Lessons learned from major accidents having significant impact on the environment

Zsuzsanna Gyenes and Maureen Heraty Wood, Institute for the Protection and Security of the Citizen, European Commission – Joint Research Centre, via E. Fermi 2749, 21027 Ispra (VA), Italy

Major accidents with environmental consequences continue to occur with a disturbing frequency in recent decades. It is therefore useful to analyse lessons learned specifically from environmental accidents to promote better awareness of why these accidents still happen and precisely how they have had impacts on the environment and to what extent. In addition, it is worthwhile considering whether risk management practices and safety culture are adequately taking such hazards into consideration. For this reason, the Major Accident Hazards Bureau (MAHB) of the European Commission (EC) performed an analysis of all accident reports involving environmental consequences in its eMARS database. The eMARS database contains major chemical accidents occurring over a period of more than 30 years in European Union and OECD countries. Overall, it was found that a considerable number of accidents have led to measurable pollution to different environmental receptors, predominantly watercourses, and to a lesser extent to soil and air. Commonalities were also identified in relation to causes and contributing factors leading to these accidents along with weaknesses in the safety management system. The failure of safety management system and lessons learned from these accidents are presented in a systematic way with recommendations for future prevention.

Keywords: Seveso Directive, major accidents, lessons learned, eMARS, impact on the environment

Introduction

A number of severe accidents with significant impact on the environment that occurred in recent decades and in the 2000's (see Figure 2 in Appendix B), have demonstrated that the consequences of industrial accidents can have serious impacts not only to human health but to the environment. For this reason, it continues to be useful to analyse environmental accidents in order to obtain recommendations to reduce the likelihood and severity of impacts of such accidents in future. A notable concern in regard to prevention of environmental accidents is that prevailing approaches to prevention focus primarily on human health impacts of accidents rather than the environmental consequences. As such, the dominant concerns about human health can lead to neglecting equally safety barriers and technical measures necessary for protecting the environment. This tendency persists despite the fact that legislative frameworks such as the Seveso III Directive (European Commission, 2012) are often considered part of policy areas in the environmental domain and process safety good practice explicitly aims at prevention of major accidents with impacts on both human health and the environment.

In 2013 MAHB published a Lessons Learned Bulletin on major accidents having significant impact on the environment (JRC, 2013) and subsequently performed a literature research to find out what had resulted from other recent studies of environmental accidents. Although, there are relatively few publications and research activities that specifically address events with environmental consequences relative to events affecting human health, some interesting and important work has been carried out in this area recently as well as in past decades. (DETR, 1997; Christou, 2000; Vince, 2008). Among the more recent publications giving attention to environmental accidents, Vince (Vince, 2008) presented a systematic analysis of the environmental aspects of the United Kingdom implementation of the Seveso Directive (COMAH) and illustrated the challenges of complying with COMAH via case studies of environmental accidents. Further to this publication, the Health and Safety Laboratory (HSL) published a study (HSL, 2012) on the analysis of UK environmental incidents and near misses between 1999 and 2010, and an analysis of the lessons learned. In addition, the Organisation for Economic Co-operation and Development (OECD) has dedicated an entire chapter (Chapter 12) to the assessment of environmental consequences in its Guiding Principles publication as part of follow-up to incidents (OECD, 2003). In 2008 the French Bureau for Analysis of Industrial Risks and Pollutions (BARPI) that manages the French industrial accidents database, ARIA, published an analysis of the effectiveness of retention systems on various industrial sites (BARPI, 2008). In 2013, BARPI also published a fact sheet on the effects of water pollution from hydrocarbon releases (BARPI, 2009).

As a follow-up to these works, the authors focused this study on all accidents with significant impact on the environment reported in the eMARS database. The earliest reported environmental accident is from 1986. The study analyses the causes and contributing factors of these events in order to derive lessons learned and offer recommendations for the future avoidance of such incidents. In general it was found that, during this period, a considerable number of accidents were reported in the database have led to measurable pollution to different environmental receptors, predominantly watercourses, and to a lesser extent to soil. In particular for releases to water, it appeared that operators in many cases were not or were hardly able to stop the contamination of the aquatic environment or mitigate the consequences. In many cases the pollution was caused by fire water runoff. In others a substantial release of dangerous substance could have been prevented if additional safety measures had been foreseen, including secondary containment, or if monitoring and feedback mechanisms had been in place.

