Loss Prevention Bulletin

Improving process safety by sharing experience

Special Issue

Environment agency special issue

Case studies of environmental incidents at major hazard sites

IChemE Safety Centre

Environment Agency

IChemE ADVANCING CHEMICAL ENGINEERING WORLDWIDE

Contents

Loss Prevention Bulletin

Articles and case studies from around the world

Special issue

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The work described in this report was undertaken by the Health and Safety Laboratory under contract to the Environment Agency. Its contents, including any opinions and/or conclusions expressed or recommendations made, do not necessarily reflect policy or views of the Health and Safety Executive.

IChemE

Foreword & acknowledgement

Foreword

The six case studies presented in this report provide a sobering reminder of the potential that high hazard sites have to harm the environment, in addition to the risks they pose to life and property. The incidents have been selected to be representative of a range of typical failures which contribute to major accidents and we share the details so that others can learn the lessons highlighted and act to reduce risk of future harm to people and the environment.

This report brings together a wealth of information gained from over a decade of incident investigations carried out by the Health and Safety Executive (HSE) and the Environment Agency. Whilst the immediate causes of the accidents differ widely, the root causes are broadly similar (and unfortunately, all too familiar) whether impact is to people or the environment. By addressing these root causes the overall risk posed by high hazard sites should be reduced. In many cases this can be by implementation of measures contained in established Health, Safety and Pollution Prevention Guidance (HSGs and PPGs).

The report also clearly identifies that in spite of efforts to prevent them, fires remain a serious concern and basic lessons for mitigating the impacts of contaminated firewater have yet to be implemented. The control of firewater features strongly in the strategic inspection topics adopted by HSE and the Environment Agency.

We welcome the role IChemE plays in sharing lessons from past accidents and hope that this special edition of the Loss Prevention Bulletin will find its way into the boardroom, providing a further catalyst to strengthening the leadership commitment necessary for improving process safety. This should prompt operators of high hazard sites to take a fresh look at their own facilities and consider whether there is more they can do to control their Major Accident risk.

Toby Willison
Environment Agency, Executive Director of Operations

> "Sharing best practice across industry sectors, and learning and implementing lessons from relevant incidents in other organisations, are important to maintain the currency of corporate knowledge and competence"..."Companies should have mechanisms and arrangements in place to incorporate learning from others within their process safety management programmes;"
>
> *PSLG Principles of Process Safety Leadership*

Acknowledgement

The assistance of Mike Nicholas from the Environment Agency in providing background information is gratefully acknowledged. Also, many thanks go to the officers, inspectors and operators who have reviewed and provided feedback on earlier drafts of this report. The analysis and case studies were prepared by Tony Holmes, Justin Holroyd and Michael Johnson of the Health and Safety Laboratory under contract to the Environment Agency.

Executive summary

The objective of this report is to provide a set of case studies of environmental incidents at major hazard sites. These studies illustrate a range of incident types, with a range of environmental impacts. Whilst only some of the incidents resulted in a Major Accident to the Environment (MATTE), it is believed all provide environmental protection lessons to be learned.

The incidents are described and the causes, both direct and underlying, are examined. Failings in measures for mitigation against environmental harm are discussed.

The case studies are widely applicable, but will be of particular relevance to the management of environmental risks at COMAH major hazard sites.

A number of themes emerge from the case studies, as summarised below:

- Serious environmental harm is most frequently associated with release of liquids to ground and water, as opposed to aerial dispersion of pollutants, and also most frequently associated with tank farms, warehousing and other storage areas.
- Problems with the management of firewater occurred in a number of cases, which in some instances resulted in contamination of the wider environment offsite. This finding is consistent with similar incident reviews, for example EEA[1] noted that the main threat to ecosystems (from industrial accidents) is the wastewater from fire extinguishing activities, which may pollute surface water or groundwater if not captured effectively. Runoff, with or without fire fighting, can mobilise dangerous substances due to fire-induced loss of containment. This highlights the need to plan for the eventuality of fires by considering the quantities of firewater that are likely to be produced throughout the incident (not just first response), the rate at which runoff will be generated and how this will be successfully managed and retained.
- Loss of liquid material to the environment via hitherto unknown pathways, or because of the availability of pathways due to a lack of impermeable barriers, was common to a number of cases. This highlights the need to fully assess pathways by which a pollutant source might travel to a receptor (both on and off-site), to produce accurate drainage plans and to use the necessary measures to break those pathways, so far as is reasonably practicable.
- In all of the incidents studied, failings in oversight were underlying factors. The specifics differed for each incident, but typically a failure to foresee and plan accordingly was observed. In addition, failure to adequately manage ageing plant continues to be highlighted as a significant underlying causal factor.
- In several cases the CA is of the opinion that pollution could have been reduced had the operators implemented the necessary measures for containment and emergency arrangements, for example those outlined in the relevant Pollution Prevention Guidelines (PPGs[2]) or HSE Health and Safety Guidance (HSGs[3]).

In addition to the case studies, COMAH Competent Authority data (2007-2011) has been analysed to provide an overview of environmental incidents.

- After stopping the process, secondary containment is the most common measure for preventing escalation of incidents. It is of course reasonable to expect this, as in most cases the secondary containment is early on in the barrier chain, and if it succeeds then the incident will cease escalating at this point. However, this does illustrate the importance of implementing and maintaining secondary containment.
- Most incidents on COMAH sites did not involve a significant failure of secondary or tertiary containment. Where they did, the most common failing was the absence of secondary containment measures, followed by leaks via drains and poor inspection and maintenance.
- Very few incidents on COMAH sites in the period studied (2007-2011) had offsite impacts, but of those that did serious environmental damage was observed in some cases (notably those involving firewater run-off to controlled waters). The potential for serious environmental damage, had the incident unfolded differently, was noted for a handful of other cases – though these represent only a small proportion of the total number of incidents at COMAH establishments.

An assessment of the major accidents reported to the European Commission indicates that relatively few were reported for environmental reasons. However, environmental harm has been seen on a large scale and has caused considerable costs to operators. In addition, closer inspection of the narrative of a subset of the incidents suggests that environmental damage is noted in around a quarter of incidents, though this damage is typically not long lasting.

Many of the findings of this report are consistent with observations from a 1997 DETR report[4].

Through better understanding of common causes and dissemination of lessons it is hoped that in future more accidents can be prevented from causing serious harm to the environment.

[1] *Mapping the impacts of natural hazards and technological accidents in Europe - An overview of the last decade, European Environment Agency (2010), EEA Technical Report 13/2010 [http://www.eea.europa.eu/publications/mapping-the-impacts-of-natural]*

[2] *https://www.gov.uk/government/collections/pollution-prevention-guidance-ppg*

[3] *http://www.hse.gov.uk/pubns/books/index-hsg-ref.htm*

[4] *Environmental Follow-up of Industrial Accidents. A report prepared by The Institute of Terrestrial Ecology; DETR, October 1997, ISBN 0 11 753457 9.*

Introduction

Report overview

The objective of this report is to provide a set of case studies of environmental incidents at major hazard sites. These studies illustrate a range of incident types and impacts, with a range of causes relevant to environmental protection. The incidents are described and the causes, both direct and underlying, are examined. Failings in measures for mitigation against environmental harm are discussed. The case studies are widely applicable, but will be of particular relevance to the management of environmental risks at COMAH major hazard sites.

Appendix A provides a broader overview of environmental incidents at major hazard sites, with information having been obtained from reports to the European Commission of major accidents to the environment (MATTEs), and from the COMAH Competent Authority's (CA's) operational intelligence system.

Appendix B provides a summary of some of the most significant environmental incidents worldwide.

