (technical, human and organisational) in making conditions more or less favourable to occurrence of a major accident. Hence, a number of models have been elaborated to diagnose and extract lessons learned how the operations and infrastructure, organisations and human beings interact to elevate or reduce risk on a major hazard site. In modern times, accident investigation and post-accident analysis of major incidents will usually require adoption of systems analysis methods for deriving lessons learned that cover the range of possible causal factors, often in combination with a barrier failure model that provides the logic behind the sequence of events for building a broader case of causality.

This section highlights how the theory behind various types of analyses was derived and how some of them function in practice. It does not cover all theories, but gives an overview and examples from various models to highlight some commonalities and differences between approaches.

1.3.1 Learning from accidents is a process

Research shows that accident rates in many cases are falling with experience over a prolonged period of time. The road traffic accident rate in Sweden rose with number of cars until mid-70's, but has fallen dramatically since then, despite continued increase in traffic. The same goes for many other areas, such as railway accidents and mining accidents.

The learning process is contextual, does not happen all at once, builds upon and is shaped by what people already know. Various experts have argued that people are not as rational in their decision making as they might think. Emotions are hard-wired and, while this human quality can be an obstacle in objective decision-making, it can also be advantageous in the learning process. In particular, people learn and remember from listening to emotional stories. That is why stories from past accidents are so important to the dissemination process.

The Rasmussen/Svedung [21] hierarchical model, as shown in **Figure 1**, describes the learning process on all levels from the individual to the society at large, where each level is tied to adjacent levels through nested loops of steering signals and feedback signals. Steering signals in the form of laws, policies, plans and resources are descending through the hierarchical levels, while feedback signals in the form of experiences from accidents, inspections and risk analysis are ascending.

³ In some countries, such as Germany, the inspection obligations are assigned to subregions (as in the German Länder) which may have different protocols and practices surrounding accident investigation and follow-up.

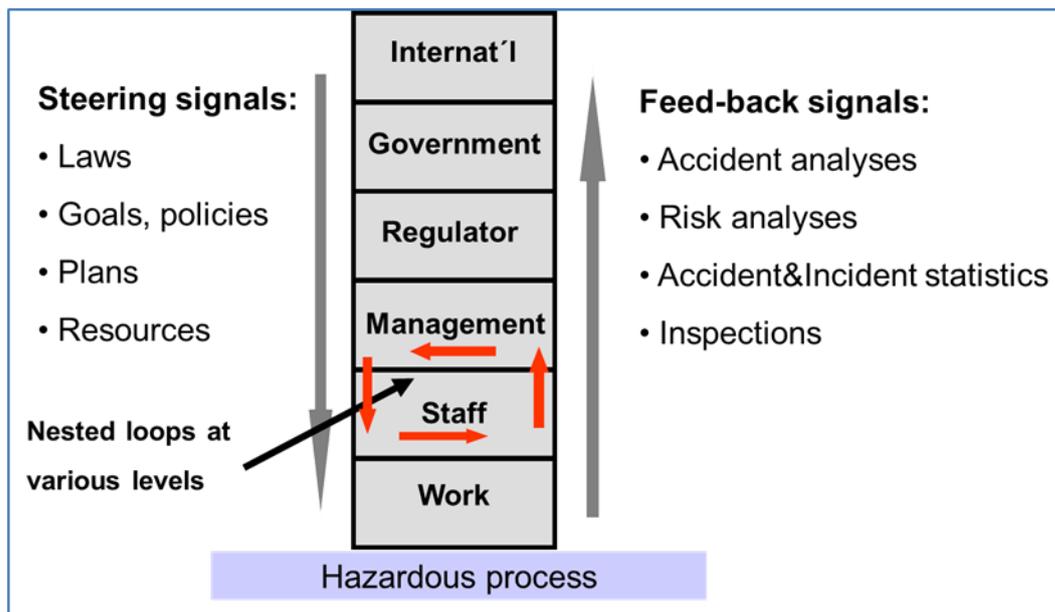


Figure 1 The Rasmussen/Svedung Hierarchical model [21]

Another way of looking at the learning process is the chain model, from reporting through investigation, dissemination, and prevention. Too much effort is often spent on the first parts of the chain, reporting and investigation, while too little is spent on dissemination of information

The process of learning after mishaps is quite natural to the human being. We want to learn and we question what has happened. More systematic incident investigations have been performed for about 150 years with early examples from shipping and railway accidents in the UK. An accident investigation is a thorough inquiry in order to find out what happened and why. There are essentially two paths to learning – learning from single incidents and learning from aggregated statistics of many incidents.

The investigation is the starting point for collecting data to enable learning lessons from an incident. The incident investigation process is sometimes divided into five steps:

- Planning
- Data collection
- Accident analysis
- Development of improvement actions
- Conclusions and reporting

The primary purpose of an incident investigation is to answer questions like *what, where, when* and *why* and to identify measures to prevent future incidents. There can be more than one investigation of an incident. This situation often occurs when different government authorities each have a legal obligation to investigate the incident. In addition, as indicated in the MJV participant survey, the operator will often conduct its own investigation for major incidents in addition to government authorities.

The purpose of the investigation shapes all the steps in the investigation process and it is very important to define this already in the planning phase. In large part, what the investigation seeks determines the scope of its conclusions. The researcher Sidney Dekker says that causes are not found, they are constructed. [4] Hence, each investigation may produce its own analysis with slightly different findings depending on the scope. For example, the investigation may not only cover the accident itself and its causes, but also the rescue operation, in order to improve future emergency operations. Inasmuch as investigation data are available, researchers may also conduct additional analyses of an incident with again a different scope based on available data.

It is also important to note that the scope of some investigations may not be aimed at lessons learned. For example, the investigation by police may have the purpose of evaluating the basis for *blame* (criminal prosecution) or *compensation* (liability). These investigations may produce data that are useful for lessons learned analysis. However, they are not as a rule “lessons learned” investigations and are outside the scope of this report. Seveso authorities may often conduct “mixed” investigations that are both intended to extract lessons learned as well as assess whether violation of major hazard regulations was a factor.

Data collection for lessons learned investigations consists of a range of activities to gain knowledge about the course of events and the conditions under which they occurred. It is very important to start this activity as early as possible, as some data may disappear very quickly and is often not possible to reconstruct or regain. The extent of the data needed to understand the sequence of events is often underestimated and the importance of data collection to identifying meaningful lessons learned can be greatly undervalued.

Accident analysis models are systematic approaches closely related to predictive risk analysis methods as well as accident investigation methods, the difference being mainly timing (before or after an incident). Often predictive models are used in combination with accident analysis models because they provide a logical framework for establishing the sequence of events.

The systematic analysis leads to the development of “improvement actions” that can include lessons learned for a number of different audiences. They also often will indicate specific corrective and remedial measures for the site or for other actors, such as emergency responders. The breadth and scope of improvement actions are highly dependent on the scope and limitations of the investigation.

The reporting phase is crucial to the dissemination of the lessons learned and the following decision and implementation steps. The report and its conclusions must go hand in hand with the purpose of the investigation. Who is going to use it and for what purpose? Through clarity and a logical, neutral and objective approach the report should convey trustworthy conclusions and suggestions. The memory of the event is condensed and preserved in the report.

The results of any investigation are only as good as the investigation process. Quality is most assured when the investigation objectives are systematically followed in an unbroken chain from purpose through data collection, analysis, conclusions and recommendations. Criteria to establish a certain *confidence* level in the trustworthiness of conclusions are determined by the degree to which the following are respected:

- The purpose of the investigation is reflected in the composition and competence of the investigation team
- Objectivity in the data collection
- Logical framework of analysis and its representation
- Adequate use of appropriate methodologies
- Recommended actions are related to the accident causes
- The report is tailored to the audience with a clear and logical structure
- There is an appropriate strategy for dissemination of results

1.3.2 Models for accident investigation and analysis

In the analysis phase questions are asked about the data collected. Systematic accident methodologies help to ask the right questions. There are several accident models available for analysing accidents. In general, they are all simplified representations of accidents but each model emphasises different aspects of the event and its causes and contributing factors. Accident models are often divided into three categories:

- Sequential models (Example: Domino Model [7], STEP [8])
- Epidemiological models (Example: Swiss Cheese Model [22], Tripod Beta [5], Deviation Analysis [6])
- Systemic models (Example: Accimap [21], STAMP [13], MTO [26])

There are at least 100 different methods for accident analysis that have been published, of which around 30 are actively used. Systematic analysis can provide a strong basis for seeking data, quality control and communication of the results. The purpose, characteristics of the accident and resources available should guide the choice of method. Notably, it is not always the case that investigations will use systematic investigative techniques, even in high profile investigations where lessons learned are a primary focus. Still, these investigations produce considerable data allowing other experts to apply systematic analyses if the data are made publicly available.

The following four methods are examples of different types of models in common use.

MTO event investigation [23] This method investigates the sub-events sequentially and analyses direct and underlying causes and safety barriers, including organisational factors. One of MTO's strengths is its simple graphical representation, as illustrated in **Figure 2**.

STEP [8] Sequential Timed Events Plotting (STEP), depicted in **Figure 3**, investigates parallel accident sequences and their interaction by identification of actors and sub-events in time order. It offers good support for data collection and quality control.

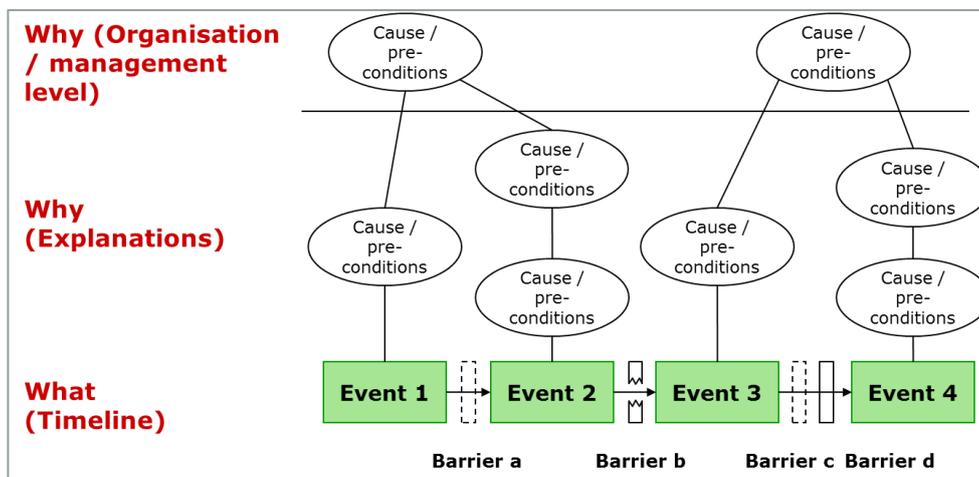


Figure 2 MTO analytical framework (Sklet, 2002) [26]

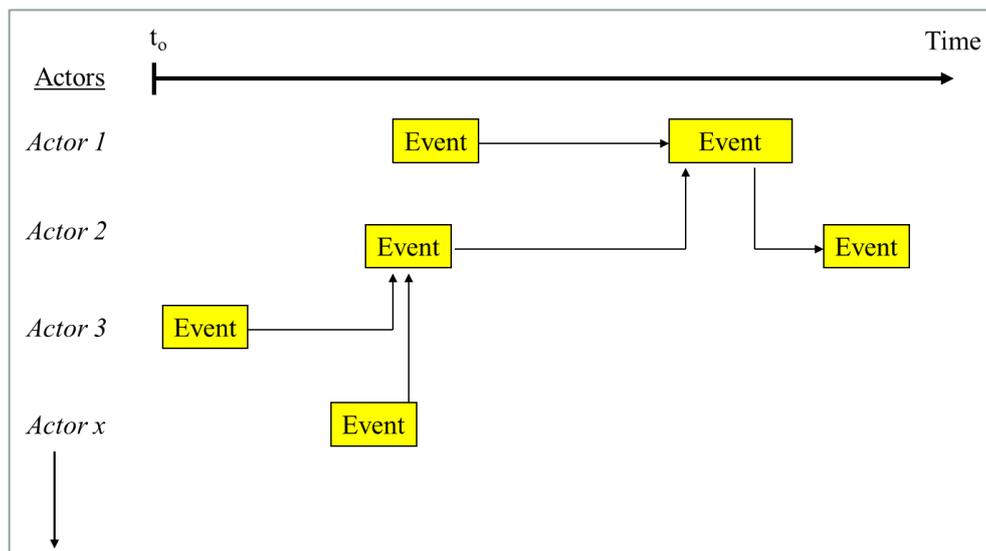


Figure 3 Diagramme of the STEP method [27]

Deviation	Risk - Problem	Evaluation	Suggestion for measure	Comments
Deviation 1	Risk for ...	S2, P3	Measure 1	
Deviation 2	Safety problem with ...	M1	Measure 2, 3	
Deviation 3		S1, M2	Measure 4	
Deviation 4		P2	Measure 5, 6, 7	
Deviation 5		H2, S1	Measure 8	

Figure 4 Framework of a Deviation Analysis [27]

Deviation Analysis [6] This approach identifies and assesses deviations that occurred before, during and after the accident, as shown in **Figure 4**. Deviation analysis is quick method that can be applied to many types of accidents.