The methodology

As a first step in performing this analysis, MAHB reviewed 900+ events reported in the eMARS database to identify which accidents had environmental consequences. Of 687 accidents were identified as major accidents according to the criteria in Annex VI of the Seveso Directive (see in Appendix A). In total, 86 cases were found as having minor or major consequences to the environment (see Figure 1 in

Appendix B) and were notified to the eMARS database. Events were recognized as accidents having significant impact on the environment on the basis of the information provided in the sequence of events, consequences, and emergency response sections of the reports. In addition, the free text of reports was also checked and additional accidents with environmental consequences were discovered on the basis of the written description of the accident. These accident reports formed the basis of the subsequent analysis.

The following step in the analysis was to determine whether common lessons learned for environmental accidents could be derived from studying the causal and contributing factors and assessing their significance in terms of the effectiveness of the safety management system (SMS). For this purpose, the accidents were first individually analysed in terms of type of impact, and causal and contributing factors. Following this exercise, the causal and contributing factors were assessed with the aim of identifying potential deficiencies in the SMS that may have increased the risk of an environmental accident. The findings were then used to make conclusions about recurring patterns in safety management associated with the accidents studied with recommendations on how sites can avoid repeating these patterns in future.

Main findings of the study

General characteristics of the accidents

The investigated accidents all had consequences to the aquatic environment. Out of the 86 events 48 accidents (56%) occurred near water resources. The impact was both immediate and direct. In 27 cases dangerous substances were released to a river body; six accidents resulted in a release of contaminated substances to the sea. In 19 cases dangerous substance were first released to the drainage system and from that point flowed towards the nearby river or sea. Of these, there were seven cases in which the contamination was specifically runoff of fire water generated from firefighting.

In addition, it is often assumed that “environmental consequences” are typically accidents on specific natural resource or conservation areas, e.g., NATURA 2000 or other protected areas and national parks. In fact, the impact on human activity is often much more tangible than is implied and often assumed by the term “environmental accident”. However, the analyses of the eMARS data show that accidents to the environment involve mainly watercourses while releases that affect terrestrial conservation areas are quite rare. In addition, these watercourses are often not “natural conservation” areas per se; rather they are often critical resources of daily relevance to the functioning of human beings living and working nearby. In particular, pollution of watercourses affects the availability of these resources for recreation, fishing, drinking water and sewage treatment. For example, eight accident reports cited fish kill as a significant impact of the release of dangerous substances.

Moreover, 33 accidents were associated with releases to water, followed by 15 cases involving releases to the soil, with the least number of eight accidents associated with dispersion into the air (see Figure 3 of Appendix B). It was found that in most cases where a release to the air was cited by the accident report as an “environmental consequence”, it was not associated directly with an impact on the environment but rather had a direct impact on human health.

The accidents studied predominantly occurred in the general chemicals industries (30%), petroleum depots or refineries (19%) and warehouses (12%). As such, in most cases the dangerous substances involved in the accident consisted mainly of petroleum products, fertilisers and general chemicals (see Figure 4 in Appendix B).

Common causal and contributing factors associated with the environmental accidents studied

The findings from the analysis of causal and contributing factors of the 86 accidents studied are presented in this section. Although quality and detail of the reports varied considerably, it was possible to conclude that there are some typical technical and management system failures common to many environmental accidents. These findings suggest that there may be a tendency to underestimate the importance of certain controls associated specifically with prevention environmental releases and mitigation of their consequences.

In general, accident reports often indicated insufficient procedures for identifying and mitigating risks connected with the environmental consequences in the risk assessment. In many cases contamination was caused by fire water runoff (PPG 18, 2000). In particular, this type of damage often occurred in situations when there was little or no risk that the original chemical spill could have reached a nearby water body. The so-called Sandoz accident, that occurred in Basel-Landschaft, Switzerland in 1986, was originally a fire in a warehouse storing agrochemical substances. Subsequent efforts to extinguish the fire resulted in a significant volume of toxic substances released to the Rhine river in the fire water runoff. This finding indicates that sites often fail to anticipate the potential risk of a secondary loss of containment due to failure to contain fire water runoff. As demonstrated by the Sandoz accident, the failure to establish appropriate controls to manage fire water runoff in the event of a major fire can have significant environmental consequences.