The specific focus of the case studies and the analysis is the impact on the environment and the implications for environmental protection and management. In several of the case studies significant harm to people was also noted.

Regulatory context

The COMAH Competent Authorities comprise, for non-nuclear establishments, the Environment Agency (EA) and the Health and Safety Executive (HSE) in England, Scottish Environment Protection Agency (SEPA) and the Health and Safety Executive (HSE) in Scotland, and Natural Resources Wales (NRW) and the Health and Safety Executive (HSE) in Wales.

COMAH is concerned with the prevention, mitigation and preparedness for Major Accidents, as defined in the regulations and discussed further in the Guidance to the COMAH regulations[1]. A Major Accident to the Environment (MATTE) is a term used in the UK to indicate when a Major Accident has caused serious harm to the environment. So:

- a Major Accident which *could* cause serious harm to the environment (i.e. leads to serious danger) is a *potential* MATTE (i.e. a Major Accident with MATTE potential);
- a Major Accident which *has* caused serious harm to the environment *is* a MATTE.

Further guidance on the thresholds that are considered to be "serious" has been published[2] and the Chemical and Downstream Oil Industry Forum (CDOIF) is currently reviewing these thresholds in light of both regulatory experience and changing environmental legislation.

The fundamental aim of COMAH is prevention and mitigation, as reflected in the general duty placed on all operators by regulation 5. However, preparedness for and learning lessons from accidents are also key aspects, such that when a Major Accident occurs the operator, emergency planners and the COMAH CA all have duties placed upon them by the regulations (see guidance on COMAH regulations for detail). Further detail on how the CA responds to incidents at COMAH sites can be found in the CA investigation procedure (CA Investigation Procedure Version 2/July 2010). Information from investigation of incidents and other inspection activity is used by the CA to guide its inspection priorities – as covered in CA Delivery Guides for strategic topics[3]. At a European level, information on Major Accidents reported to the Commission can be found on eMARS[4], including details of incident, causation, impacts and lessons learned.

Selection of case studies

The case studies that follow were chosen to represent a selection of different types of Major Accidents that had a range of environmental impact. Case studies 3, 4 and 5 were MATTEs. The other incidents caused less serious environmental harm and are presented for lessons to be learned — whilst they did not result in MATTEs, the causes and root causes are representative of failings that could cause a MATTE at other establishments or with different incident outcomes (e.g. escalation). Incidents from the UK were selected because the sites are regulated under the same regulatory regime, COMAH, and HSL is able to access detailed CA investigatory material. The incidents cover a range of type of site, from manufacturing through to fuel storage and waste management, and a variety of consequence types including fires, explosions, and leaks to groundwater. The causes and lessons highlighted here are relevant to a wide range of COMAH establishments where there is potential for a MATTE.

[1] *A guide to the Control of Major Accident Hazards Regulations (COMAH) 2015, L111, ISBN: 978 07176 605 8, HSE Books, 2015*

[2] *DETR (1999) Guidance on the Interpretation of Major Accident to the Environment for the purposes of the COMAH regulations, ISBN 011753501X, The Stationary Office*

[3] *http://www.hse.gov.uk/comah/ca-guides.htm - for CA procedures and delivery guides*

[4] *https://emars.jrc.ec.europa.eu/*

Case study

Case study 1: Tees Storage, Seal Sands, July 1999

Incident 1: July 1999 – Tees Storage, Seal Sands	
Date of incident	21 July 1999
Operator name (at time of incident)	Tees Storage
Site address	Seal Sands, Middlesbrough
EC reportable Major Accident?	Yes
Major Accident to the Environment?	No (incident included for relevant lessons)

The incident

Tees Storage (now Vopak Ltd) operated a bulk chemical storage facility at Seal Sands adjacent to the River Tees. The site is a top tier COMAH site due to its inventory of toxic and flammable chemicals.

On 21 July 1999 a worker discovered that a storage tank, containing 750 tonnes of 30% sodium cyanide solution, was leaking and there was a pool of liquid in the bund. Tees Storage immediately started transferring the contents of the leaking tank into another tank. Around 16 tonnes of toxic liquid had been lost from the tank, with about 4 tonnes being recovered from the bund. The balance was assumed lost to the environment.

Samples from the effluent system confirmed that cyanide had entered the River Tees, via the site drainage system. Environment Agency staff surveyed the river for several days but found no evidence of harm to fish and the levels of plankton were normal.

Description of the causes

The cause of the leak was a weld slag inclusion that had been formed during the original fabrication of the tank in 1977. The tank was designed in accordance with BS2654:1973 and went into sodium cyanide service in 1991. In September 1998, following a discrepancy in a routine stock reconciliation, it was found that the tank was leaking as a result of the construction defect in the floor welds. It was concluded that the failure of the defect was caused by high pressure water jetting during routine maintenance in May 1998. The tank was repaired subsequently, inspected and found to be fit for purpose. Despite the clean bill of health, the tank leaked again in July 1999. This time the loss was detected by its strong almond odour and the visible trace of sodium cyanide on the berm.

Though the bund was sufficient in protecting people it did not prevent release to the environment. Two failure modes were highlighted:

- the base of the bund allowed some seepage into the ground; and

Tees storage leak: sodium cyanide leaking onto tank 713 berm – 21 July 1999.

- the bund drain valve was closed but not seated correctly allowing the release to enter the drainage system and hence to the discharge point to the river.

In this case the seepage into the ground was small compared to the loss via the drainage system.

Design and process control factors

The immediate cause of this incident was corrosion of the tank, which resulted in a loss of containment of the tank contents to the bund. The corrosion occurred at a weld where defective fabrication had lead to the presence of an inclusion in the weld. Over time, rusting at the weld-inclusion interface enabled the inclusion to become dislodged, creating a route for the leakage to occur. This raises issues relating to the control of construction, the inspection of tanks, and the management of ageing plant. Even though tanks may apparently be designed and inspected to appropriate standards, defects can occur and they can still fail.

From an environmental perspective the major causal factor was the inadequacy of the secondary and tertiary containment system. This allowed seepage of cyanide containing liquor into the ground and discharge via drains to the river.

Ageing plant

The tank was constructed in accordance with BS 2654, the applicable code at the time. This code did not require welders to pass a qualification test if they were making fillet welds. The original welding would have followed common practices of the time, e.g. one run weld technique. Welds would have only been subject to visual checking. The welding rods, equipment and inspection techniques (including supervision and monitoring) of today were not available and even though current inspection techniques have improved, tank defects can still go undetected.

Subsequent changes include 3 pass welding techniques and improved design standards. Modern inspection equipment and techniques are now in place that reduces the risk of weld failure but additional consideration needs to be given to tanks of this age.

Secondary/tertiary containment design factors

The design of the bund dated back to the 1970s and it has become apparent following this incident that bunds of similar design are widespread throughout the UK. The bund consisted of a concrete wall that provided lateral containment preventing spillages spreading out over the site, but it did not have an impermeable floor. More significantly in this case, the bund featured a gravity drain which discharged to the site drainage system then to the river, which allowed liquid to escape the bund. The bund was built to the industrial standards of the day and was expected to have a life span of 30-40 years. Current good practice for bunds requires a blind pumped sump (the preferred option) or discharge to a closed drainage system.

A thorough risk assessment may have identified that it was time that containment systems were upgraded, with the aim of better protection of the environment. The need to upgrade containment would be dependent on an ALARP assessment to determine tolerability of risk and whether the cost involved in reducing the risk of a leak, by upgrading the bund and drainage arrangements, was proportionate to any benefit gained. Taking learning from this, the terminal stopped discharge to the river and effluent is now contained and handled via an off-site plant.