AcciMap [21] This method was developed by Rasmussen and Svedung (see **Figure 5**) with reference to the contributions to risk management of different hierarchical levels of society. In a socio-technical context, decisions and information flows between different levels.

A Swedish research project conducted by Strömgren of the Swedish Civil Contingencies Agency [27] aimed to evaluate nine accident investigation methodologies covered in a university course at Karlstad University in Sweden. Five of the methodologies originated from work in the Nordic countries. Findings were collected from participants across eight repetitions of the course. In total, the exercise involved 114 different analyses in which each student applied one or more of the nine methods to at least one of 36 real incidents. For this purpose, the investigation process was divided into 9 distinctive steps and the support that each method provided for each step was evaluated.

SYSTEM LEVEL

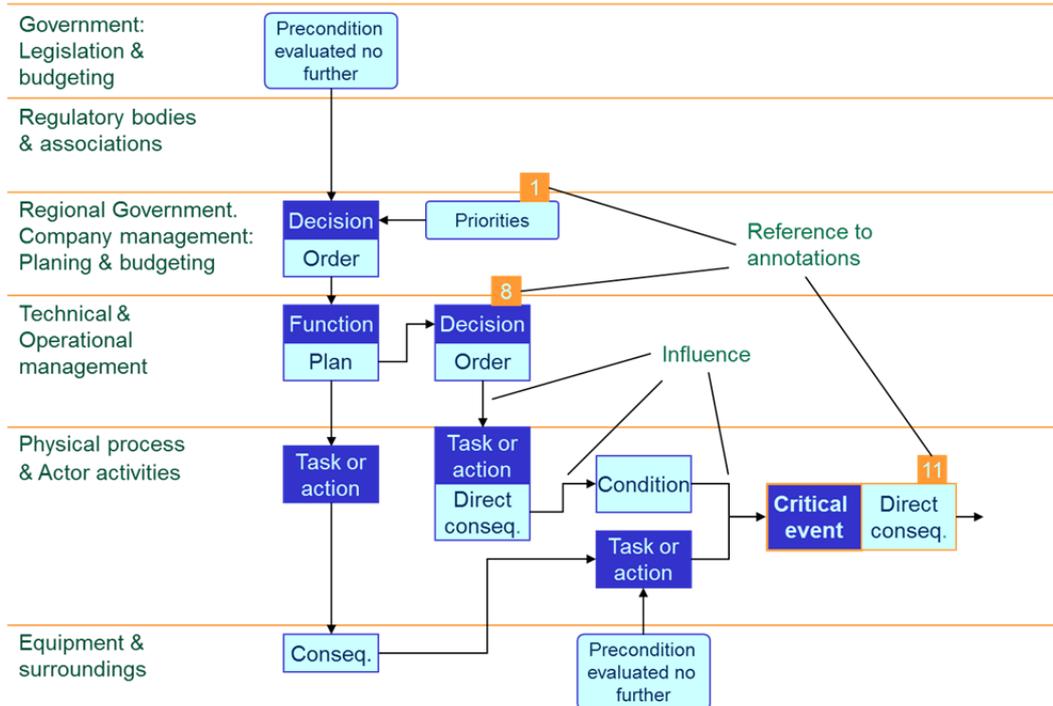


Figure 5 Diagramme of the Accimap method [21]

The project concluded that none of the compared methods provided full support for all phases. Most methods concentrated on the analysis phase, and only three of them gave good support for the data collection phase. The evaluation step is often overlooked. One recommendation is therefore to combine methods so that all steps in the investigation are well-supported.

1.4 Conclusions

The investigation of an accident is normally planned with the view to identifying both the technical causes of the accident and the underlying causes. In the case of a technical accident, the technical cause is usually the failure that directly caused the release. The underlying causes can be a variety of upstream failures that make it more likely that the release will occur. They also can include failures that condition the likelihood of failure of measures intended to mitigate the impacts of the release.

Theories on understanding what causes an industrial accident have continued to evolve from ongoing research on this topic. Recent work has uncovered potentiality causality associated with human and organisational factors. They suggest that accident causality can often be complex and arise from systemic failures. A number of different analytical methods have been developed to examine these influences.

There has also been considerable focus on uncovering causality by diagnosing failures in terms of the difference between the expected outcome and the actual outcome (barrier analysis, deviation analysis). These methods often produce findings on the sequence of events and at what point there were opportunities to stop the sequence leading towards an accident or modify it to reduce the impact. The findings from these types of barrier and deviation analyses often form the basis of a further systemic analysis of the same incident.

In general, it can be concluded from this discussion that:

- Learning from accidents is a process. Different models frame the process in different ways. Often investigators use more than one model to analyse an accident.
- The primary purpose of an incident investigation is to answer questions like what, where, when and why and to identify measures to prevent future incidents.
- The purpose of the investigation shapes all the steps in the investigation process and it is very important to define this already in the planning phase. The results of any investigation are only as good as the investigation process.
- Accident analysis models are systematic approaches closely related to predictive risk analysis methods as well as accident investigation methods, the difference being mainly timing (before or after an incident). Often predictive models are used in combination with accident analysis models because they provide a logical framework for establishing the sequence of events.
- The systematic analysis leads to the development of “improvement actions” that can include lessons learned for a number of different audiences.
- The reporting phase is crucial to the dissemination of the lessons learned and the following decision and implementation steps. The report and its conclusions must go hand in hand with the purpose of the investigation.

2 The accident investigation in a Seveso Directive framework

The quality of an accident investigation influences learning from accidents. Inspectors can play a role in influencing the quality of an accident investigation. In particular, some important things to look for in an accident investigation report are:

- The quality of the investigation team and its diversity of skills are aligned with the needs and purpose of the investigation
- The purpose of the investigation is well-defined
- All areas of investigation are identified and be included in the investigation strategy
- The investigation is of sufficient depth that potential underlying causes associated with organisational and management system failures are examined and discussed
- Recommendations are clearly linked to all causes identified in the investigation
- Recommendations include lessons learned in the safety management system and other parts of the organisational memory
- There is no strong evidence of bias, such as blaming individuals for the accident or the reports arguments consistently reflect the perspective of one stakeholder

A credible and thorough accident investigation includes proper planning and an investigation team with adequate skills, authority, objectivity and, most importantly, independence. It is important that the purpose and scope of the investigation is clearly defined in the planning stage and serve to guide decision making throughout the investigation process.

Outlining the structure of the final investigation report can also help to determine the type of data and evidence that should be collected during the investigation. This process can assist brainstorming on people that should be interviewed in the investigation, background research needs, and the types of data and evidence that would be useful to the investigation. The output from the investigation should be divided in two parts, one about causes, and one about lessons learned. Typical headings in an investigation report would be:

- Purpose and scope
- Information on the site, including ownership and management, site character, (e.g., age, size, historical uses, current business activities, accident history, dangerous substances present, etc.)
- Accident description, that is, the sequence of events up to and including emergency response
- Human, environmental, economic, and social consequences of the accident
- Description of site operations relevant to the accident, including manufacturing, storage or handling processes at the source of the accident, as well as other operational functions (e.g., maintenance, control room) that may be relevant
- Accident analysis methodologies used
- Identification of direct causes and underlying causes, supported by an analysis of the time line and presentation of evidence
- Violations of regulations and/or standards relevant to the accident
- Recommendations and how their implementation could prevent a re-occurrence

2.1 Learning lessons in a Seveso Directive framework

Since its inception, the Seveso Directive has always emphasised the importance of follow-up to major chemical accidents and near misses to acquire lessons learned that can be used to prevent major accidents.

Over the years the responsibility of competent authorities for accident follow-up has progressively increased with each version of the Directive.

- The Seveso I Directive required the competent authorities "to collect, where possible, the information necessary for a full analysis of the major accident and possibly to make recommendations."
- The Seveso II Directive (96/82/EC) was more specific such that competent authorities should "collect, by inspection, investigation or other appropriate means the information necessary, etc.". It also was required for the competent authority to "make recommendations on future preventive measures".
- The Seveso III Directive explicitly requires an inspection following a major accident or near miss. "Non-routine inspections shall be carried out to investigate serious complaints, serious accidents and 'near misses', incidents and occurrences of non-compliance as soon as possible."

2.1.1 Who conducts the investigation

In the majority of cases, the company investigation is the only investigation that takes place. The operator is almost always supposed to carry out an investigation on its own or in co-operation with the authorities, even if the authorities carry out one themselves. In most cases inspection authorities do not make recommendations or place a demand on the operator on what investigation methods to use. However, in a survey of participants conducted prior to the workshop⁴, it was revealed that investigating entities vary considerably across the EU. Depending on the country and the circumstances, entities with investigating roles may be operators (69%) and other government agency or agencies (52%), such as the fire brigade, the public health office and/or a national safety investigation body. Nonetheless, the MJV participants generally agreed at the workshop that central authorities should be able to investigate major accidents, ideally establishing a dedicated organisation for the purpose or embedding a dedicated expert investigation team within a related organisation.

2.1.2 The role of the Seveso inspector in an incident investigation

According to the participant survey, the role of the inspectorate in case of an accident differs depending on the protocols surrounding accident follow-up in each country. The majority (87%) of the countries⁵ indicated that the Seveso inspectorate had an investigating role following a major incident (see **Figure 6**). Most of them (19, and some German Länder) could also investigate other chemical incidents besides those identified as "Seveso major accidents". Sometimes more than one inspectorate may be involved in an investigation.

Objectivity and independence of the investigation team as well as competence are crucial to obtaining trustworthy conclusions out of the investigation. Therefore participants recommended that authority's investigation of major accidents should preferably be made by dedicated expert teams within the inspectorate or a specific government body dedicated to investigation.

Over 70% of respondents indicated that the inspector has some role in reviewing the analysis derived from the investigation report (see **Figure 7**). MJV participants expressed different opinions in regard to how much the governmentinspector should influence the scope of the operator's investigation and methodologies used. Most felt that it depends very much on the nature of the accident that in turn influences the scope of the investigation. It can also depend as well on the circumstances surrounding the accident, such as the size of the company, the type and severity of impacts, and other factors that may justify more or less government oversight. For example, small companies may have little experience with accident analysis and may need advice, or alternatively, accidents with notable off-site impacts (e.g.,

⁴ The survey form distributed to the participants prior to the workshop is contained in **Annex 6**.

⁵ Note that % refers to the number of countries and not individual respondents.

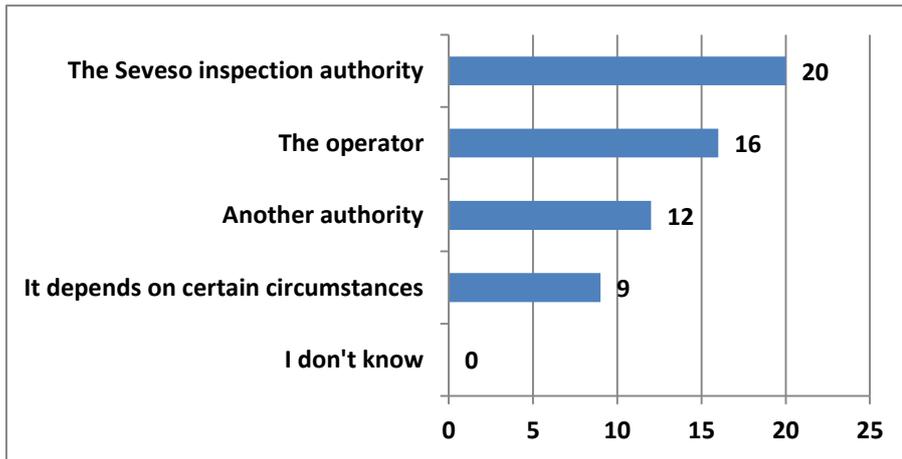


Figure 6 Who does the accident investigation for a typical major Seveso accident in your country? (N = 23 countries) (Respondents could check more than one option.)