The vast majority of accidents consisted of a spill of contaminants in liquid form or in a liquid mixture. Insufficient or nonfunctioning safety barriers associated with storage tanks, for example, the corroded sump of a storage tank, a failed bund , etc. often resulted in contaminants spilling into soil or ground water. Nineteen accidents resulted in spills reaching water bodies via a sewage or drainage system. The accident that occurred in Italy in a closed petroleum oil depot in the Po Valley region in 2010 is a typical example. Approximately 2,600 tonnes of hydrocarbons was released from storage tanks on the site. An apparent lack of secondary containment allowed the release to eventually reach the Lambro river and the river Po after passing through the municipal sewage system. A failure to give sufficient attention to proper functioning and regular maintenance of spill control measures was a relatively common causal factor in the accidents studied.

The lack of sufficient instrumentation to monitor loading and unloading activities was a factor in at least six accidents involving oil spills to water bodies and ground water. This type of deficiency was an important factor leading to the accident occurring in Donges, France in 2005, in which the failure to detect a leak from a corroded pipe while loading fuel into a tanker, resulted in the spill of 478 tonnes of cargo fuel oil, of which 180 tonnes flowed into the Loire river over the course of more than 5 hours. This is a well-known factor contributing to accident risks at many sites and is not notably more or less a cause of environmental accidents. However, it is important that operators recognise that safety instrumentation is equally important to the prevention of environmental accidents as well as toxic releases, fires and explosions.

Commonalities associated with deficiencies in the Safety Management System

The analysis revealed that many environmental accidents can be tied to similar deficiencies in the safety management system. The results of the analysis of findings in relation to the safety management system are shown in Appendix B (Figure 5). Figure 5 represents findings from only those accidents where adequate information was available to analyse the accident report to identify safety management system failures. Highlights of the analysis are as follows:

- In 10 cases a deficiency of the first SMS element; Organisational and Personal Failure, was identified as one of the main causes. This finding indicates that training of personnel and contractors were not sufficient, which is a major contributor factor to the accident.
- In 23 cases inadequate operational procedures was a leading factor in the accident. Most commonly in these cases, the release occurred because the equipment was not operated properly or it malfunctioned due to misuse or lack of maintenance. In 17 cases non-adherence to operational guidelines, or lack of written procedures altogether, was a leading cause of the accident. In four cases the failure to recognise and address significant corrosion of a tank or pipework was the main cause of the accident. The safety valve was mistakenly left open in five cases causing an immediate release of dangerous substances contained in process equipment or being conveyed via pipe transfer. Also, a defect in the material composition of the process equipment was a contributing factor to the accident in nine cases.
- Management of change appeared to be insufficient in seven cases. Often, good safety practices were not respected by employees for maintenance activities. Insufficient management of change practices were often connected to a failure to conduct a risk analysis. In three cases, for example, establishments did not have adequate measures to prevent equipment failure from extreme weather events, such as flood or heavy rainfall. In four cases no risk analysis was conducted prior to maintenance.
- Emergency response and the activation of the internal emergency plan were problematic in four cases. Operators should ensure that employees have a clear understanding about what to do in case of an emergency, in particular, in the event of a catastrophic rupture or spill, and their role in mitigating the consequences. In three cases the management was not informed at all or was only informed later about an important loss of containment.
- A failure to take account of past incidents implied insufficient audit and review procedures particularly following accidents and near misses. In three cases, the accident appeared to be a repeat event.