Causal summary

Direct causes	Underlying causes
Corrosion – internal	Planned plant inspection
Manufacturing defect	Supervision
Defective equipment	Ageing plant
Secondary and/or tertiary containment failure causes	
Secondary not impermeable (wall / floor)	
Secondary leak via drain	
Secondary / tertiary inadequate design	

Environmental impacts and EC reporting

Based on the quantity of material lost from the tank, and the amount accounted for when transferring solution from the bund to another tank, it has been calculated that 12 tonnes of cyanide solution had entered the environment. Monitoring of the river Tees indicated that cyanide had entered the watercourse, via the drainage system, but no evidence of lasting environmental harm has come to light. Sampling showed localised contamination near to the leak, but this was not serious.

This incident was EC reportable by virtue of the quantity of cyanide solution lost to the environment.

Penalties

In 2000, Tees Storage pleaded guilty to breaching its discharge consent and was fined £5,000 with £640 costs. The actual cost of the incident to the operator was of course higher than this, including £20,000 for environmental monitoring, as well as less tangible costs such as loss of reputation.

Further reading

Major accidents notified to the European Commission 2000, HSE, www.hse.gov.uk/comah/eureport/car2000.htm

Case study

Case study 2: Upper Parting Tar Works, Sandhurst, October 2000

Incident 2: October 2000 – Upper Parting Tar Works, Sandhurst	
Date of incident	30 October 2000
Operator name (at time of incident)	Cleansing Service Group Ltd
Site address	Upper Parting Tar Works, Sandhurst Lane, Sandhurst, Gloucester
EC reportable Major Accident?	Yes
Major Accident to the Environment?	No (incident included for relevant lessons)

The incident

In 2000, the Cleansing Service Group Ltd was operating a hazardous waste treatment facility and transfer site on the site of a former tar works at Sandhurst, near Gloucester. In the early hours of 30 October 2000, following a severe storm, a fire started in the laboratory waste storage area of the transfer station. Although the ignition source has never been identified, a possible ignition source was a chemical reaction between wastes that were stored within the same drum. The compound where the fire started was packed full of flammable substances (including isopropyl alcohol – IPA). The fire soon became self-fuelling, due to the release of IPA, and as other containers ruptured they exploded under the intense heat, producing large fireballs.

The fire soon spread to other parts of the site, including the site office and a road tanker. When the fire service arrived, they found the fire blocked the only access road; this prevented them from gaining immediate access to the site to tackle the fire. The site was unoccupied at the time. Nearby residents had to be evacuated: many reported breathing difficulties consistent with inhalation exposure to toxic combustion products and respirable air particulates. In all, nine people were taken to hospital, but not detained, and sixty people were evacuated for twelve hours.

Three days after the fire the River Severn burst its banks resulting in water inundating the site, causing it to be accessible only by boat for four days. Local residents were evacuated for a second time, though the extent to which this would have happened due to the flooding anyway is not recorded.

Description of the causes

The direct cause of this incident was the ignition of flammable materials in an area of the site that was storing intermediate bulk containers (IBCs) containing IPA, in addition to large numbers of one litre containers of acetone and lab "smalls" (primarily flammable solvents). The ignition source has never been identified, though a number of possibilities have been proposed, including:

- arson;

Crown copyright

Crown copyright

(Top to bottom): CSG Sandhurst: seat of fire and flooding

- a leak of pyrophoric (spontaneously flammable in air) material;
- loss of containment of lab "smalls" leading to uncontrolled chemical reaction.

The fire easily breached the plastic containers that held the flammable and highly flammable liquids, and rapidly spread, causing the explosion of waste aerosol containers and drums of toxic and flammable materials stored nearby.

Analysis of 500 environmental samples taken after the incident indicated that there was no significant contamination off-site. Calculations carried out by the Health and Safety Executive concluded that it was unlikely that off-site levels of toxic substances reached the dangerous dose threshold. There were however numerous reports of ill health in the days following the incident.

Underlying causes are discussed below.

Design and process control factors

There was no provision given to controlling the burning liquid in the event of a fire (e.g. designated bunded areas for flammable liquids), and there were no firebreaks between the storage areas on the site.

A number of questions have arisen regarding the adequacy of the storage arrangements on the site, in particular whether the segregation of materials was appropriate. Although IPA is classified as highly flammable this was not taken into account when providing for its storage. Drums of waste were stored in stacks, and it is possible that this arrangement was unstable during the high winds of the storm, leading to toppling of drums and loss of containment.

The prevailing wind during the fire prevented the emergency services from accessing the site via the only access road. This necessitated a time consuming alternative approach to site over neighbouring fields. The adequacy of having only a single access road to a site of this nature is therefore a pertinent issue.

The subsequent flooding of the site compounded the problems in dealing with the incident. It became necessary to move substantial quantities of potentially harmful waste to higher ground, and this operation had to be undertaken after accessing the cut-off site by boat. Flooding is a factor that needs to be considered at a significant number of COMAH sites due to the frequent juxtaposition of industrial sites to rivers and estuaries.

There was no substantial loss of contaminated firewater from the site, though approximately one acre of adjacent land was affected by wash-water, leading to the death of worms and localised contamination by solvents, heavy metals, cyanides and acids. It would appear that in this incident the provision made for firewater containment was adequate. It is not clear however whether this was more by luck than design, and it is important that operators consider the arrangements for handling contaminated firewater.

Operating procedures

Standard operating procedures were in place but they were not always being followed. For example, the operators had a rejection procedure, but this was not being followed. Acceptance testing did not take place for all containerised waste, with the result that wastes were being stored inappropriately and, moreover, rejected wastes were not being removed from site.

Management systems

The management of the site is brought into question by the failure of management systems such as keeping accurate inventories. A case in point was having missed off the site's inventory waste that originated from the Veterinary Laboratories Agency, and had been designated for disposal by incineration.

Causal summary

Direct causes	**Underlying causes**
Incompatible substances	Operating procedures
Static / spark or other ignition source	Hazard analysis / risk assessment
Flooding / extreme weather	Leadership / management systems
Secondary and/or tertiary containment failure causes	
No secondary containment	

Environmental impacts and EC reporting

No long-term adverse environmental impacts have been identified.

The incident was reportable to the EC based on the quantity of material involved in the fire and the extent of the evacuation.

Further reading

1. *Review of Incidents at Hazardous Waste Management Facilities, April 2012 (Version 2.6) http://publications.environment-agency.gov.uk/PDF/GEHO0512BUPV-E-E.pdf*
2. *Report for the Deputy Prime Minister the Right Hon John Prescott MP into the major fire on 30 October 2000 at Cleansing Service Group Ltd Sandhurst, COMAH Competent Authority, 1 January 2001, http://www.hse.gov.uk/chemicals/sandhurst.pdf*
3. *Research Report 564, Fire performance of composite IBCs, Prepared by the Health and Safety Laboratory for the Health and Safety Executive, 2007 [http://www.hse.gov.uk/research/rrhtm/rr564.htm]*
4. *Guidance on Flood Risk Assessment and how to prepare for flooding can be found on the gov.uk website http://www.gov.uk/prepare-for-a-flood/make-a-flood-plan including guidance for regulated sites https://www.gov.uk/government/publications/preparing-for-flooding-a-guide-for-regulated-sites*

Case study

Case study 3: Petroplus, Milford Haven, August 2005

Incident 3: August 2005 – Petroplus, Milford Haven	
Date of incident	2005
Operator name (at time of incident)	Petroplus Tank Storage Ltd
Site address	Waterstone Refinery Milford Haven
EC reportable Major Accident?	Yes
Major Accident to the Environment?	Yes


Environment Agency

Tank 115 base internal sump and pipes (below) with erosion and corrosion causing hole in the sump wall (left)


Environment Agency

The incident

The Petroplus facility in Milford Haven (now operated by SemLogistics Milford Haven Ltd) is a COMAH top tier oil/fuel storage establishment, the remaining operational part of what used to be the Gulf refinery.