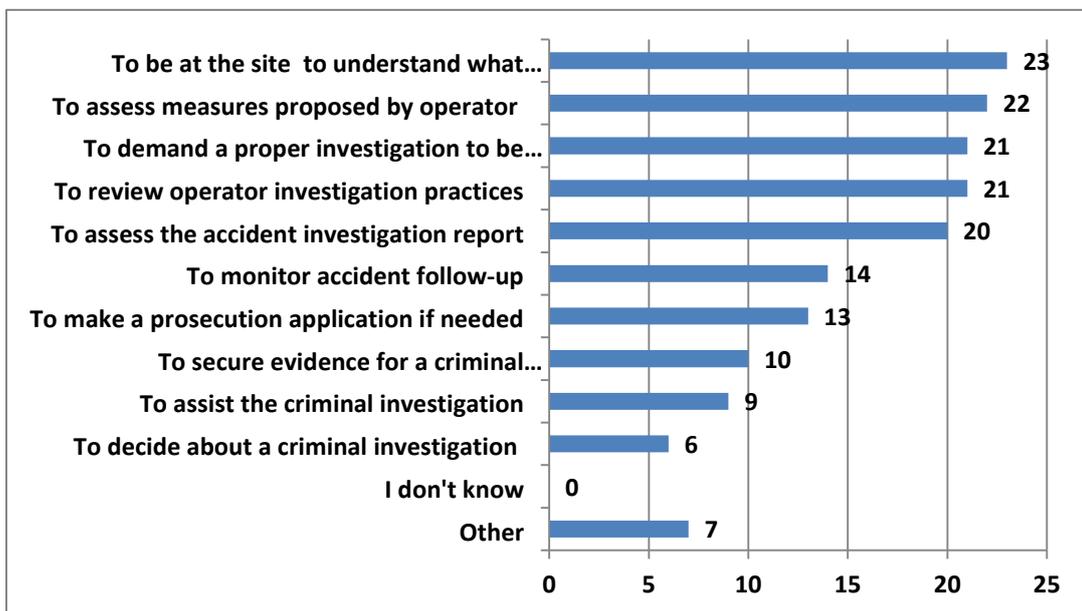


Figure 7 What is the role of the Seveso inspector before, during or after an accident?(N = 28)

environmental pollution, property damage) or disturbances (e.g., evacuation, shelter-in-place, road closure) may have political implications.

In discussions, MJV participants additionally concluded that inspectors can play an important role in the outcome of the investigation even when they are not directly investigating the incident. Ways in which the Seveso inspector can add value to the investigation can include

- overseeing the quality of the investigation by providing guidance on the investigation process to the investigation team, especially to small operators
- evaluating the quality of the investigation report
- engaging in dialogue with the operator to reach agreement on what corrective measures should be taken to restore safe operation and avoid a similar accident in future
- coordinating and communicating between different stakeholders and authorities involved in the investigation

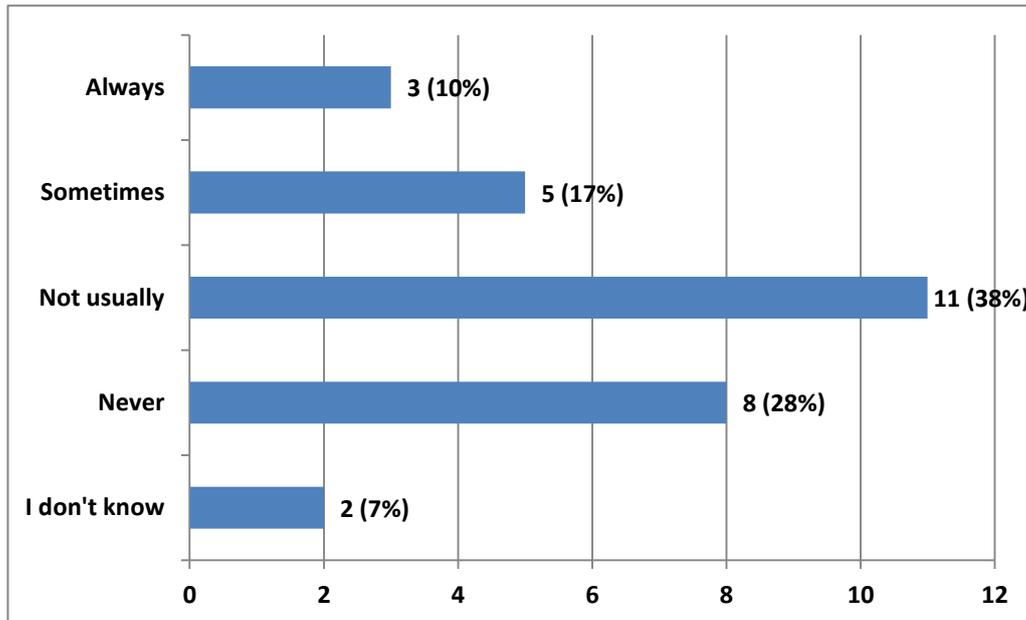


Figure 8 Does your inspection authority (or another inspection authority) make any demands or recommendations on what methods should be used for the accident investigation in case the operator does the investigation? (N = 29)

Only 10% of respondents (N=3) indicated that their Seveso authority made recommendations about methods that the investigating team should use. In contrast, nearly 30% (N=9) never provided any such guidance. (See **Figure 8**).

Authorities who provided guidance on the investigation process did so in different ways, such as:

- Operators may be required to follow specific guidance or follow a template for accident analysis
- The operator may be required to appoint an external expert to investigate the accident.
- If the methods or the qualifications of the operator are deemed insufficient, the authority may demand better methods or more qualified investigation personnel.
- No method is recommended or demanded, but the method applied has to be described in the investigation report.
- The method(s) used for the investigation of accidents at a specific company should be specified in a procedure in their safety report.

It was also noted by participants that the decision to intervene or not to intervene in the investigation has certain implications for the government. On the one hand, if the inspection authority intervenes at any level, it must assume some responsibility for the outcome of the investigation. Intervention also requires the inspectorate to have adequate expertise and confidence to make a judgement in this regard. On the other hand, by not intervening, the inspector has few alternatives for improving a flawed or incomplete investigation results after the investigation is completed.

2.2 Effectiveness and competency in Seveso accident investigations

Notably, a majority (61%) of participants consider the investigation system in their country to be effective or somewhat effective (See **Figure 9**). Many who responded positively seemed to indicate that the composition of the expert team and/or investigation process helped to achieve good results. For example:

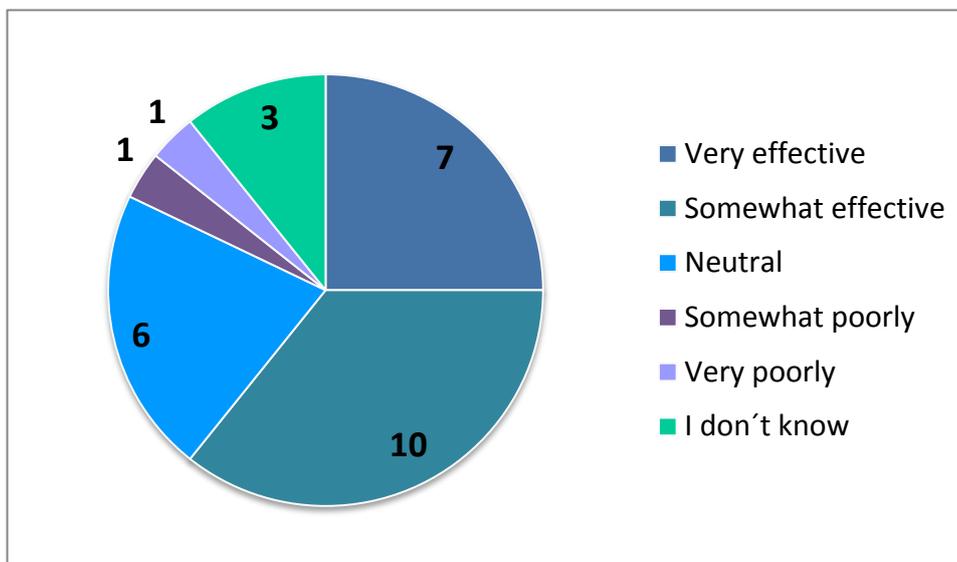


Figure 9 How effective is your country's system for investigating major Seveso accidents in your opinion? (N=28)

"[The] system for investigating major Seveso accidents is quite effective in [country], because accidents are investigated [by] various professionals, law enforcement officials and experts."

"We have a long established procedure which has been very effective in determining all facts."

Nine respondents reported not having much experience with investigations at all and responded either "neutral" or "I don't know". One of the two respondents who rated the investigation approach poorly cited "poor communication" across "geographic distances" as an important weakness. The other indicated that "Little information is normally reported about accidents and lessons learned are normally not included." One respondent, who ranked the national system as poorly effective, said that "potential effectiveness [is] reduced by communication issues brought about by [the] geographical spread of the authority and the availability of resources."

It was broadly accepted by workshop participants of Seveso inspectors that competency varies a lot by country. Across the EU only some Seveso inspectors have knowledge about investigations methodologies or have access to relevant tools and expertise. Many inspectors at the workshop did not feel that they or their colleagues had a lot of knowledge about investigation methodologies.

In contrast, there were some participants that were trained or had access to experts or tools such as checklists within the inspectorate to support investigation work. Indeed, it was generally agreed that such tools should be available to all Seveso inspectors if possible. They could even include background explanations so that non-experts can use them efficiently.

2.2.1 Inspector actions in case of an accident

It was generally agreed by participants that the inspector should go to the site as soon as the emergency phase has ended and the site is safe to visit. Inspectors should be trained for accident follow-up if given this assignment, and if not, he or she should be accompanied by a colleague with this training.

An inspector charged with performing an investigation should have specific training on this topic in advance, to maximise chances of obtaining accurate and complete information. The knowledgeable inspector can anticipate and mitigate or overcome typical challenges in an investigation that can impede information gathering for determining causality and lessons learned, such as witnesses' fear of a criminal prosecution to assign guilt, clean up and dismantling of the site once the incident is over, need for specialist knowledge, etc. Adequate resources and support from the inspector's hierarchy are also factors that can help the inspector conduct a thorough investigation.

The actions taken by the inspector will be different depending on the role(s) that the Seveso inspector is undertaking. At minimum, before going to the site of an accident, the inspector should be well prepared as follows:

- Have a well-defined role in the accident follow-up, that may include a description of what is expected that the inspector will do as well as limitations of jurisdictions and tasks
- Have sufficient training in performing the role to which the inspector is assigned including any protocols established under the law and by the authority
- Consider what chemicals, processes and equipment were likely to have been involved, based on information available on the incident as well as in available documentation, e.g., the safety report (if available) and past inspection reports
- Review any information reported by the media, in preparation for the site visit but also to support preparation of communications to the public
- Contact other authorities involved, especially local authorities to notify them of the inspectorate's involvement and to facilitate collaboration and exchange of information that may be useful
- Prepare an agenda for the site visit, including meeting with key persons at the site and with other authorities
- Bring personal safety equipment and investigation and inspection checklists that could be relevant

Although inspector's roles may vary depending on the authority and accident circumstances, it is relatively common that inspectors will have some involvement in the accident in its immediate aftermath. Some typical immediate actions on-site could be, depending on the role:

- Demanding an investigation and a preliminary report
- Gathering basic information in order to understand what has happened and be able to inform the public and other authorities
- Giving advice on limiting the consequences of the accident
- Initiating or supporting a criminal investigation and securing evidence

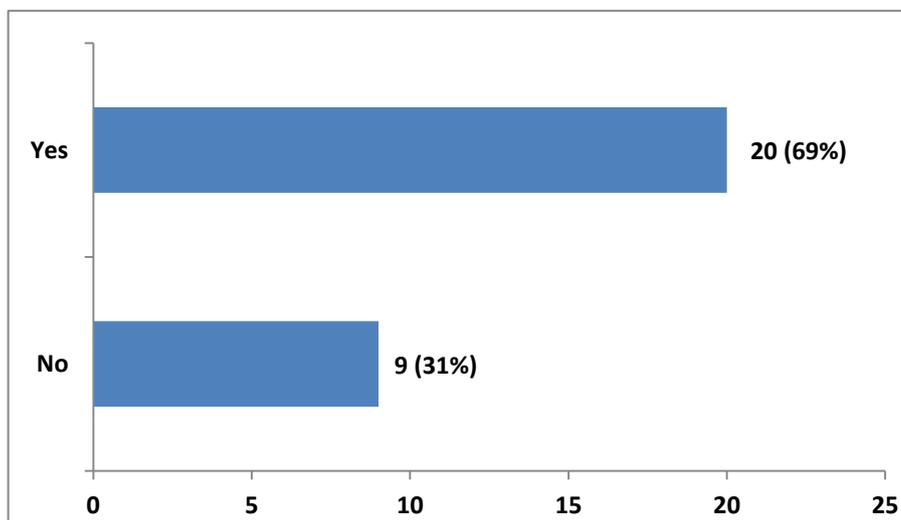


Figure 10 Do you review and quality assess accident investigation reports? (N=29)

2.2.2 Investigation reports and findings

Survey responses indicated that over two-thirds of respondents (69% or 20 respondents) assessed the investigation report provided by the operator, or other third party (e.g., another authority) (see **Figure 10**).

According to the respondents the most common deficiencies in investigation reports are:

- The search for root causes is not deep or broad enough.
- Organisational, management and human factor issues are overlooked in favour of technical and engineering factors.
- Lessons learned are missing or not specific enough.
- Corrective actions are often limited to the relevant plant or equipment only and not applied on similar facilities or equipment.
- Investigations are carried out to fulfil formal requirements or in an attempt to prevent legal or civil claims.

Moreover, accident investigation methodologies used by the operator are seldom described in documentation shared with the competent authority. The system for the incident learning cycle is most often described in detail in the safety report without any detail on methods to extract lessons learned from incident information. Many companies have developed their own methodologies, and they often choose between different ones depending on the severity of the incident.