Lessons Learned

Based on the analysis of technical and safety management failures, a number of lessons learned could be derived. Risk assessments should identify necessary control measures specifically for preventing environmental accidents. For some sites, there are preventive measures that should be automatically considered to avoid a major release to the environment. In particular:

- Safety barriers should be established to mitigate the consequences where there is potential for a major spill and no secondary containment is in place. Backup systems should be in place.
- Separation of chemicals in warehouses and reduction of the size of their internal fire compartments is advisable in order to mitigate the consequences of an accident.
- If a dangerous establishment is placed close to water resources, the operator must be sure that the drainage system does not let dangerous substances escape into those water bodies directly.
- Adequate technical systems such as automatic level control system on the tanks or automatic locking systems should be in place to serve the loading docks and/or its pumping equipment or systems for automatic sensory devices on the equipment (under a remote control) such as pumps for the transportation of hydrocarbons.
- Regular auditing, inspection and monitoring is necessary to control corrosion in safety-critical equipment in the establishment.

Operators should ensure that identification and evaluation of major hazards with written safety procedures and guidelines are in place and updated on the basis of change, and lessons learned from audits and incidents. More specifically:

- The operator should have clear and updated documentation of all major accident hazard scenarios associated with the site.
- Operators also need to consider potential environmental releases in the safety management system, e.g., in maintenance planning, inspections and feedback on findings of audits.

- Hazard analysis and risk assessment should take into account potential extreme weather phenomena and their consequences. When a potential accident trigger is newly identified (e.g., inundation by flood waters, security threat, etc.), the operator should consider recalculating the risk to the establishment.
- High hazard sites should have management of change procedures that include a process for evaluating whether any changes to the equipment or process could have an impact safety and thus, must be subjected to a proper risk assessment.

There also must be sufficient communication and training for all site personnel in regard to the major hazards on site, correct operational and safety procedures associated with the hazards relevant to their work, what to do in case of a release, and how to react if there is an emergency. In particular, written safety procedures and guidelines should be in place and extensive training to all personnel on the procedures must be followed.

In at least one case, the major release occurred when the establishment was under decommissioning and therefore, no surveillance system was in place. Seveso authorities should continue to monitor dangerous industrial activities during the entire life cycle of a process unit from design to decommissioning. Progressive decommissioning of an installation may eventually incur a reduction in the level of attention from the site operator in particular if the site is declassified as a major hazard site and therefore regulatory controls cease to apply.

Conclusion

The analysis revealed many common failures and deficiencies in the sequence of events leading to the environmental accidents studied. This overall finding demonstrates the value of continuing to analyse these types of accidents in order to reduce the possibility of a recurrence of such events in future. In particular, a common element of a risk management strategy to prevent environmental accidents is to have adequate control measures in place to preventing releases from reaching water or soil.

The accidents analysed for this study indicated that environmental consequences more often than not are directly relevant to the daily life of surrounding communities. In particular, environmental accidents can have implications for human health (e.g., drinking water contamination), economic well-being (fish kills and contamination of fish habitat) and social well-being (e.g. contamination of recreation areas such as beaches, recreational fishing grounds, and rivers along community parks). More sharing of analyses of environmental accidents could also introduce a greater sensitivity to the range of threats posed by such accidents with the result that operators and authorities may be even more attentive to reducing their risks.

Moreover, the accidents exhibited some commonalities in terms of both technical deficiencies and potential weaknesses in the safety management system. In particular, inadequate mitigation to contain spills of dangerous substances was a factor that exacerbated accident consequences in many cases. Insufficient management of operations to avoid improper use of equipment or its malfunction was another leading cause of the accidents studied. Communication to employees of correct procedures under normal operation as well as during emergencies appeared also to be a factor in several accidents. It is noted that areas of weakness in the safety management system identified in this study may not necessarily be associated only with environmental accidents but may be more representative of a general insufficiency in attention to safety matters on the individual sites concerned.

APPENDIX A - Criteria for the notification of a major accident to the European Commission

Criteria relating to immediate damage to the environment

(a) permanent or long-term damage to terrestrial habitats:

(i) 0,5 ha or more of a habitat of environmental or conservation importance protected by legislation;

(ii) 10 or more hectares of more widespread habitat, including agricultural land;

(b) significant or long-term damage to freshwater and marine habitats:

(i) 10 km or more of river or canal;

(ii) 1 ha or more of a lake or pond;

(iii) 2 ha or more of delta;

(iv) 2 ha or more of a coastline or open sea;

(c) significant damage to an aquifer or underground water:

1 ha or more.