This environmental incident evolved over a prolonged period, culminating in August 2005 with the discovery of kerosene at neighbouring premises. The contamination was found in gardens, farmland, and on the shoreline, and hydrocarbon fumes were present in local houses. It transpired that over a seven-week period approximately 650 tonnes of kerosene leaked from a hole in the base of tank T115 and spread offsite via groundwater.

Description of the causes

Design and process control factors

The cause of this incident was corrosion in the sump of tank T115, leading to the release of kerosene from the tank base. Although the tank was internally lined in 2001, it is believed the presence of the corrosion was due to either erosion of the lining (from movement of one of the pipes in the sump) or more likely there was no lining there as there was no access for painting with the pipes in situ. The corrosion was greatly accelerated by further erosion of the corrosion, each time the pipe was used. The pipe was not securely fastened and could move up and down against the wall of the sump. This is important as it would not be expected that corrosion alone would have penetrated an 8mm thick sump in such a short period.

An underlying cause was the absence of an impermeable layer under the tank bottom, which enabled the leaking contents to enter the ground below the tank rather than be directed into the bund.

Though there were no visible external signs that fluid was leaking from the tank, measuring and trending of the tank contents should have alerted the company to the presence of a leak.

Because this type of incident was not identified as a potential major accident scenario for the site, the emergency plan was not implemented.

Maintenance and management of change

Up-to-date standards exist for the maintenance of storage tanks (API 653 and EEMUA 159). In API 653 the repair of tanks is outlined detailing the acceptable types of repair and procedures for carrying out repairs. Unfortunately, in this instance these standards were not adhered to.

Moreover, a modification was made that allowed a third pipe to be put into the sump, which forced the try line against the sump wall. The standards do not deal with multiple pipes into a single sump. It should also be noted that the pipe support system across the tank floor did not prevent vertical movement of the pipes and this was a direct cause of the incident.

Supervision

Supervision of this activity appears to have been lacking with Petroplus management failing to ensure adherence to the correct procedures as outlined in the standards.

Inspection

API 653 describes tank inspection methods, including internal inspection and alternatives to internal inspection. This includes an overview of the risk-based approach to inspection. Comprehensive inspection checklists for in-service and out-of-service inspection are presented, as is information on the certification of inspectors.

EEMUA 159 focuses on inspection of tanks, the ageing processes relevant to each part of the tank and the repair of tanks. The guide includes checklists for use during inspections, which inspection methods to use and how to interpret inspection data.

Appropriate inspections were not carried out, possibly due to the unavailability of suitably qualified tank inspectors. If an inspection of the appropriate standard had been carried out then the clearance between the piping and the sump would have been checked, as would the integrity of the surface coatings. A competent inspection would have also ensured that the pipes were adequately supported to ensure that they did not contact any part of the sump wall. Had such remedial action been taken, then this incident could have been avoided.

Situational awareness

An awareness of the inherent risks on site is critical to safe operations. Site management did not have a full appreciation of the risks that their activities posed, as tank bottom leakage was not considered a potential hazard, and as such was not included as a major accident hazard scenario in any of the risk assessments included in the safety report. This meant that in the event of a leak the offsite emergency plan was not initiated and the impact of the incident was greater than it would have been had the appropriate action been taken.

Causal summary

Direct causes	Underlying causes
Corrosion – internal	Planned plant inspection
Incorrect installation	Management of change including plant modifications
	Supervision
	Ageing plant
	Plant and process design
Secondary and/or tertiary containment failure causes	
Secondary not impermeable (tank base)	

Environmental impacts and EC reporting

Over 600 tonnes of kerosene was lost to ground in this incident, finding its way into groundwater and via this pathway onto the adjacent beach. The ground, beach and groundwater were polluted, and marine wildlife adversely affected. This MATTE is unusual in that it developed slowly over a prolonged period of time, rather than occurring as a catastrophic event. This serves as a reminder that not all MATTE scenarios are sudden, and chronic events should be considered at the scenario identification stage.

The remediation costs have been estimated at £3 million.

The incident was EC reportable on the basis that over 1ha of groundwater was significantly damaged.

Penalties

Petroplus was prosecuted and pleaded guilty to a number of environmental offences. It was fined £29,900 with costs of £39,801. The cost of remediation has been estimated to exceed £3 million.

Further reading

COMAH – Major Accidents Notified to the European Commission, England, Wales and Scotland 2005 - 2006. Report of the Competent Authority, http://www.hse.gov.uk/comah/eureport/car2006.htm

Case study

Case study 4: Buncefield oil storage depot, December 2005

Incident 4: December 2005 – Buncefield oil storage depot	
Date of incident	1 December 2005
Operator name (at time of incident)	Hertfordshire Oil Storage Ltd (HOSL) British Pipeline Agency (BPA)
Site address	Green Lane Hemel Hempstead Hertfordshire
EC reportable Major Accident?	Yes
Major Accident to the Environment?	Yes

The incident

The incident occurred when a petrol tank on the Hertfordshire Oil Storage Ltd (HOSL) site was overfilled and the subsequent explosion and fire caused escalation to the adjacent BPA site. The incident was caused by failings at the HOSL site (leading to loss of primary containment). The environmental consequences can be attributed to failings on both HOSL and BPA sites (leading to loss of secondary and tertiary containment).

The oil storage site at Buncefield was fed by three pipelines, two of which staff at HOSL had little direct control over (i.e. in terms of flow rate and timing of receipt). From around 1850 hours on Saturday 10 December 2005 unleaded petrol started being delivered from one of these two pipelines into one of HOSL's storage tanks. The tank had a capacity of 6 million litres and was fitted with an automatic tank gauging system measuring the fuel level and displaying this information in the control room. At 0305 hours on Sunday 11 December the display stopped registering any rise in fuel level, and as a result the high and high-high alarms failed to operate, despite the fact that the tank was continuing to be filled.

An independent high-level switch also failed (due to poor maintenance and testing) and by 0537 on Sunday 11 December the level of fuel exceeded the capacity of the tank and petrol started to overflow through the tank roof vents. A vapour cloud with a diameter of around 360 metres engulfed the area surrounding the tank, including a car park and a tank containing aviation kerosene. The existence of the vapour cloud was reported to on-site employees who subsequently sounded the alarm and initiated the firewater pump.

Almost immediately a huge explosion followed, the largest in the UK since the Second World War (probably ignited by an electrical spark from one of the HOSL firewater pumps starting). The subsequent fire enveloped over 20 tanks, in seven separate bunds. Over 40 people were injured as a consequence; the human and environmental toll has been considerable. The fire burned for five days with fuel, water,

Environment Agency

Environment Agency

Buncefield: leaking bund wall (top), firewater runoff (bottom)

firefighting chemicals and foam leaking down drains and soakaways, both on and off site. Pollutants penetrated the soil and entered the chalk stratum below, which is an aquifer from which potable water is extracted.

Description of the causes

The immediate cause of the incident was the failure of both forms of level control on HOSL's tank (i.e. the automatic tank gauging system and the independent high level switch). The sticking of the automatic tank gauging system resulted in the computerised control system failing to shut off the flow of fuel to the storage tank. An independent high level shutdown system had been provided on the tank, but this was inoperable so did not activate. Eventually petrol began to overflow the tank via the vents on the tank roof.