However, the workshop also debated as to the degree to which knowledge about investigation methodologies was necessary for an inspector who does not conduct investigations. There was considerable disagreement on this topic. Some did not consider it necessary at all, while others considered that some knowledge is necessary in order to evaluate the quality of accident investigations. In any case, a majority of participants (17, or 61%) reported feeling that they did not have enough knowledge about accident analysis methodologies to perform the quality assessment of the investigation report. (**See Figure 11.**)

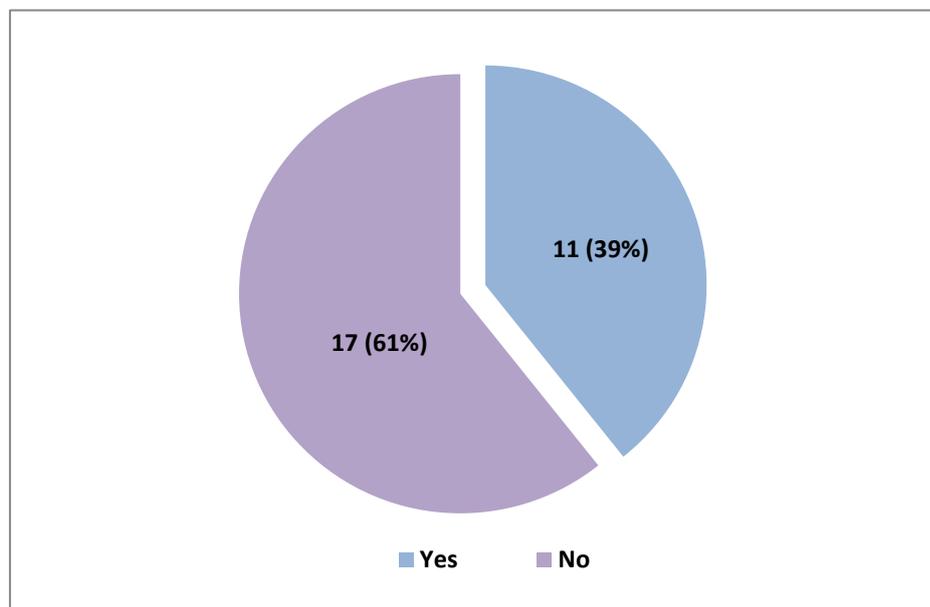


Figure 11 Do you feel that you have enough knowledge on accident investigation methodologies to perform the quality assessment? N = 28

2.3 Conclusions

The Seveso Directive envisions a shared role of operators and inspectors in analysing accidents and identifying its lessons learned. For any major accident, the operator is expected to conduct an investigation. The role of the competent authorities in the investigation is more varied. Some authorities routinely conduct investigations, while others may not directly investigate but they may oversee the quality of the investigation and the investigation report. In some countries, several authorities may have a role in the investigation.

Some of the most important principles regarding the investigation function within the Seveso Directive are summarised as follows::

- Operators should normally have a system for categorisation of incidents, which governs the investigation methodology and depth, based on the potential severity of the accident
- Using standardised investigation methods provide a better basis for seeking data, quality control and communication of the results. Inspectors should require systematic methods to be applied, but not necessarily specify exactly which method, when operators investigate accidents themselves.
- Accident investigation methods do not necessarily have to be described in the safety report.
- Inspectors need more knowledge about investigation methodologies in order to be able to evaluate the quality of the reports. They also saw a need for tools, such as checklists, in order to evaluate investigations effectively. Some points in such a checklist were mentioned by participants.
- The authority's investigation of major accidents should preferably be made by a dedicated expert teams, or a dedicated organisation, with the necessary expertise and training required to produce accurate and complete findings regarding causes and lessons learned.

3 The role of lessons learned in chemical accident prevention

A lesson learned is something that changes how things are done, in a manufacturing process or in an organisation, and which at the same time contributes to the prevention of similar accidents in the future. They are identified by thorough investigations of accidents down to the root causes. Often that means to identify barriers that failed. Sometimes it may also be important to identify those barriers that actually worked. One challenge for authorities is to extend lessons learned beyond the operator duties and also apply them to the duties of the authorities themselves. All stakeholders benefit from a robust process for learning and disseminating lessons from past events (see **Text Box 3**),

From the very outset the Seveso Directive has required that major accidents be reported by operators to the respective competent authorities and that an analysis of the accident, together with recommendations is made by the competent authorities. The Member States are required to report the occurrence of major accidents including a specific set of data to the Commission, available in the eMARS database (<https://emars.ec.europa.eu>). With the Seveso II Directive and the requirement for operators to establish Safety Management Systems operators need to develop procedures for the reporting and investigation of accidents and near-misses and to follow-up with measures on the basis of lessons learnt.

Moreover, safe operation and sustainable success in business cannot be separated from the consequences of getting control of major hazards wrong. This conviction led the OECD Working Group on Chemical Accidents to develop guidance for senior leaders in high hazard industries “Corporate Governance for Process Safety”. [20]

The lessons from past incidents demonstrate that strong process safety leadership is vital in preventing catastrophe, and it is essential that these lessons are learned and adopted across all sectors to prevent the same failings leading to more accidents in the future.

Learning from accidents is also a critical activity for inspectors and inspection authorities. Attention has been drawn to this in work by the UK HSE which considered the role of HSE’s Offshore Division. [24] This work also gives insights into how the concept of a learning organisation encompassing the regulatory authority might be achieved.

3.1 Sources of lessons learned

Having knowledge about which accidents have occurred and the measures taken as a consequence are fundamental to the assessment of the safety report. Emergency planning is carried out on the basis of scenarios. Therefore, awareness of which accidents have already occurred in similar establishments may give an indication of which scenarios are relevant for the development of both the on-site and the off-site emergency plans.

Who can benefit from lessons learned from chemical accidents?

Senior leaders in industry and in authorities need to recognise the need to learn through sharing and to encourage cultures within their organisations that promote lessons learning.

Companies and individual sites, where major hazards are present, need to learn from accidents to manage their risks appropriately and share these lessons with **their employees and contractors** who play a role in controlling the risk. Small and medium enterprises need to be aware of their potential vulnerability and work within trade organizations to share with each other.

Competent authorities need to recognise their own need to learn from accidents so as to be effective in supervising hazardous industries.

Professional engineers and scientists that advise on process safety, regardless of whether they work in industry, government service or as independent consultants need to share lessons learned for the benefit of society in general.

Communities where hazardous sites are located, or may be potentially located, can also benefit from lessons learned by developing strategies to promote accident prevention and strengthen their response to chemical emergencies in the event of an incident.

Text Box 3 Communities that benefit from lessons learned from chemical accidents

This section looks at tools and practices for disseminating and applying lessons learned in industry and government, and how Seveso inspectorates can apply lessons learned knowledge in their role in enforcing and overseeing implementation of the Seveso Directive.

3.1.1 The role of industry and government in dissemination of lessons learned

Industry organisations, sector groups and companies that sell licenses for processes should be able to help operators to compile accidents related to the use of certain processes or substances. In particular, government inspectors as well as industry organisations and other safety organisations play a crucial role in supporting small and medium sized companies. They serve as valuable conduits of information for particular sites or subsets of hazardous industries where awareness of chemical accident hazards may be more limited.

Government research organisations in the EU are also important as centres of reference for lessons learned. A number of these institutions, such as the European Commission’s Major Accident Hazards Bureau (part of the Joint Research Centre) and the French Bureau for Analysis of Industrial Risks and Pollution (BARPI), are centres of reference for lessons learned. They maintain online databases that can be consulted for lessons learned from accidents in a variety of industries. They also publish studies of lessons learned on specific topics associated with past accidents, relevant to specific types of processes, substances or equipment, as well as on horizontal topics, such as ageing or the use of contractors.

There are a number of sources of information on lessons learned from chemical accidents that operators and authorities can consult to identify potential improvements and troubleshoot risks associated with specific substances, processes and equipment. The main sources can be grouped generally as investigation reports and analyses that are directly made available online and databases of reports and information on chemical accidents.

3.1.2 Databases of chemical accident and lessons learned information

In large part, the majority of major hazard sites would be expected to maintain a database of chemical accidents that have occurred on the site and have access to a larger company database, if they are part of a corporation. Survey responses revealed that 15 least 17 EU and EEA countries (out of 22 responding countries) plus Switzerland maintain national databases specific to chemical accidents. (See Figure 12.)

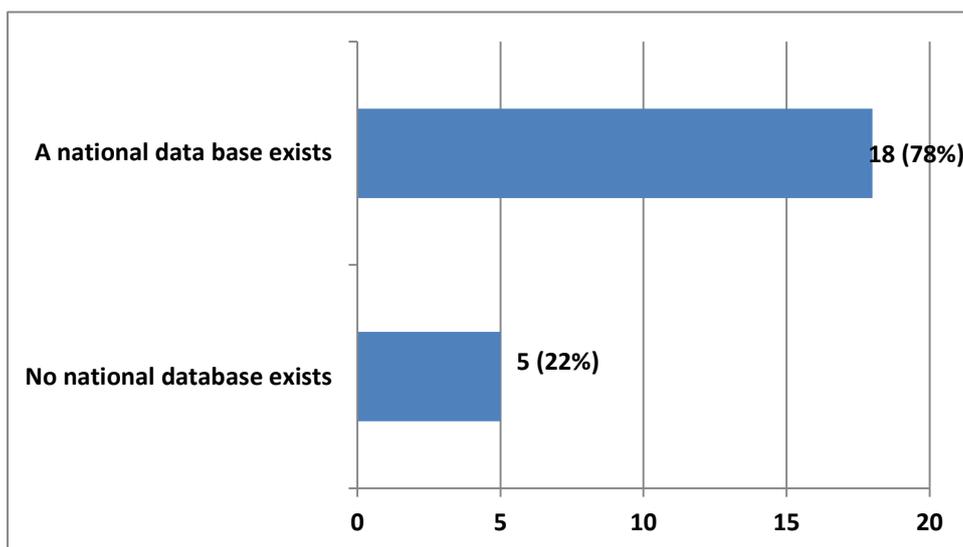


Figure 12 Does your country have a national database for Seveso accidents or for major industrial accidents including Seveso-types? (N = 29)

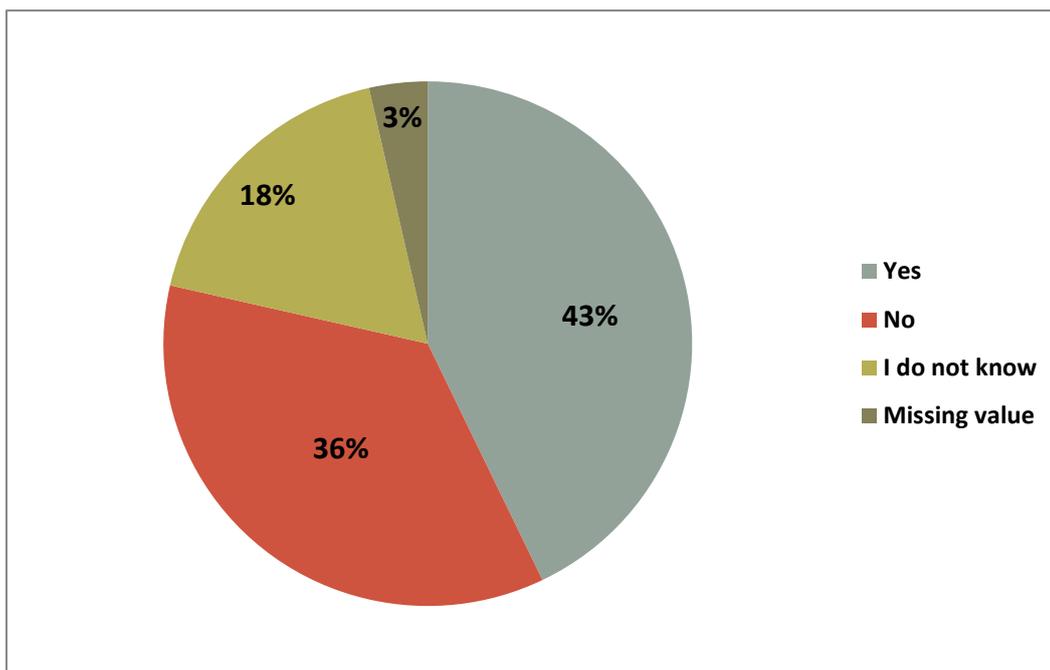


Figure 13 Do you have difficulties extracting lessons learned from databases? (N = 29)

Some of the national databases are broader than chemical accidents, for example, they may encompass information from other types of accidents or be integrated in an inspection database. In contrast, other national databases are intended mainly for accident registration and not intended for lessons learned analyses. Only three national databases are open to the public over the web, namely ARIA in France, ZEMA in Germany and the VARO database in Finland. (See Annex 2 for a list of open source chemical accident databases).