APPENDIX B - Statistical analysis of the studied accidents

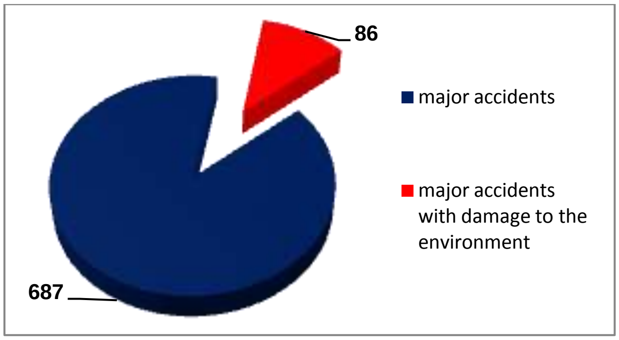

Figure 1: Number of major accidents with damage to the environment (eMARS)

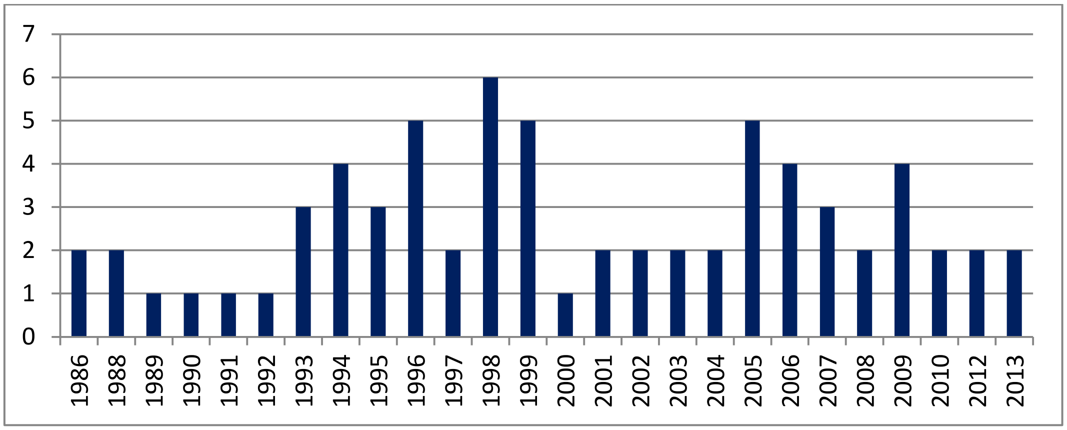

Figure 2: Number of accidents having impact on the environment by year (eMARS)

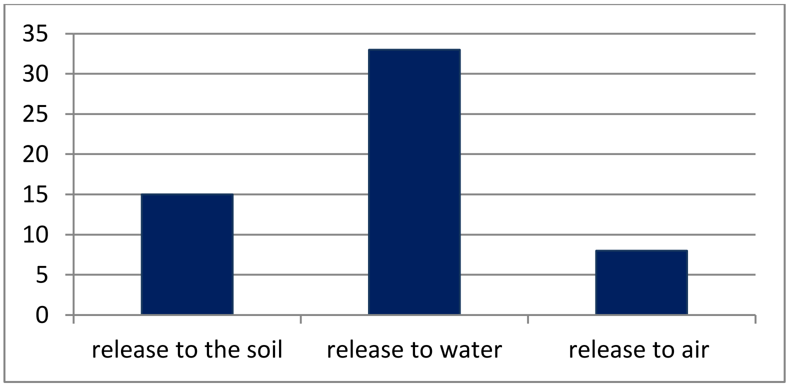

Figure 3: Distribution of main types of release in the accident reports (eMARS)