A large vapour cloud formed which eventually found a source of ignition and exploded. Following a series of further explosions, a large fire took hold of the site, and this burned for several days, producing a large cloud of black smoke. Over 40 million litres of petroleum fuels were consumed in the fire.

Some of the root causes that underpin this loss of containment are detailed below.

Design and process control factors

The HOSL tank gauging system was unreliable at the time of the incident; it was prone to sticking, and therefore failed to correctly register the level of liquid in the tank. The overfilling of the tank should then have been prevented by a second protection layer, namely the independent high level shutdown system. This system critically depended on the functioning of a high level switch in the tank, but this too was inoperable. Poor design of the switch, coupled with incorrect installation and setup, resulted in a test handle on the switch being left free to move under gravity into a position that prevented the switch from working. Had this handle been locked into the correct operating position using the supplied padlock the switch would have remained operable. A better designed switch would not have depended on this padlocking arrangement, and would have been less prone to failure, and more straightforward to maintain and test.

It has been established that the construction of the tank was such that a liquid cascade from the roof became substantially dispersed as an air entrained vapour cloud, which spread outwards from the tank and the tank bund. Coupled with the cold, still weather conditions on the day of the incident this resulted in the formation of a very large vapour cloud, which eventually ignited with catastrophic consequences.

Multiple design, modification, inspection and maintenance issues with the bunds meant that these vital secondary containment measures failed during the fire. The major cause of bund failure on both HOSL and BPA sites was the failure of flexible sealant joints between concrete sections. The sealant was incapable of withstanding the temperatures generated in the fire, leaving gaps in the bunds through which liquids could escape. This was exacerbated by the presence of holes in some of the bund walls through which pipes had been routed and in some cases pipe movement caused the HOSL bund walls to catastrophically fail.

Tertiary containment on the site (at HOSL and BPA site boundaries and the common effluent plant) also failed to prevent the flow of firewater, fuel and foam offsite. This was because tertiary containment walls either did not exist or were limited to low kerbs, and because previously unidentified pathways, on and off-site existed. Runoff was able to directly pass into the underlying aquifer.

Competency of operators and contractors

The way the independent high-level switch had been designed, installed and maintained gave HOSL's operators and managers a false sense of security. The critical role played by the padlock was not understood, which meant that following initial testing the padlock was not fitted. The safety criticality of the padlock had not been effectively communicated through clear guidance being given to the installers and the users.

Safety management systems

The site management at Buncefield did not have a sufficient understanding of the safety critical equipment within the tank storage facility and therefore did not exercise sufficient management of change oversight in ordering, installing and testing the independent high-level switch. The other immediate cause of the incident, the faulty automatic tank gauging system, was not logged as faulty by supervisors. Primarily this was because there was no proceduralised fault logging process in place, and the management of maintenance activity was deficient, so both these failures meant that the issue of the automatic tank gauge sticking on a regular basis was not recognised as safety critical and was never properly rectified.

The HOSL control room display screen showed a red 'stop' emergency shutdown button but unbeknown to a number of supervisors this was redundant; had it been working it would have provided a useful method for closing the valves in an emergency. This issue is symptomatic of poor management control and poor system design.

More stringent monitoring, testing and auditing by management should have revealed the numerous shortcomings on the HOSL site and put in place appropriate controls for the prevention of major accident hazards (e.g. the need to upgrade the automatic tank gauging system to one where an alarm would be triggered by inconsistencies between tank level measurements and filling data, as this would have detected the faulty automatic tank level gauge).

Control room and interface design

The tank gauging system had only one display screen and this was sufficient to display data for only one or two tanks at any one time. On the night of the incident the status of the overfilling tank was behind several other display windows, so visibility of tank levels was compromised.

Workload

Whilst HOSL staff did have the ultimate ability to shut a tank and prevent any further fuel delivery into any tank, they had limited control over the nature of fuel parcels delivered to the HOSL site (e.g. flow rate and timing of delivery). This, together with other issues, such as the unreliability of the automatic tank gauging system, all added to the pressure on staff. The pressure was further compounded by the working patterns employed on site. Supervisors worked 12-hour shifts whereby they could be blocked to work five shifts and would sometimes work up to 84 hours in a seven day period.

On the night of the incident, there were unpredictable job demands that added to the workload of control room operators (e.g. some road tanker filling systems had crashed). Throughput on site had recently increased and this added more pressure to staff and management on site. This pressure was made even worse by the fact that staff had no access to engineering support from Head Office.

Procedures and alarm handling

The written standard operating procedures relating to the filling process were short on detail. There was no guidance on how to choose the tanks to fill and in what circumstances it might be appropriate to fill the tank to the 'high' or the 'high-high' level. As a result, a lack of consistency had developed between the supervisors with each having their own way of responding to the alarm level indicators (automatic tank gauge data). For example sometimes the level was allowed to pass the 'high' or the 'high-high' level alarm, because supervisors relied on the alarms to control the filling process and this created unacceptably risky working practices.

Mitigation

With respect to mitigation of the environmental impacts, as noted in the design and process control factors commentary, the measures in place fell short of those expected. Bunds leaked, there was insufficient tertiary containment and emergency arrangements could not prevent the release of fuel and firewater runoff to the wider environment. The CA has highlighted that:

- Bunds should be treated as safety critical equipment. They should be designed, built, operated, inspected and maintained to ensure that they remain fit for their containment purpose.
- Where appropriate, tertiary containment should be provided to ensure that in the event of a spillage of hazardous liquids, such as fuel or fire run-off water, these are contained and pollution is prevented.
- The assessment of risks posed by a site should provide the necessary foresight to develop response plans. For environmental protection, risk assessments should identify, for credible accident scenarios, all on- and off-site pathways to environmental receptors so that measures to reduce environmental impact can be planned, implemented, maintained and exercised.

Domino issues

The incident has also highlighted the importance of the domino issue, whereby operators of multiple sites in close proximity must share information and ensure they take account of the overall hazard. The combined consequences of a major accident at one establishment which is triggered by an incident at another needs to be reflected in the measures taken to prevent and mitigate harm to people and the environment.

Work by industry and emergency responders following Buncefield has included not only better understanding how domino sites might impact each other, but also how shared use of resources (e.g. through mutual aid agreements) can be more effectively put to use to mitigate impacts should an incident occur.

Causal summary

Direct causes	Underlying causes
Defective equipment	Operating procedures
Inadequate control	Management of change including plant modifications
Incorrect installation	Selection and management of contractors
None / faulty indicator	Plant commissioning
Overflow	Plant and process design
	High workload
	Leadership / management systems
Secondary and/or tertiary containment failure causes	
Secondary leak at joint (concrete)	
Secondary structural failure	
Secondary leak other pathway	
Secondary leak at wall penetration	
Secondary fire damage	
Tertiary containment inadequate	
Tertiary other failure (general arrangement)	
Secondary / tertiary inadequate inspection and maintenance	

Environmental impacts and EC reporting

Significant quantities of pollutants entered the local environment, including the underlying chalk aquifer. The quantities of material lost have never been established. Remediation work is still ongoing with the estimated environmental costs being in the region of tens of millions of pounds.

The incident was EC reportable on many grounds (quantity of loss of substance, cost of damage, duration of evacuation) and also on the basis that over 1ha of groundwater was significantly damaged.

Penalties

Prosecutions were brought against five companies: Total UK Ltd., Hertfordshire Oil Storage Ltd., British Pipeline Agency Ltd., Motherwell Control Systems 2003 Ltd., and TAV Engineering Ltd.

The court found that environmental legislation was breached by Total, Herefordshire Oil Storage, and British Pipeline Agency. All three were guilty of polluting controlled waters. In July 2010, the court imposed fines and costs against the five companies totalling £9.5 million.