Nonetheless, a number of participants in the MJV workshop (43% of 29) who reported having difficulties extracting lessons learned from the available databases. (See Figure 13.) The survey did not ask the reason why they had difficulties, and therefore, this is a question that could be explored further. There could be a number of possible reasons, for example, related to the quality and completeness of the data or to the competence and experience of the participants.

3.1.3 Chemical accident investigation reports

Investigation reports, case studies and research on chemical accidents are also rich sources of information for lessons learned. Often, they have far more detail than the accident reports and database and as such, can be mined for information on a wide range of topics. For example, investigation reports from well-known disasters such as BP Texas City (USA, 2005), Buncefield (UK, 2005), Esso Longford (Australia, 1998), etc. have been widely used as a basis for systems theory and to explore theories of organisational and human behaviour influences on accident risk. A list of several open sources with chemical accident investigation reports is contained in Annex 3. In addition, lessons learned presented at conference such as the IChemE Hazards conference series and CISAP, are sometimes also made freely available. (See Annex 4.).

3.1.4 Research and topic-based summaries of lessons learned

A number of organisations also produce analyses of lessons learned from analysing collections of chemical accident reports. Often these analyses are based on accidents that share particular characteristics (e.g., type of substance, type of equipment, type of equipment, type of causality, etc.) A long-standing source of summaries of lessons learned from chemical accidents is the IChemE Loss Prevention Bulletin. Since 2012, the EC-JRC-MAHB has also produced the Lessons Learned Bulletin that focuses on specific themes. These references are also included in Annex 3.

3.2 Dissemination and implementation of lessons learned

Government and industry have developed structures and mechanisms to promote lessons learned, especially organisational learning, such that incidents continue to be actively applied and referenced in the organisation. In a process safety context, it is not only important for individuals to learn but the companies that manage the processing, handling and storage of dangerous substances must also learn. Databases on lessons learned do not solve the problem, as there is no simple path between databases and the experience of design teams and operational teams. Databases mainly provide statistics on failures. It is in fact quite challenging to embed lessons learned in the memory of any organisation.

Organisational memory is the body of data, information and knowledge which an organisation has accumulated over its existence. It is not the people (who may come or go over time) or products or technologies themselves which constitute the memory of the organisation. Organisational memory only exists in the collective individual memories of those people present in an organisation at any one time, together with the documentation and organisational processes for recording, retrieving and utilizing that documentation. A company or an inspector body does not remember. Learning from accidents within organisations needs to be embedded into the organisational framework, so that reorganisation or retirement does not leave irreparable damage to the organisational memory. **Text Box 4** gives an example of how one company has worked towards embedding lessons learned into the organisational framework.

Lessons learning at Nynas

Nynas is a small oil company, with global presence, producing bitumen and naphthenic specialty oils. Incidents are administered in a Continuous Improvement Module of the computerised management system. When an accident or near miss occurs, the reporter may enter information about the incident directly into the system, or alternatively, fill in a handwritten form that is then input later into the system. All incidents in the system are categorised according to their seriousness, which determines investigation methods and resources applied to accident follow-up. Serious accidents (involving substance release or human health impacts) are reported to the upper management within 24 hours of the occurrence. Incidents that have not led to a release or injury, but could have done so under somewhat different circumstances, may also be classified as serious. Management expects that all recommendations resulting from an incident investigation will be completed in the specified time frame. Management focuses on overdue actions. The computerised system allows easy access to information about incidents, status of the corrective actions as well as your individual duties related to those actions. Lessons learned are spread through flyers, the internal web-site and group safety meetings, the latter with a frequency of 4-6 times per year. Information is also shared with the authorities.

Text Box 4 Nynas: A case study of lessons learned practices

Rather, it is the social interactions between the people, that enable them to carry out the activities which fulfil the organisation's purpose and it is through social interaction that the organisation's memory can be preserved. As with human memory, organisational memory can only be applied and become organisational learning if it is accessible. Therefore, organisational learning exists when practices and processes are required within an organisation's regular activities that make use of this information and knowledge thus maintaining its accessibility.

There are many factors that influence memory, particularly in association with a number of current trends that may be in some cases detrimental to company memory, such as:

- Mergers, acquisitions, reorganisations and reduction in corporate engineering resources undermine corporate memory
- Fewer resources on corporate and company standards
- Industry standards are stagnating and diluted because only companies with short term vested interest can afford to participate in their development
- Move towards goal setting standards; require more experience and judgement than prescriptive standards
- Contracting of engineering work also reduces corporate memory
- Increase in personnel turnover, rapid career progression, fewer resources for training and in-depth education reduces individual experience

There is a parallel between individual learning and organisational learning. Individual learning takes place when a person decides to alter some aspect of their behaviour. Learning of organisation, such as companies, takes place when individuals decide to change part of the processes governing the organisation and interaction of the people. Sudden changes in an organisation which result in personnel changes such as outsourcing, early retirement incentives, and job rotation, will have an effect on the organisational memory.

How lessons learned are analysed and disseminated varies widely and is connected to the way accidents are investigated in each country.

- Some countries have specific bodies which analyse and disseminate information through public web-pages and collaboration with authorities and industry bodies – BARPI in France and ZEMA in Germany for example. Others may organize multi-agency investigations or public inquiries for major accidents, for example Buncefield in UK, which had a web-page of its own.
- In several countries annual reports and specific lessons learned are published on public web-sites. Some may issue safety alerts or conduct specific research. Common meetings or conferences between authorities and operators are also used.

A proposed model for achieving organisational lessons learned is contained in **Chapter 4** with a supporting question checklist in **Annex 5**.

3.2.1 Obstacles in the dissemination of lessons learned in industry

Transferring lessons learned into implementation is a responsibility shared by both authorities and industry. All incidents should be investigated, but the methods, level of depth and resources should differ depending on the actual and potential consequences of the incident. Incidents not being investigated undermine the willingness to report and may spread rumours about hiding certain facts. There is always something new to learn. Incidents that have major similarities may still have different root causes.

Establishing relevant findings from the incident investigation is one major challenge. Even when the investigation process is producing relevant findings, there may still be considerable other challenges to making the information accessible and ensuring it is applied where it is necessary and appropriate.

The workshop identified a number of factors that can hinder the sharing and use of lessons learned information, in particular:

Lack of resources or accountability. It is time consuming to transfer lessons learned from a specific case to more general use. Companies and authorities may believe strongly in the role of lessons learned for driving improvements but fail to allocate any resources to accomplishing it. This task can be the responsibility of individuals or allocated to experts that serve as a resource for other staff. Ongoing reporting and consulting of lessons learned are more likely to occur when managed as a routine and essential part of the job.

- Ongoing criminal or civil prosecution. While a criminal or civil case concerning the accident is ongoing, the information flow may be limited and by the time it is released it could be years later when the incident has been already forgotten in the public memory. As part of a civil settlement, the parties may even agree not to release certain information that may have relevance to the cause of the accident.
- Culture and training on the use of databases. Some companies may not have a practice of using incident databases to improve their risk management. They also may not routinely share of lessons learned between sites or with other companies in the industry. Similarly, some inspectors may also not be experienced in the use of accident databases nor be fully aware of open sources, such as eMARS, that can be easily consulted. Some databases require training and/or time to practice using them so that users can run find useful information easily.
- Lack of a strategy to promote continuous learning from accidents. It can be that many companies as well as authorities simply lack any strategy for using and applying lessons learned from accidents. For example, it is a particular challenge for an operator to deal with a large amount of incident reports with very wide range of severity. A systematic categorisation,

which governs the investigation methodology and depth, based on the potential severity of the accident, can be helpful in this regard.

- Presence of a “blame” culture. The tendency of a company to blame workers for any failures that occur may hinder sharing of information on incidents. In this situation, some incidents, particularly near misses, may not be reported and full information about causality may not be provided for investigations. The attitude of the authorities and the society in regard to incidents may also play a role in the openness of employees as well as the companies in regard to sharing information on accident events and identifying their causes.
- Too little effort spent on dissemination of results. Efforts to report and investigate an incident often outweigh efforts to share the information once the investigation report is completed. This failure to share lessons learned may stem from a lack of resources, a lack of culture surrounding lessons learned, a lack of leadership, or a combination of any of these elements. In particular, it is not enough to post the lessons learned in a general database. The hazard information needs to reach those facing the hazard on the line, such as the person issuing a work permit for maintenance in hazardous installations, subcontractors responsible for maintenance, production process operators, etc.
- Lack of awareness of chemical risks. Small and medium enterprises, and particularly companies that are downstream users, rather than manufacturers, may also not fully appreciate the risk management requirements that come into play when they handle hazardous substances in certain volumes. Small agricultural product distributors, food production and storage companies, semiconductor manufacturers, are some typical sites of this nature. Moreover, they often do not have a sufficient level of hazardous activity to experience process safety accidents or near misses very frequently. They often may not recognise the seriousness of the hazard or that they should be actively refreshing their knowledge of potential accident scenarios.

3.2.2 Improving dissemination and application of lessons learned in industry

Implementing a commitment to lessons learned requires a multidimensional strategy. In the first instance, a company has to create an atmosphere where active lessons learning is clearly encouraged. Secondly, the company also has to continually work on reducing barriers to reporting and using lessons learned. Finally, it has to take every opportunity to reinforce the value of lessons learned and convince employees and contractors that they are relevant to their work. Some techniques that can create conditions for active lessons learning include:

- Presence of an open “no-blame culture”. The leadership can have a tremendous influence on whether a site has a learning culture, by actively promoting neutral exchanges on failures and potential failure scenarios. Such a trust environment is often recognisable from certain attributes, such as ample communication about past failures, co-operation on all levels to prevent failure, and extensive exchange of competence and experiences across the organisation about risks and risk management associated with known hazards.
- Promoting reporting and exchange by the company. Allocation of adequate resources and time for maintaining high safety awareness is also important. For example, companies can promote reporting through simplification of the process, and routinely giving training on the importance of prompt investigation of incidents and implementation of improvements. Regular discussion and distribution of information, such as safety alerts, lessons learned and key performance indicators, is another way of promoting reporting and exchange of information.
- Making good quality narratives available. Lessons learned is often about telling stories in a way that both the lessons are memorable and can be easily generalised for application in other contexts. Making good quality narratives available from investigation reports and in databases online may help spread *a selection* of good stories and important lessons learned.
- Making databases more readable and searchable. The use of an efficient search engine and keywords can help promote use of the database. An additional technique is to present the

accidents in a list or as a result of a search as short summaries, so that the user can filter the selected accidents quickly, and only click on links to the full report of those that fit the user's criteria. Where there are language differences in the work place, a translation function may be necessary, for example, in multinational corporations or on sites where many line workers are not native speakers of the national language.

- Reinforcing the relevance of lessons learned through action. There is nothing more powerful than demonstrating the importance of lessons learned by applying them when they are relevant. Companies have several opportunities to incorporate lessons learned into routine activities, through process hazard and job analyses, in audit and control functions, review of processes and procedures, change management, discussion in safety meetings, and various other functions.
- Promoting reporting and exchange by the authority. Authorities may review, as part of inspections, the site's previous incidents over a period of time and check if all notifiable incidents, including incidents that are interesting for lessons learned, have been reported. This practice allows for a good discussion with the operator about the selection criteria and how to decide when to report border-line cases. Authorities may also advise operators to have an automatic prompt in their investigation procedure when external reporting requirements might be relevant. In general the authority should also seek to refrain from using punishment to stimulate reporting, except in extreme cases.

Notably, authorities may be both responsible for preventing re-occurrence of incidents and assigning guilt. These are two different goals that are partly in conflict with each other. In some countries the inspectorates have both roles. There are no simple resolutions to the conflict, but one possibility mentioned was to separate the reporting of causes from the reporting of lessons learned and actions to prevent similar accidents.

3.2.3 Dissemination of lessons learned in inspection authorities

The interaction with operators at different points of the learning cycle, in order to obtain lessons learned transferred into implementation among operators, was seen as a key challenge for inspectors. According to the MJV participant survey, sharing of lessons learned, having sufficient time and resources, the identification and application of relevant lessons learned at site level, and obtaining sufficient good quality information were the challenges most often by the 28 respondents.

The following is a list of all the challenges mentioned with the number of times it was cited by respondents in brackets:

- Taking into account lessons learned of other organisations (5)
- Having the time and resources to study and produce lessons learned (4)
- To ensure that lessons learned are known and applied on the sites where they are relevant (5)
- Having sufficient good quality information in the report to fully understand lessons learned of the accident (3)
- Obtaining a thorough investigation and full cooperation of operators with a full disclosure of all the pertinent facts and information (2)
- Good cooperation between authorities during the investigation (2)
- Quality of information technology used for searching and reporting (1)
- Knowing where and how to find useful information (1)
- Training of inspectors on investigation of accidents (1)
- A lot of lessons learned are not in one's native language (1)

Many opportunities exist for spreading information from lessons learned. The most important thing is to make conclusions and lessons learned from incidents publicly available. At the workshop, the participants listed a number of mechanisms for spreading the information, as follows:

- Bulletins and reports of accident case studies
- Presentation at conferences
- Inspection campaigns based on a lessons learned
- Leaflets on specific lessons learned topic
- Joint workshops between different authorities with a role in Seveso implementation
- Industry specific workshops on accident cases
- Workshops between inspectorates in different countries (see **Text Box 5**)
- Videos and interactive tools describing the accident event and what went wrong (**see Text Box 6**)
- Teaching packages based on lessons learned themes from specific accidents
- Professional development and training courses on specific process safety topics

The IMPEL Lessons Learned Seminar

In France, BARPI organizes every second year, within the framework of IMPEL, a lessons learnt seminar, where inspectors from all European countries are invited. Presentations can be downloaded from the ARIA web-page. Tukes in Finland discusses the investigation report with the operator, shares the report on their web-page and organizes briefings about the accident in different forums.