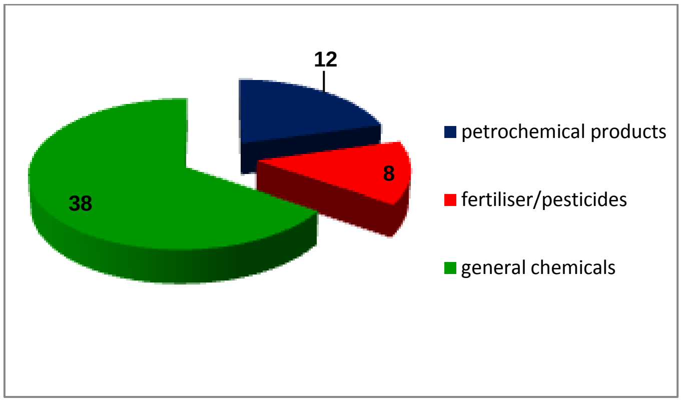

Figure 4: Type of substances involved in the accidents (eMARS)

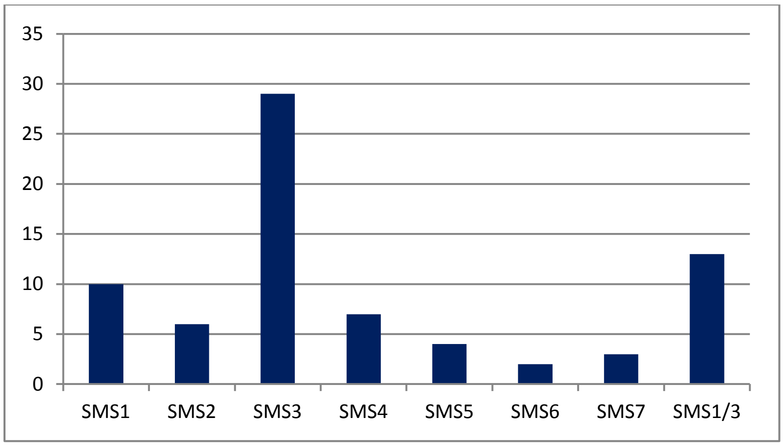

Figure 5: Safety Management System elements involved in accidents (eMARS)

APPENDIX C – Elements of the Safety Management System

For the analysis of the accidents demonstrated in the study, the safety management system elements contained in Annex III of the Seveso Directive (European Commission 2012) was used as reference framework. For the purpose of implementing the safety management system, the following seven elements should be addressed by the operator:

1. organisation and personnel — the roles and responsibilities of personnel involved in the management of major hazards at all levels in the organisation, together with the measures taken to raise awareness of the need for continuous improvement. The identification of training needs of such personnel and the provision of the training so identified. The involvement of employees and of subcontracted personnel working in the establishment which are important from the point of view of safety;
2. identification and evaluation of major hazards — adoption and implementation of procedures for systematically identifying major hazards arising from normal and abnormal operation including subcontracted activities where applicable and the assessment of their likelihood and severity;
3. operational control — adoption and implementation of procedures and instructions for safe operation, including maintenance, of plant, processes and equipment, and for alarm management and temporary stoppages; taking into account available information on best practices for monitoring and control, with a view to reducing the risk of system failure; management and control of the risks associated with ageing equipment installed in the establishment and corrosion; inventory of the establishment's equipment, strategy and methodology for monitoring and control of the condition of the equipment; appropriate follow-up actions and any necessary countermeasures;
4. management of change — adoption and implementation of procedures for planning modifications to, or the design of new installations, processes or storage facilities;
5. planning for emergencies — adoption and implementation of procedures to identify foreseeable emergencies by systematic analysis, to prepare, test and review emergency plans to respond to such emergencies and to provide specific training for the staff concerned. Such training shall be given to all personnel working in the establishment, including relevant subcontracted personnel;
6. monitoring performance — adoption and implementation of procedures for the ongoing assessment of compliance with the objectives set by the operator's MAPP and safety management system, and the mechanisms for investigation and taking corrective action in case of non-compliance. The procedures shall cover the operator's system for reporting major accidents or 'near misses', particularly those involving failure of protective measures, and their investigation and follow-up on the basis of lessons learnt. The procedures could also include performance indicators such as safety performance indicators (SPIs) and/or other relevant indicators;
7. audit and review — adoption and implementation of procedures for periodic systematic assessment of the MAPP and the effectiveness and suitability of the safety management system; the documented review of performance of the policy and safety management system and its updating by senior management, including consideration and incorporation of necessary changes indicated by the audit and review.

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