Further reading

1. *Buncefield: why did it happen*, COMAH Competent Authority, 2011, http://www.hse.gov.uk/comah/buncefield/buncefield-report.pdf
2. *Buncefield investigation final report*, Major Incident Investigation Board, 2008, http://www.buncefieldinvestigation.gov.uk/reports/index.htm#final
3. *Safety and environmental standards for fuel storage sites: Process Safety Leadership Group Final report*, ISBN 9780717663866, HSE Books 2009 [www.hse.gov.uk/comah/buncefield/response.htm]

Case study

Case study 5: Biolab Fire, September 2006

Incident 5: September 2006 – Biolab Fire	
Date of incident	4 September 2006
Operator name (at time of incident)	Biolab UK Ltd
Site address	Unit 4, Andoversford Industrial Estate Andoversford, Cheltenham
EC reportable Major Accident?	Yes
Major Accident to the Environment?	Yes

The incident

Biolab UK Ltd stored and packed swimming pool and water treatment chemicals in Unit 4 Andoversford Industrial Estate, near Cheltenham. The factory was split into two sections, one for storage and one for production. At around 1020 hours on 4 September 2006 a fire started in the production area at the back of the factory unit. Specifically the fire had started in screw conveyor equipment used to transfer granular dichloroisocyanurate dihydrate (dichlor) from a one tonne bag at ground level to holding hoppers at mezzanine level.

The electric motor driving the screw conveyor had been left running while operators went on a break. On their return, the equipment was emitting smoke, the alarm was raised and the factory was evacuated. The Fire Service arrived, following the automatic alarm, and while they were making plans on how to tackle the fire there was a fireball around 20m in height that spread the fire throughout the unit.

The Fire and Rescue Service played a significant role in reducing impact – minimising their use of water by adopting a controlled burn strategy and deploying mobile containment systems, containing some 40,000 litres of runoff. However, the speed of the fire meant that emergency bunds were not in place before chemicals (with a pH of 1) were released and entered the River Coln, following the rupture of containers. More than 2,500 fish were killed over a 6km stretch of the river.

Description of the causes

The immediate cause of the incident was a fire that started in the packaging conveyor equipment and quickly spread, resulting in the release of toxic chemicals into the River Coln. No forensic evidence has been available to identify with certainty the method of rapid fire spread or the cause of the fireball, as the factory was completely destroyed in the fire.

Design and process control factors

The most likely direct cause of the fire was mechanical overheating in the polypropylene tube of the conveyor carrying sodium dichloroisocyanurate dihydrate. It would appear that the mechanical heating caused the chemical to reach its thermal decomposition temperature, followed by self-heating decomposition and the subsequent fire.


Environment Agency


Environment Agency

(Top to bottom) Biolab fire: damage and emergency containment

At the time the incident started, the conveyor had been left running in an unattended state, the presence of automatic level switches enabling this to take place. The possible scenarios that could result from unattended operation should have been considered during the risk assessment process.

An issue that has emerged from the incident is the quality of material safety data sheets, which for this chemical stated a decomposition temperature of 240°C. The actual decomposition temperature of a bulk sample would appear to be significantly lower.

The U.N. classification of the chemical concerned has also been implicated, because it was not classified as self-reactive. This resulted in transportation in packages of 1 tonne being permitted, rather than a restriction to packages of 50 kg or under.

As the incident progressed, the fire melted through a plastic water main within the factory and caused the rupturing of chemical containers, leading to spillage of liquids. With inadequate containment offered by the factory itself, these, and the firewater produced during the emergency response, found their way into the adjacent watercourse via previously unidentified drainage routes. This highlights the importance of operators possessing complete knowledge of the layout of the drainage network and the location of outfalls, together with the need for containment using the building and surrounding areas.

There was over reliance by the operator on the emergency services to put in place containment provision, in the form of emergency bunds and drain bungs. Previously unknown pathways from the site drains to the river were identified by the Environment Agency as the incident progressed. In short, the firewater containment measures in place were insufficient.

Situational awareness

A good awareness of the environment, including the inherent risks, is critical to safe operations on site. Site management did not have a full appreciation of the risks that their activities posed. Fires are common in chemical warehouses and as such, this was a foreseeable/predictable event that was considered as a major hazard scenario in the company's environmental risk assessment. However, they never carried out an assessment of the residual risk and whether or not they had done enough to reduce this.

Senior management commitment to safety

Biolab senior management had responsibilities under the Health and Safety at Work Act (1974) to keep residual risk as low as reasonably practicable. The events of 4 September 2006 demonstrated that senior management had failed in their responsibility. To highlight this lack of commitment to safety the Biolab Major Accident Prevention Policy was never reviewed or developed, despite requests from the regulator for clarification.

The company failed to meet their obligations to control major accident hazards (COMAH Regulations), they demonstrated failures in major hazard assessment and as a result had a partial/incomplete view of the risk their activities presented. In addition the site emergency planning was lacking in detail (e.g. procedures to identify foreseeable emergencies by systematic analysis had not been adopted), which meant that there was inadequate provision given to responding to the emergency.

Causal summary

Direct causes	Underlying causes
Auto ignition / spontaneous combustion	Operating procedures
	Hazard analysis / risk assessment
	Leadership / management systems
Secondary and/or tertiary containment failure causes	
Secondary fire damage	
No tertiary containment	

Environmental impacts and EC reporting

The environmental damage following this incident was significant. The immediate aftermath led to the death of over 2,500 fish in a 6 km stretch of the River Colne. It is estimated that the river will take four to seven years to return to its pre-incident condition.

This incident was reported to the EC due to the quantity of qualifying substances involved.

Penalties

In 2010, Biolab was ordered to pay £66,000 fine and £80,000 costs at Gloucester Crown Court.

Further reading

2005-2006 biennial report from the COMAH Competent Authority, http://www.hse.gov.uk/comah/background/2005-2006biennialreport.pdf

Case study

Case study 6: Shell Bacton Gas Terminal, Norfolk, February 2008

Incident 6: February 2008 – Shell Bacton Gas Terminal, Norfolk	
Date of incident	28 February 2008
Operator name (at time of incident)	Shell UK Ltd
Site address	Paston Rd , Norwich Norfolk, NR12 0JE
EC reportable Major Accident?	No
Major Accident to the Environment?	No (incident included for relevant lessons)

The incident

Shell Bacton is a gas reception terminal situated on the Norfolk coast. The site receives natural gas from the North Sea fields via the SEAL pipeline, and from the Netherlands through the BBL pipeline. Gas is processed to meet the standards required for entry into the national transmission system. This includes the removal of hydrocarbon condensate and clathrate inhibitor, followed by drying and adjustment of temperature and pressure.

At approximately 1742 hours on the 28 February 2008 an explosion and fire occurred in the environmental wastewater treatment plant. The concrete roof was blown off the buffer tank, scattering metal and concrete debris over a wide area, including areas of the Bacton terminal where hazardous substances are handled.

The incident did not result in injuries to people, but did lead to significant environmental harm, in particular due to the run off into the sea of condensate and fire-fighting foam.

Description of the causes

The explosion was precipitated by highly flammable condensate flowing into a waste treatment plant that was not designed to handle flammable liquids. Due to the fact that a separator vessel upstream of the plant had failed due to internal corrosion, water that was heavily contaminated with condensate entered the buffer tank (a large concrete storage vessel).

Heating elements at the bottom of the buffer tank ensure the contents of the tank are kept at a constant temperature. The operators were running the tank in manual mode, which meant, unbeknown to them, that all safety cut outs are overridden. The highly flammable condensate vapour came into contact with the heating elements causing the explosion.