Text Box 5 An example of good practice: The IMPEL Lessons Learned Seminar

The Learning Experience Report

Major chemical companies have, over the past years, developed structures and mechanisms to try and tackle the issues of organisational learning. One of the techniques that have been adopted by many companies is that of "Learning Experience Reports" (LER). The concept here is to improve safety performance by sharing knowledge through the analysis of events and the exchange of experiences.

Often these LER are held on company computer systems and can be accessed throughout the organisation. However it is not only the free accessibility of the reports which is important, but also organisational requirements which ensure that LER are accessed when carrying out design work, plant safety reviews, site audits, training etc. Additionally internal business meetings are required to include (or start) with a "safety moment", that is a short review or presentation of a safety relevant aspect. This would typically cover recent accidents or process safety "near misses" either from their own site or another location within the company

Text Box 6 An example of good practice: Learning experience reports

Many participants in the workshop also cited the particular problem of finding exact matches in lessons learned sources for hazards and risk management problems associated with specific sites. Most often one needs to generalise lessons learned or transfer them into a slightly different context. This requires time, experience and knowledge.

Participants mentioned various ways to overcome this challenge including periodic review of lessons learned publications, participation in yearly workshops on lessons learned, and learning how to research lessons learned from open sources on the Internet including the various chemical accident databases and sites linked to chemical accident investigation reports. Specific suggestions of this nature included:

- Planning resources in the inspectorate and making available or assigning certain staff to be specialists on topics, e.g., corrosion, reactive hazards, etc., with up-to-date knowledge on the lessons learned available for that topic.
- Assigning lessons learned as a specialist task of one inspector or group of inspectors in the inspector.

Results from inspection of the learning cycle of accidents and incidents

From 2008 to 2012, one country conducted an inspection program directed towards the learning cycle of accidents and incidents. A total of 70 companies were visited by 14 different inspectors. The majority of the companies belonged to chemical (38%), distribution & warehousing (29%), energy (12%) or plastic producing industry (9%). The inspection program was supported by a Site Inspection Tool (SIT) that consisted of a questionnaire for field inspections. The questionnaire was developed by a working group, which applied two criteria on the selection of questions:

- Relevant – enforceable by legislation or codes of good practice
- Verifiable – through visual documents, installations or interviews

Questions related to individual incident investigations were verified by several spot checks. All checked documents had to completely fulfil the requirement in order to pass the test positively. The questionnaire and the inspection result are listed in a table at the end of this paragraph.

The top five questions that most companies failed were (percentage of companies that failed in brackets):

- Was a target date set for each action resulting from the investigation? (36%)
- Were the underlying organisational causes identified? (36%)
- Does the general instruction specify an investigation technique that is explicitly focused on not only investigating the immediate causes but also the underlying organisational causes? (27%)
- Does an instruction exist that determines how accidents and incidents should be reported? (27%)
- Is the person assigned who determines whether an accident or incident should be reported to the authorities as a major accident? (27%)

The inspection result could be summarised by the following picture of the learning cycle, where green elements work quite well, while red elements does not work so well. *Most deficiencies were found in the depth of investigation and the monitoring and follow-up of actions.* The results indicated strongly that companies should focus on improving their mechanisms for learning lessons, identifying actions for applying lessons learned, and following through on implementation of these actions once identified.

From this exercise, the competent authority identified five points of attention for future inspections:

- Width: Look for enough generic causes.
- Depth: Look for enough system causes, always look for human + organizational + equipment related causes.
- Time: go enough back in time.
- Scope: look for sufficient quantity of cases.
- Implementation: look for target date, responsibility and expired actions.

Text Box 7 Results from inspection of the learning cycle of accidents and incidents

- Basing inspection themes on a specific lessons learned topic and building awareness of lessons learned on this topic among operators.
- Checking scenarios in safety reports against past accidents both at the operator and elsewhere.
- Share inspection themes (campaigns) as well as tools with other inspectorates within the country or internationally, for example, through OECD and EU networks.
- Use lessons learned by one operator when inspecting others
- Include a lessons learned a discussion item in routine internal meetings.

3.2.4 Inspection of industry to promote a learning organisation

The Seveso Directive explicitly promotes the use of lessons learned. Through its various requirements, e.g., the safety report, the safety management system, accident investigation and reporting, the Directive gives opportunities for the authorities to intervene with operators regarding investigation, reporting, consultation and application of lessons learned. For this purpose, participants shared several suggestions on how the information can be applied in inspection:

- Ask operators how they broadcast and apply their own lessons learned. Inspections can include checking dissemination within a company, for example, by interviewing maintenance personnel
- Verify with multinationals that they are drawing experience from incidents from other branches or from sites in the company
- Check that relevant incidents occurred at the operator or elsewhere are covered by the scenarios and risks presented in the safety report
- Identify a lessons learned them relevant to safety management, e.g., management of change. Check that lessons learned on this topic are reflected in the safety management systems during an SMS inspection
- Review whether the operator has consulted its industry sources for lessons learned relevant to site operations and substances used

One inspector also presented a model of an inspection questionnaire that could be used to inspect the first loop of the learning cycle, based on an inspection campaign that took place in Belgium (The results of the inspection campaign are shown in **Text Box 7**. The questionnaire used in the campaign is featured in **Annex 5**). Results from applying this questionnaire in Belgium showed that most deficiencies were in identifying root causes and in implementation and follow-up of actions.

3.3 Conclusions

The dissemination of lessons learned so that they are understood widely is possibly even more challenging than any aspect of the lessons learning process. It takes both time and skill to communicate lessons learned in an effective manner. A further difficulty is identifying lessons learned and matching them to specific sites that may need them because they are relevant for a particular type of substance, process, or equipment.

The following observations represent the highlights from this discussion:

- Government inspectors as well as industry organisations and other safety organisations play a crucial role in supporting small and medium sized companies.
- Actions that are not designed to embed lessons learned into the organisational memory will fade away very quickly. Therefore, it is important to evaluate to what extent measures are sufficiently embedded.

- There should already be a dissemination strategy included in the investigation report, with time stamped actions.
- An accident should also trigger a review within the inspection authority on lessons learned on their part.
- Operators and authorities should maintain a second loop in the learning cycle, where lessons learned from a bulk of accidents are drawn, and measures are taken.
- Emotional stories from accidents are important for people to understand and act upon.
- Inspectorates also need to learn from accidents and incidents to improve their inspections, in general, and on specific sites.
- Inspectorates should evaluate whether accidents could have been prevented by improved guidance, improved enforcement or improved legislation.
- There are a number of way in which information from past incidents can be used in inspections. For example, inspection themes may be based on lessons learned, lessons learned from an accident on one site could be applied on sites of other operators, etc. Scenarios in safety reports can also be checked against past accidents at the site, in the company, and in the industry at large.
- Inspectors can be particularly effective in playing an advisory role rather than adopting a punishing regime when it comes to stimulating operators to report accidents and incidents to the authority.
- To help resolve the conflict between prevention and assigning guilt, the reporting of causes could be separated from the reporting of lessons learned and actions to prevent similar accidents.

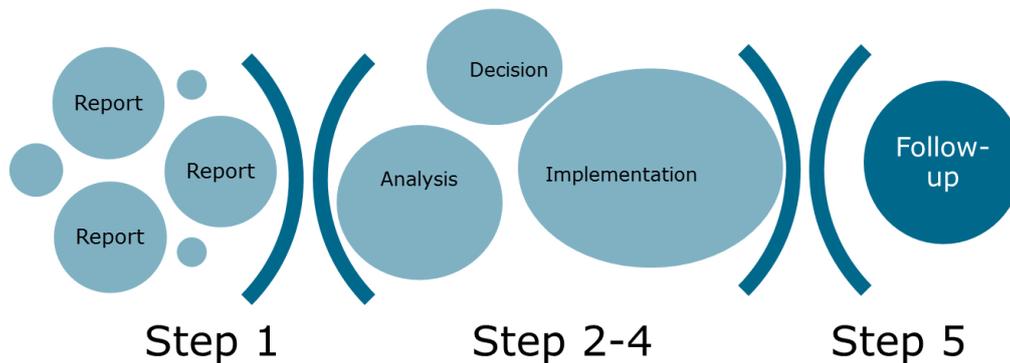
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4 A learning cycle model

Based on a doctoral thesis by Anders Jacobsson (Jacobsson,2011) and other research, a model for learning lessons that can be applied to learning lessons for chemical disasters was proposed by Carina Fredstrom of the Swedish Civil Contingencies Agency. The model is based on a learning cycle of 5 steps, which all are necessary for optimal learning:

- Step 1 – reporting
- Step 2 – analysis (or investigation)
- Step 3 – decision on measures
- Step 4 – implementation of measures
- Step 5 – follow-up of measures

The learning cycle



Questionnaire for the incident learning cycle

- Is there a formal incident management system?
- Are the 5 steps of the learning cycle present? Remember: Reporting, Analysis, Decision on measures, Implementation of measures and Follow up of measures
- Do all steps work? Are there weaknesses?
- Are there any employees who can work as learning agents? If yes, do they have the right competence? Are they given enough resources?
- Is there a second loop? Remember the first loop when you analyse one incident and the second loop when you look at the bigger picture and compare several accident investigation reports.
- What is the threshold for reporting? Is it reasonable? Is it well-known to the employees?
- Are there a lot of hidden statistics? Compare to the rule of thumb of 1 incident worth reporting per employee and year.
- What form do the procedures for analysis take? Do the analyses have enough depth? Are any accident models used? Causal trees?
- How well are lessons transmitted to the organisational memory? Does information really reach all employees?
- Are there enough resources allocated to every step of the learning cycle?

Text Box 8 Questions for the incident learning cycle

The investigation of individual incidents is called the *first loop* in the learning cycle. There is also a *second loop* in the learning cycle, where a number of incidents are analysed together. This allows extraction of significantly more knowledge. Are there similarities or patterns in terms of location where incidents happened, time of day, who was involved, type of injuries, equipment or process concerned? Are some causes more common than others? If for instance new employees are more often involved in incidents it may point to general deficiencies in the introduction or training of new employees. The second loop involves more or less the same five steps as the first loop.

Similar terms, but with a different meaning, include the *single loop* and *double loop learning* from incidents, that describe the depth of learning achieved. Single loop learning leads only to minor modifications often related to the specific circumstances of the incident, such as correcting a procedure or repairing a piece of equipment. Double loop learning affects the governing variables of the organisation and leads to profound changes in ways of working or to the technical solution. Double loop learning may occur both from investigation of individual incidents and from the second loop learning cycle on a large number of incidents.

To make sure that knowledge is actually gained learning agents are needed at the different steps of the learning cycle. Learning agents are persons who are responsible for the efficiency of one or more steps of the learning cycle. They are visible and respected in the organisation and have the ability to encourage people to contribute.

Text box 8 contains a short checklist for evaluating the efficiency of the learning cycle, in conjunction with inspections, supervision and policy work, following the principles outlined below. A company can also use it in order to evaluate its own organisation.

Step 1 – Reporting

The challenge is to get even minor incidents reported in order to obtain a clear, truthful picture of what goes on in the organisation. If employees fear blame and punishment, incidents will not be reported. The safety culture and the behaviour of individual leaders in the organisation are crucial. Blaming is not the only obstacle. Many employees might not report because they do not find minor incidents worth reporting. Often people believe that the more severe consequences, the more reasons for reporting it, which is not the case. Instead, all incidents with potential for learning should be reported. Clear instructions on what should be reported and well educated employees are needed.

The incident management system should be easy to use, especially at the first step of reporting, and be possible to adapt to the needs of the specific organisation. Despite a well-functioning reporting system and educated employees some incidents will never be reported. One rule of thumb could be that an organisation should *as a minimum* have at least as many incident reports per year as they have employees. sation

Step 2 – Analysis

Useful analysis of individual incidents requires time and resources. The person in charge of the analysis must be well informed of the situation but also respected within the organisation. He or she may need support from management as well as from specialists. As much information about the incident as possible, should be gathered as soon as possible in order to understand what has happened. This is done by studying the initial incident report, inspecting the location, interviewing those involved and reviewing written documentation like logbooks.