Design and process control factors

The immediate cause of the explosion was the highly flammable condensate vapour entering the wastewater treatment buffer tank and coming into contact with the

Crown copyright

(Top to bottom) Shell Bacton: explosion damage and separator tank

heated elements in the vessel. There should not have been flammable hydrocarbon vapours in the wastewater buffer tank as this was designated a no-hydrocarbon zone. The presence of hydrocarbon condensate was due the malfunctioning of a separator vessel upstream of the wastewater plant, VG110.

VG110 failed to operate correctly because of severe internal corrosion, leading to the carry over of condensate into the wastewater stream.

Maintenance failings

There was a catalogue of maintenance failings leading up to the explosion at the Bacton terminal.

Underpinning the maintenance failings was the inadequacy of the maintenance regime itself. As VG110 was originally designed as a 'bullet' pressure vessel, the regime focused on maintaining the integrity of the pressure envelope, i.e. the external walls. The in-service purpose of the vessel as a separator depended critically on the integrity of various internal features, in particular the bucket and weir plate. It is these internal features that prevented the carry-over of condensate into the wastewater treatment plant.

Internal inspections of the vessel in 1996 and 2000 identified significant, and worsening, corrosion in the weir plate. The next scheduled internal examination however was not due until 2008. This emphasises the need to draw up an inspection regime that is suitable for the purpose of the vessel – more attention should have been paid to the integrity of the critical internal parts.

IChemE

More missed indicators that there was a problem

It was also evident as early as 2004 that hydrocarbon vapours were leaving via the water feed from VG110 to the wastewater buffer tank. Attempts to fit an online hydrocarbon analyser on the feed line had to be abandoned due to the high levels of hydrocarbons in the line.

In early 2006 a large layer of condensate was observed in the wastewater buffer tank, another sign that VG110 was not operating correctly. In late 2006 condensate was observed to overflow from the buffer tank. In May 2007 condensate was again recorded in the buffer tank. In January 2008 it was discovered that a sample taken from the outflow of VG110 was entirely composed of condensate.

Failure to appreciate the significance of the problems

Shell failed to understand the significance of flammable condensate reaching the wastewater buffer tank. The wastewater plant was not intended to contain flammable hydrocarbons, was rated as a non-hydrocarbon environment, and consequently the electrical equipment contained within the plant was not suitable for use in explosive atmospheres. Shell should have understood the significance of flammable hydrocarbons entering a zone that was rated as non-hazardous.

Process problems in the buffer tank

One week prior to the explosion problems with the low level sensor in the buffer tank resulted in a switch to manual operation of the buffer tank pumps. Unbeknown to the operators, this meant that the level of water in the buffer tank could be pumped lower than the minimum required, exposing the electrical heating elements, which eventually heated the condensate vapour to temperatures above its flash point, resulting in the explosion.

Failure in emergency response

Shell failed to close the Bacton sea gate until around one hour after the start of the fire, which resulted in the loss of 850 tonnes of a mixture of water, fire-fighting foam, and hydrocarbon condensate into the North Sea. In addition, emergency response arrangements to block drainage pathways could not be carried out in practice because incident conditions made them too difficult and dangerous – issues which were foreseeable.

SMS (including management of change, major hazard evaluation and monitoring performance)

The buffer tank was commissioned in 2000 and no risk assessment of the environmental waste water treatment plant was ever carried out to consider the safety implications of the tank receiving water with traces of condensate in the event of a failure of the separator. As a result the electrical equipment located in the buffer tank was not explosion-rated and the zone around the tank was incorrectly designated as non-hazardous.

Operational staff had expressed their concern relating to condensate in the buffer tank. This had been noted, but no remedial action been taken. The management on site had every opportunity to assess the changing situation and realise that there was a significant risk of explosion, but they failed to do so.

Training, instructions and communication

The significance to safety of switching the buffer tank pumps from automatic mode and placing them into manual operation was not appreciated by the operators on site i.e. that in manual mode there is no lower level cut off. This safety critical piece of information was never communicated to staff through training, instruction manuals, standard operating procedures or on the equipment itself.

Causal summary

Direct causes	Underlying causes
Auto ignition / spontaneous combustion	Planned plant inspection
Corrosion – internal	Operating procedures
Inadequate control	Management of change including plant modifications
Inadequate procedures	Plant and process design
Unsuitable equipment	Handover / communication
	Ageing plant
	Leadership / management system
Secondary and/or tertiary containment failure causes	
Tertiary other failure (procedural)	

Environmental impacts and EC reporting

Whilst 850 tonnes of a mixture of water, fire-fighting foam, and hydrocarbon condensate were lost to the North Sea, there have not been any apparent long-term impacts.

Although considered a Major Accident, the incident did not exceed any of the criteria for reporting to EC.

Penalties

In June 2011 Ipswich Crown Court ordered Shell to pay a total of £1.24 million in fines and costs, pertaining to breaches of both environmental and health and safety legislation.

Information sources

A selection of further sources of case study material

Whilst the incidents presented in this report have been selected to highlight a variety of the causes and underlying causes of most relevance to environmental protection, inevitably a report such as this cannot be fully comprehensive. To ensure lessons are learned from previous incidents and implemented as necessary, operators should not only review their own incidents and near misses, but should review those of others, available from various sources (with examples below). This process can be optimised by focusing on the specific plant type and/or the dangerous substances relevant to the characteristics of the establishment.

In many cases, trade associations and professional bodies are involved in promoting the dissemination of lessons, including via various established safety groups, forums and conferences. In addition, operators need to periodically review the measures they use to prevent and mitigate accidents against updated codes, standards and guidance (good practice), since these will often incorporate learning from accidents.

The following links provide sources of information on incidents relevant to COMAH sites, providing detail of causes, root causes and lessons / recommendations. Since the frequency of high impact events is low, then lessons need to be learned from all relevant global incidents.

UK

- HSE (on behalf of the COMAH Competent Authority)
  - reports of CA investigations [http://www.hse.gov.uk/comah/investigation-reports.htm]
  - summaries of incidents reported to Europe [http://www.hse.gov.uk/comah/accidents.htm]
  - COMAH incident case studies [http://www.hse.gov.uk/comah/sragtech/casestudyind.htm]
  - Safety Alerts and Bulletins [http://www.hse.gov.uk/comah/alert.htm] and [http://www.hse.gov.uk/safetybulletins/index.htm]
  - UKPIA – Process Safety Alerts [http://www.ukpia.com/process-safety/process-safety-alerts.aspx]
  - Process Safety information and alerts from the UK Process Safety Forum [http://www.p-s-f.org.uk/

Europe

- eMARS – incident records [https://minerva.jrc.ec.europa.eu/en/emars/content/index]
- EC MAHB – The Minerva Portal of the Major Accident Hazards Bureau. A Collection of Technical Information and Tools Supporting EU Policy on Control of Major Chemical Hazards. Includes themed lessons learned bulletins in the publications section. [https://minerva.jrc.ec.europa.eu/en/minerva]

Global

- ARIA – incident reports, sorted by sector (detailed sheets), activity and theme (analysis and feedback), plus proceedings of IMPEL conferences [http://www.aria.developpement-durable.gouv.fr/index_en.html]
- US CSB – detailed investigation reports, recommendations and safety videos [http://www.csb.gov/]
- IChemE
  - Loss prevention bulletin [http://www.icheme.org/lpb]
  - Hazards symposium series [http://www.icheme.org/communities/special-interest-groups/safety%20and%20loss%20prevention/resources/hazards%20archive.aspx]
  - Lessons Relearned [http://www.tcetoday.com/lessonsrelearned.aspx]
- AIChE
  - CCPS Process Safety Beacon [http://www.aiche.org/ccps/resources/process-safety-beacon]
  - CCPS Process Safety Incident Database [https://www.aiche.org/ccps/resources/psid]

Appendix

Appendix A: MATTE statistics

eMARS data

A search of the eMARS database was conducted for the period 1980 to 2010 in order to obtain figures for major accidents that were reported to the European Commission (EC) under the Seveso directives. It should be recognised that not all incidents will meet the qualifying criteria for a report to be submitted to the Commission.