When enough information has been gathered the next step is to derive every possible cause of the incident back to its root. This can be done just by asking the question “why” over and over again, until no explanation within the authority of the organisation can be found. This method is the simplest form of a group of methods called causal trees. An alternative is to use more rigorous forms of logic trees or predetermined causal trees, where different causes are already suggested.

One can apply different models in order to visualize the causal relationships. There are at least three different types of models, sequential, epidemiological and systemic models. The latter is the type mostly used in recent research. The incident is in that case not seen as a line of events but rather a number of parallel and independent series of events that contribute to an accident.

Step 3 – Decision on measures

Based on the facts collected and the analysis of the causes in step 2, flaws in the safety system can be pinpointed and corrective actions proposed. Measures should correspond to lessons learned in the analysis phase, and root causes should be addressed. It is important to remember that the same lesson learned

should be spread geographically, for example to a similar operation, at another department, in another part of the company or even to customers or competitors.

An example of measures based on single loop learning could be regular replacement of a specific item that had corroded and caused an incident (direct cause). It could also be to increase the corrosion competence in the organisation, both in terms of employing a corrosion expert and by training of the construction and maintenance departments (root cause). Double loop learning would be major alterations of the product or production method in order to reduce corrosivity and make the manufacturing process inherently safer.

Step 4 – Implementation

When decisions have been made the corrective actions should be implemented. This requires that the decisions have been made on the right management level, so that leaders have authority and resources to implement them. Information about necessary changes needs to reach everyone, and not to stay within the safety department. This suggests that the incident management system should have a direct line to the internal network for all co-workers.

Step 5 – Follow-up

This step is intended to make sure that the corrective actions are fully implemented within the stipulated time frame. Normally this should be executed at management team level, with support from the person in charge of the incident handling system.

Both technical staff and managers need to learn. The learning culture is more effective on the technical side than on the managerial side for several reasons:

- Reluctance to share managerial shortcomings.
- Less specific knowledge, therefore more difficult to transfer.
- Lack of managerial standards and training to embed lessons learned.
- Lack of use of the written word, combined with less value attached to experience

Memory declines very rapidly, unless it is internalised in the knowledge base that is transferred to future generations of employees. This requires a learning culture. Lessons must be embedded in design codes, engineering standards, operational standards, training and education. The written word has a longer lifetime but requires that it is actually used.

Thus the lessons learned must reach all employees, be included in policies and instructions as well as in engineering standards, and implemented in the manufacturing process.

List of Text Boxes

Text Box 1 Break-out session 1	12
Text Box 2 Break-out session 2	12
Text Box 3 Communities that benefit from lessons learned from chemical accidents.....	27
Text Box 4 Nynas: A case study of lessons learned practices.....	30
Text Box 5 An example of good practice: The IMPEL Lessons Learned Seminar.....	34
Text Box 6 An example of good practice: Learning experience reports	34
Text Box 7 Results from inspection of the learning cycle of accidents and incidents	35
Text Box 8 Questions for the incident learning cycle	40

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List of Figures

Figure 1 The Rasmussen/Svedung Hierarchical model [21].....	14
Figure 2 MTO analytical framework (Sklet, 2002) [26].....	16
Figure 3 Diagramme of the STEP method [27].....	16
Figure 4 Framework of a Deviation Analysis [27].....	17
Figure 5 Diagramme of the Accimap method [21].....	17
Figure 6 Who does the accident investigation for a typical major Seveso accident in your country?.....	21
Figure 7 What is the role of the Seveso inspector before, during or after an accident?	21
Figure 8 Does your inspection authority (or another inspection authority) make any demands or recommendations on what methods should be used for the accident investigation in case the operator does the investigation?.....	22
Figure 9 How effective is your country's system for investigating major Seveso accidents in your opinion? 23	
Figure 10 Do you review and quality assess accident investigation reports?.....	24
Figure 11 Do you feel that you have enough knowledge on accident investigation methodologies to perform the quality assessment?.....	25
Figure 12 Does your country have a national database for Seveso accidents or for major industrial accidents including Seveso-types?	28
Figure 13 Do you have difficulties extracting lessons learned from databases?	29

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E-mail services related to accidents

ARIA database (France) also has a Newsletter function which provides e-mail notification of recent occurrences (in French). <http://www.aria.developpement-durable.gouv.fr/inscription--4864.html>

CCPS Process Safety Beacon – this is a resource, which does not report individual accidents, but rather highlights one specific process safety message per month and is designed for manufacturing and operating personnel.
<http://www.aiche.org/ccps/resources/process-safety-beacon>

European Media Monitoring (EMM) service - Free, over 50 languages, media around the world. Links to automatic Google translations in English, French and German. Possible to subscribe (for free) to a daily delivery of all the latest news from around the world in the language(s) of your choice.

Chemical accidents:

<http://emm.newsbrief.eu/NewsBrief/alertedition/en/mahb.html>

Petroleum refinery accidents:

<http://emm.newsbrief.eu/NewsBrief/alertedition/en/PetroleumRefineries.html>

U. S. Chemical Safety Board (CSB) e-mail services: You can find the e-mail sign-up fill in box at www.csb.gov .

ZEMA database (Germany). The reader is required to register online and then information is provided when a reportable event occurs (in German). <http://www.infosis.uba.de/index.php/de/aim/index.html>

Videos about accidents

Piper Alpha emotional video at <http://www.joinedup-thinking.co.uk>.

CSB videos at www.csb.gov .

Piper Alpha emotional video at <http://www.joinedup-thinking.co.uk> The presentation by Sir Charles Haddon Cave at the Piper 25 conference. http://www.youtube.com/watch?v=y99_lhFFCsk

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Annex 2 Selection of sources of investigation reports and analyses of chemical accidents

ARIA (France) <http://www.aria.developpement-durable.gouv.fr/>

Hosts the ARIA databases of industrial accidents but also contains many in-depth reports of those accidents including chemical accidents.

Dutch Safety Board <https://www.onderzoeksraad.nl/en/>

The Dutch Safety Board investigates into the causes of disasters and accidents, including industrial disasters.

EC-JRC Lessons Learned Bulletin <https://minerva.jrc.ec.europa.eu/en/shorturl/minerva/publications>

A summary of lessons learned from accidents based on a thematic topic.

IChemE Loss Prevention Bulletin <https://www.icheme.org/knowledge/loss-prevention-bulletin/free-downloads/articles/articles/>

The IChemE Loss Prevention Bulletin (LPB) is a leading source of process safety case studies from 40 years of publication. Subscription to the LPB can be ordered at <https://www.icheme.org/knowledge/loss-prevention-bulletin/subscribe/>

Several articles are also available free of charge online: <https://www.icheme.org/knowledge/loss-prevention-bulletin/free-downloads/articles/articles/>

A few special complete issues of the LPB are also available online <https://www.icheme.org/knowledge/loss-prevention-bulletin/free-downloads/issues/issues/>

United Kingdom COMAH Competent Authority

<http://www.hse.gov.uk/comah/investigation-reports.htm>

The COMAH Competent Authority undertakes investigations as a result of an incident or complaint at a COMAH establishment.

U.K. Health and Safety Executive Safety Bulletins <http://www.hse.gov.uk/safetybulletins/>

The UK HSE issues safety bulletins to communicate major faults that would result in a serious or fatal injury and where immediate remedial action is required. Many of these are derived from a chemical incident occurrence.

UK Health and Safety Executive accident reports <https://www.icheme.org/membership/communities/special-interest-groups/safety-and-loss-prevention/resources/hse-accident-reports/>

By arrangement with HSE a selection of old/out-of-print accident reports are available through the IChemE.

U.S. Chemical Safety Board www.csb.org

The CSB is an independent federal agency charged with investigating industrial chemical accidents.

U.S. National Transportation Safety Board

<https://www.nts.gov/investigations/Pages/default.aspx>

The NTSB investigations include accidents in transportations and pipelines carrying dangerous goods.

UEMS (Unplanned Explosions at Munitions Sites) database

<http://www.smallarmssurvey.org/home.html>

Hosts a database of unplanned explosions occurring at munitions sites, including production and storage but also a list of publications associated with munitions explosions, including accident studies, on its website.

The following organisations investigate incidents in transport and their site includes reports from investigations of accidents in transport involving dangerous substances.

Finnish Safety Investigation Authority <https://www.turvallisuustutkinta.fi/en/index.html>

The Safety Investigation Authority investigates all major accidents regardless of their nature as well as all aviation, maritime and rail accidents and their incidents.

Japanese Failure Knowledge Database <http://www.sozogaku.com/fkd/en/>

The Japanese Institute for the Advancement of Technology hosts the Failure Knowledge Database, a collection of case studies covering 16 industries, including the Petrochemical and the Chemical industries. There are 100 cases presented for each industry.

Swedish Accident Investigation Authority <https://www.havkom.se/en> /

The SHK is a government authority which investigates accidents and incidents with the aim of improving safety, including accidents involving dangerous substances.

Swiss Transportation Safety Board <https://www.sust.admin.ch/en/stsb-homepage> /

The STSB investigates accidents and dangerous incidents involving trains, aircraft, inland navigation ships, and seagoing vessels.

Transportation Safety Board of Canada <http://www.tsb.gc.ca/eng/>

The Transportation Safety Board of Canada (TSB) is an independent agency that advances transportation safety by investigating occurrences in the marine, pipeline, rail and air modes of transportation, including incidents involving dangerous goods.

Annex 3 Selection of publicly available databases of chemical accident data

ARIA (France) <http://www.aria.developpement-durable.gouv.fr/>

A database operated by the 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. Chemical accidents are reported that meet established criteria.

Number of events: >10,000 **Time span:** > 1970 **Geographic coverage:** France and some major disasters in other countries

Purpose: Lessons learned **Format:** Free text only

Description of content: Concise, and sometimes, comprehensive technical summaries of serious accidents from all hazard sources. Reports are verified by technical experts. Impacts are reported in free text. All accidents associated with sources classified as high hazards and meeting a certain impact criteria are recorded in this database in accordance with French legislation.

Data on impacts: Each incident is classified according to the EU Gravity Scale based on human health, environment, community and economic impacts

CSC (Korea) Chemistry Safety Clearinghouse <https://csc.me.go.kr/>

Chemical accident and near miss data notified to authorities according to Korean law

Number of events: > 400 **Time span:** >2014 **Geographic coverage:** Korea

Purpose: Lessons learned and causal and impact statistics **Format:** Classified by technical cause

Description of content: Short summaries of chemical accidents on fixed sites and in transportation, reported in accordance with Korean legislation. For each accident there are statistics on human health impacts, and a mix of qualitative and quantitative information on other impacts.

Data on impacts: Quantitative data on human health impacts. Inconsistent data in all other categories. Economic impacts not collected

eMARS <https://emars.jrc.ec.europa.eu>

Accidents reported to the European Commission in compliance with Seveso Directive Annex VI criteria.

Number of events: >1,000 **Time span:** > 1984 **Geographic coverage:** EU/OECD countries

Purpose: Lessons learned and causal and impact statistics **Format:** Free text and classification of events by various filters (substance, industry type, impact, etc.)

Description of content: Completeness and precision of descriptions varies considerably. For each accident there is a free text description of the incident, statistics on human health impacts, and a mix of qualitative and quantitative information on other impacts. All EU accidents on high-hazard (Seveso) fixed sites meeting a certain impact criteria are recorded in this database in accordance with the EU Seveso Directive.

Data on impacts: Quantitative data on human health impacts. Inconsistent data in all other categories. Economic impacts not collected

<p>IOGP Safety Performance Indicators and Process Safety Events (International Association of Oil and Gas Producers-IOGP) https://www.iogp.org Accident data reported by IOGP participating member companies</p> <p>Number of events: >6,000 Time span: 2015 Geographic coverage: Participating members worldwide</p> <p>Purpose: Lessons learned and causal and impact statistics Format: Classified by technical and underlying causes</p> <p>Description of content: IOGP is one of the first industry organisations to report aggregated data on process safety events occurring in member company operations. Activities by level of impact (Tier 1 or Tier 2) and type of operation. Individual events are described separately from statistics in a case study format (Process Safety Events).</p> <p>Date on impacts: Each incident is classified as Tier 1 or Tier 2 severity based on human health, environment, community and economic impacts</p>		
<p>ProcessNet (German industry) https://processnet.org/en/incident_db.html Hazardous incidents in process engineering facilities managed jointly by DECHEMA and VDI</p> <p>Number of events: ~100 Time span: > 2000 Geographic coverage: Not available</p> <p>Purpose: Lessons learned and causal information Format: Free text</p> <p>Description of content: Concise technical summaries of chemical accidents.</p> <p>Data on impacts: Very limited if available at all</p>		
<p>Process Safety Incident Database (PSID) http://www.psidnet.com/ Process safety incidents reported by member companies of the AIChE Center for Chemical Process Safety</p> <p>Number of events: ~100 Time span: > 2000 Geographic coverage: USA</p> <p>Purpose: To pool process safety incident experience among participating companies so they can learn from the experiences of others without suffering the consequences of failures, while minimizing corporate liability.</p> <p>Description of content: Concise summaries of serious chemical accidents. Detailed explanation of lessons learned and adequate detail on circumstances.</p> <p>Data on impacts: Specific numbers provided on deaths and injuries. Limited detail on other types of impacts</p>		
<p>RISCAD (Japan) Relational Information System for Chemical Accidents Database https://sanpo.aist-riss.jp/riscad/ Operated by the Japanese National Institute of Advanced Industrial Science and Technology</p> <p>Number of events: >7500 Time span: > 1949 Geographic coverage: Japan</p> <p>Purpose: Lessons learned and causal and impact statistics Format: Technical causes by keyword</p> <p>Description of content: Summarises accidents reported by various firefighting, response and safety organisations. For each accident there is a free text description of the incident, statistics on human health impacts, and free text descriptions of other impacts.</p> <p>Data on impacts: Quantitative data on human health impacts</p>		

UEMS (Unplanned Explosions at Munitions Sites) database

<http://www.smallarmssurvey.org/home.html>

Unplanned explosions occurring at munitions sites, including production and storage, since 1979

Number of events: >500 **Time span:** >1979 **Geographic coverage:** Global

Purpose: Motivate improved reduction of risk associated with munitions sites

Format: Classified by ty technical and underlying causes

Description of content: The Small Arms Survey defines UEMS as the accidental explosion of stockpiles of ammunition and explosives at storage sites, whether the stockpiles are properly stored or are abandoned, damaged, or improperly stored. Its work is intended to highlight a global problem with poor risk management at many these sites.

Data on impacts: Statistics on fatalities and injuries

Work Accident Map (China) China Labour Bulletin

<http://maps.clb.org.hk/accidents/en#201801/201807/1821>

Work accidents collected from the media and other sources by the China Labour Bulletin

Number of events: >1700 **Time span:** >2014 **Geographic coverage:** China

Purpose: Lessons learned and impact statistics **Format:** Mapped by location, location links to short summary with reference to a news report

Description of content: Database and map of workplace accidents including chemical accidents. Short summaries plus a link to a newspaper description are included. Statistics on human health impacts only.

Date on impacts: Quantitative data on human health impacts (onsite only)

ZEMA (Germany) <http://www.infosis.uba.de/index.php/de/site/12981/zema/index.html>

Database managed by the German Federal Environment Agency of hazardous incidents and incidents in process engineering facilities.

Number of events: >750 **Time span:** > 1980 **Geographic coverage:** Germany

Purpose: Lessons learned and causal and impact statistics

Format: Free text

Description of content: Concise technical summaries of chemical accidents. All accidents associated with sources classified as high hazards and meeting a certain impact criteria are recorded in this database in accordance with German legislation.

Data on impacts: Quantitative data on human health impacts. Inconsistent data in all other categories. Economic impacts not collected

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Annex 4 Selection of conferences and symposium series that publish proceedings with lessons learned from chemical accidents

AICHE Annual Loss Prevention Symposium

Future events - <https://www.aiche.org/ccps/resources/conferences>

Archive of proceedings: <https://www.aiche.org/ccps/resources/publications> (Available for purchase)

AIDIC CISAP Conference series

Future events - <https://www.aidic.it/eventi.php>

Archive of proceedings - <https://www.aidic.it/cet/> (open access – free of charge)

The Italian Association of Chemical Engineers organises an international conference on safety and environment in Italy every 2 years. Notably, all presentations are published in its open source journal Chemical Engineering Transactions in English.

European Safety, Reliability & Data Association.(ESReDA) Project seminars

The website of upcoming seminars and archives of past seminars - <https://www.esreda.org/events/>
(open access – free of charge)

For many years ESReDA has fostered exchange and research through project groups on accident analysis, safety and reliability, sharing their work and soliciting discussion through frequent seminars.

European Conference on Process Safety and Big Data

Future events - <https://epsc.be/Events/Current+events.html> and <https://www.aiche.org/ccps/resources/conferences>

Archive of proceedings - <https://www.aiche.org/ccps/resources/publications> (Available for purchase)

A relatively new conference series jointly organized by the European Process Safety Centre and the Center for Chemical Process Safety

IChemE Hazards Annual Symposium

The most recent Hazards Symposium - <https://www.icheme.org/events>

The archive of past Hazards Symposiums - <https://www.icheme.org/membership/communities/special-interest-groups/safety-and-loss-prevention/resources/hazards-archive/> (many are free of charge, some require payment)

IMPEL Seminar on Lessons Learnt from Industrial Accidents

Future events - www.impel.eu

Archive of proceedings - <https://www.aria.developpement-durable.gouv.fr> – Search on “IMPEL”
(open source – free of charge)

On behalf of the European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL), the French Ministry of Environment organizes a seminar on lessons learned every two years in France. Proceedings are available to the public on the website of the ministry’s industrial accident data management service, ARIA.

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Annex 5 Inspection questionnaire – Accident and incident learning cycle

Reporting system
Does an instruction exist that determines how accidents and incidents should be reported?
If the notification method differs for different categories of accidents and incidents, are the different categories defined in an instruction?
Is it possible for everyone within the company to report an accident or incident?
Is the person who reported an issue informed of what happened to this issue?
Does the reporting system cover accidents and incidents involving both its own employees but also third parties?
Does the company have an overview of all accidents and incidents that have happened on its premises and that were reported?
Notification to the different regulatory agencies
Is the person assigned who determines whether an accident or incident should be reported to the authorities as a major accident?
Is the person assigned who determines whether an accident or incident should be reported to the authorities as a severe occupational accident?
Were all major accidents reported to the Coordination and Crisis Centre of the Government and the Seveso inspection agencies?
Investigation report
Do all reports mention the persons who were involved in the investigation?
Is there an investigation report available of all incidents and accidents?
Do all reports mention the date of the investigation report?
Investigation methodology
Does an instruction exist describing the investigation of accidents?
Does the instruction fix the depth of the investigation?
Are the investigations executed as prescribed in the instruction?
Investigation team
Were all the persons directly concerned involved in the investigation?
Were the members of the hierarchy involved in the investigation?
Was the safety officer involved in the investigation?
Description of the facts
Does the investigation report give a complete and comprehensible description of the facts?
Were the reports supported with photographs?
Were the testimonies necessary in the context of the investigation included?
Depth of investigation
Were the underlying organisational causes identified?

Does the general instruction specify an investigation technique that is explicitly focused on not only investigating the immediate causes but also the underlying organisational causes?
Has the effectiveness of the intervention been studied?
Content of actions
Are the actions sufficient to address the underlying organisational causes?
Are the actions sufficient to address the direct primary causes?
Are the actions sufficient to prevent similar situations elsewhere in the company?
Assignment of actions
Was a target date set for each action resulting from the investigation?
Was the responsibility assigned for the execution of each action resulting of the investigation?
Monitoring of actions
Is there a follow-up to the implementation of the actions?
Are there only a limited number of actions with an expired deadline?
Is there a procedure that describes the management of actions?
Additional suggestions from MJV participants
Does a second loop exist (analysis of a number of incidents together)?
Are the actions sufficient to embed lessons learned into the organisational memory?
Are the actions sufficient to disseminate the lessons learned both within and outside the company?

Annex 6 Participant survey questions

1a. Do you work as a Seveso inspector?

- (1) Yes
- (2) No

1b. What is the role of the Seveso inspector before, during or after an accident?

- (1) To review the operators routines for their accident investigation of different types of incidents
 - (2) To quickly be at the site after an accident to better understand what happened
 - (3) To quickly be at the site after an accident to follow the after work
 - (4) To demand a proper investigation to be done
 - (5) To review and quality assess the accident investigation report
 - (6) To read and judge if the measures proposed by the operators are enough
 - (7) To quickly be at the site after an accident to secure evidences for a potential criminal investigation
 - (8) To make a prosecution application to the police/prosecutor if needed
 - (9) To decide if there should be a criminal investigation or not
 - (10) To assist the criminal investigator/s
 - (13) I don't know
 - (12) Other, please explain your answer below
-

2a. Who does the accident investigation for a typical major Seveso accident in your country? Please check all that apply.

- (1) The operator
- (2) The Seveso inspection authority
- (3) Another authority
- (4) It depends on certain circumstances
- (5) I don't know

2b. If you have answered the Seveso inspection authority in 2a, which of the Seveso inspection authority/ies? Please check all that apply.

- (1) The environmental
- (2) The Seveso/Safety
- (3) The labour inspection
- (4) Other, please specify: _____
- (5) I don't know

2c. If you have answered another authority in 2a, please specify which authority/ies:

2d. If you have answered It depends on certain circumstances in 2a, on what does it depend?

- (1) Severity of accident
- (2) Fatalities
- (3) Environmental impact
- (4) Special points of interest
- (5) Regional regulations
- (6) Others, please specify: _____
- (7) I don't know

2e. Please clarify your answers further for 2a-2d if needed:

3a. Is your authority authorised to investigate major Seveso accidents?

- (1) Yes
- (2) No
- (3) I don't know

3b. What criteria is used to determine when your authority investigates an accident?

3c. If another authority also investigate accidents and you know (more or less) their criteria, please indicate the authority and their criteria here:

3d. Can your authority investigate chemical accidents that do not meet the Seveso criteria (Annex VI in the Seveso II directive)?

- (1) Yes
- (2) No
- (3) I don't know

3e. Is there any another authority that can investigate chemical accidents that do not meet the Seveso criteria (Annex VI in the Seveso II directive)?

- (1) Yes, please indicate which authority/ies: _____
- (2) No
- (3) I don't know

4. If an authority does not perform the investigation of a major Seveso accident, who will? For every box you check, please indicate if the organisation is involved "always" or "sometimes".

- (1) The operator, please indicate always or sometimes: _____
- (2) A consultant hired by the company, please indicate always or sometimes:

- (3) An independent government investigation service, please indicate always or sometimes: _____

(4) Other, please describe: _____

Please provide any further information that will help explain your answer.

5a. Do you review and quality assess accident investigation reports?

(1) Yes

(2) No

5b. Do you feel that you have enough knowledge on accident investigation methodologies to perform the quality assessment?

(1) Yes

(2) No

5c. Are there any deficiencies in the investigation reports that are more common than others? Please describe shortly.

6. Does your inspection authority (or another inspection authority) make any demands or recommendations on what methods should be used for the accident investigation in case the operator does the investigation?

(1) Always

(2) Sometimes

(4) Not usually

(5) Never

(6) I don't know

Please explain your answer and also, please indicate any guidance that are used or have been created for this purpose.

7. How effective is your country's system for investigating major Seveso accidents in your opinion?

(1) Very effective

(2) Somewhat effective

(3) Neutral

(4) Somewhat poorly

(5) Very poorly

(6) I don't know

Please explain your answer.

8. How does your country gather, analyze, conclude lessons and disseminate the information from national accidents?

9. Does your country have a national database for Seveso accidents or for major industrial accidents including Seveso-types?

- (1) Yes
- (2) No
- (3) I don't know

9a. Please name the database:

9b. Who manages the database?

9c. Why and when was the database established?

9d. If there is an Internet link to the database, please provide it here:

9e. What kinds of accidents are in the database? Please check all that apply.

- (1) Major Seveso accidents only
- (2) Other chemical accidents under related legislation, please explain:

- (3) Near-misses, please define: _____
- (4) Other, please explain: _____

9f. How many accidents:

...are in the database? _____

...are normally added each year? _____

I don't know _____

9g. Please explain how the database works. Who contributes to the database? Are their guidelines to how reports are submitted? Is it limited in detail or can one provide full reports? Are lessons learned normally included?

9h. Who uses the database in your country? Please check all that apply.

- (1) Seveso inspection authorities, please indicate which: _____
- (6) Other authorities, please indicate which: _____
- (2) Industry
- (3) Academia
- (4) The public
- (5) Other, please indicate: _____

9i. Please explain how each user uses the database, e.g., for case studies, are any reports, lessons learned or statistics produced, etc. and how frequently?

9j. What do you consider to be the strengths and weaknesses of the database?

9k. Are there any other databases on industrial accidents that also contain Seveso-type accidents or are otherwise useful for statistics or lessons learned applicable also to chemical processing sites? Please name and briefly explain. If there is an Internet link, kindly provide it.

10. Please indicate what databases or information sites you use for extracting lessons learned?

- (1) Our country's national database(s), please indicate the name(s):

- (2) eMARS
- (3) ARIA
- (4) ZEMA
- (5) CSB
- (6) Other, please indicate: _____
- (7) I do not use lessons learned from accidents in my work.
- (8) Other, please comment below

11. Do you have difficulties extracting lessons learned from databases?

- (1) Yes
- (2) No
- (3) I don't know

Please explain your answer:

12. Are some databases better than others?

- (1) Yes
- (2) No
- (3) I don't know

Please explain your answer:

13. Please explain how lessons learnt from accidents are gathered administered/managed between inspectors within the inspectorate/s in your country?

14. Please describe what you think are the most important challenges for inspection authorities in learning lessons from accident investigations?

15. Do you have good practices concerning learning from accidents that you follow in your authority and that you would recommend to other countries? If possible please provide three of them.

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