The definition of a major accident given in the COMAH regulations is:

"major accident" means an occurrence (including in particular, a major emission, fire or explosion) resulting from uncontrolled developments in the course of the operation of any establishment and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances.

The requirements for reporting to the EC are set out in Schedule 7 Part 1 of the COMAH regulations. For environmental damage the stipulations are:

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

- *0.5 ha or more of a habitat of environmental or conservation importance protected by legislation;*
- *10 or more hectares of more widespread habitat, including agricultural land;*

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

- *10 km or more of river or canal;*
- *1 ha or more of a lake or pond;*
- *2 ha or more of delta;*
- *2 ha or more of a coastline or open sea;*

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

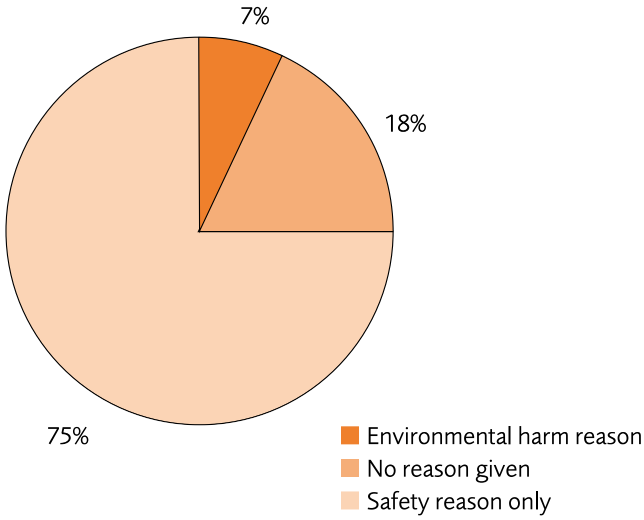
- *1 ha or more.*

The data obtained from the eMars searches are tabulated below.

eMARS major accidents reported 1980 - 2010	
Major accidents reported	670
Seveso I/II reports (i.e. COMAH type)	651
- of which environment is referred to in reason for reporting	45
- of which no reason for reporting is given	117
Balance (reported as OECD only)	19

As shown in the figure that follows, 7% of the EC reportable accidents over the period analysed specifically referenced harm to the environment as a reason for reporting.

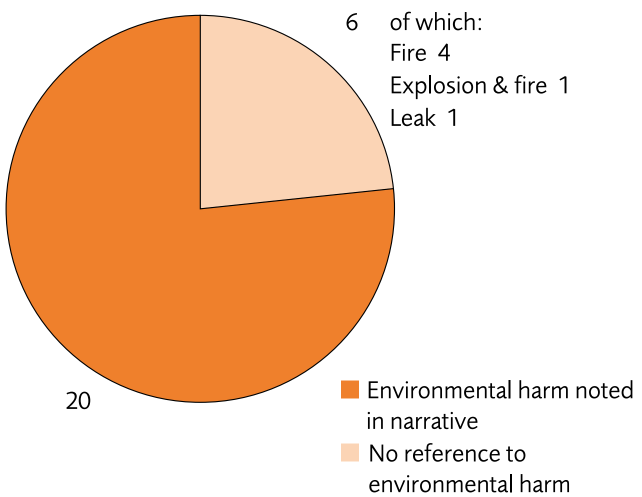
It should be noted that the presence of environmental harm as the reason for reporting does not mean that the other incidents resulted in no release or damage to the environment



at all. It is probably likely that a proportion of the other incidents did have some impact on the environment, though perhaps not long lasting. Fully 18% of the incidents reported had no reason for reporting given. This highlights that the data set is potentially unreliable, as there must have been some reason for the report being made – it is likely that not all report correspondents fill in the database fields fully.

Further analysis was undertaken on a subset of incidents reported by the UK over the period 2000 – 2009. Each incident report was studied in full and any mention of environmental harm was noted. The results for the 26 incidents reported are presented below.

In the case of the UK data, environmental harm was noted for six of the incidents (23%). Fire was involved in five of the six environmental incidents, with the remaining one involving the leak of chemical inventory. Overall five of the incidents involved environmental harm through firewater runoff, and two of them via loss of chemical inventory to the



environment (the leak and one of the fires). The environmental harm was caused by liquid leaks or fire runoff, whilst aerial releases (e.g. smoke from fire) have not created long-term environmental harm. In some cases, even though there has been an EC reportable fire, runoff has been contained and pollution minimised. Two eMARS entries (8%) specified environmental harm as a reason for the reporting to the EC (Buncefield and Petroplus, as detailed in the case studies).

Data in the latest three-year report from the EC (2006-2008)[1] shows the European Major Accident rate decreasing (a slight decrease in numbers of accidents combined with an increase in total number of Seveso sites). According to the report, "The frequency of accidents, which had for many years been higher than three per 1000 establishments per year, seems to be falling to under three on average for the latest reporting period and will hopefully approach two in the near future".

COMAH Competent Authorities' data

The COMAH Competent Authorities collect data on incidents at COMAH sites. Data for the period April 2007–November 2011 was extracted from HSE's corporate information system, the COIN database (though some data has only been available since new causation and impact categories were created in 2010 following the COMAH remodelling initiative www.hse.gov.uk/comah/remodelling/index.htm). This has been analysed as part of the COMAH Competent Authority's intelligence gathering work. Extracts from this that are relevant to the environmental aspects of COMAH are reproduced below.

Mitigating measures (data for 2007–2011)

Graph 1 illustrates the mitigating measures that were deployed to arrest the progress of the incidents. The type of dangerous occurrence is illustrated by the colour codes. Stopping the process was the most commonly deployed mitigation measure, followed by a successful containment of spillages within the secondary containment provision. Manual shut-off valves are also frequently resorted to for mitigation. Mitigation by the effluent system / tertiary containment system featured in 17 cases. Restoration and cleanup offsite was rarely resorted to, which demonstrates that most incidents do not escalate to the extent that environmental harm results.

Failures of secondary / tertiary containment (data for 2010–2011)

An analysis of the failures, or otherwise, of secondary and tertiary containment measures is presented in Graph 2. In most cases for which data are available there was no significant failure of secondary or tertiary containment. However, when there was a failure, the most common one identified was the complete absence of secondary containment.

Area affected (data for 2010–2011)

When considering environmental incidents, understanding the area affected is important. Graph 3 illustrates the area affected for the incidents recorded. In the majority of cases only the area onsite is affected.

By stripping out the onsite category more clarity can be obtained on the other areas affected, as illustrated in Graph 4. Potential serious damage to the environment is recorded in two instances. Over the period of study, no actual serious damage to the environment was noted on COIN.

Summary

The data analysed indicate that environmental damage and offsite effects are experienced with incidents on COMAH sites, but occur in a relatively small proportion of cases.

The importance of secondary containment measures is illustrated by the fact that these measures are the second most relied on measure for preventing escalation. It is therefore comforting that in the majority of cases examined, no significant failings were found in the secondary containment system. However, it must also be considered that the data set is currently limited, with some 2010/11 incident data yet to be entered (some environmental investigations currently ongoing).

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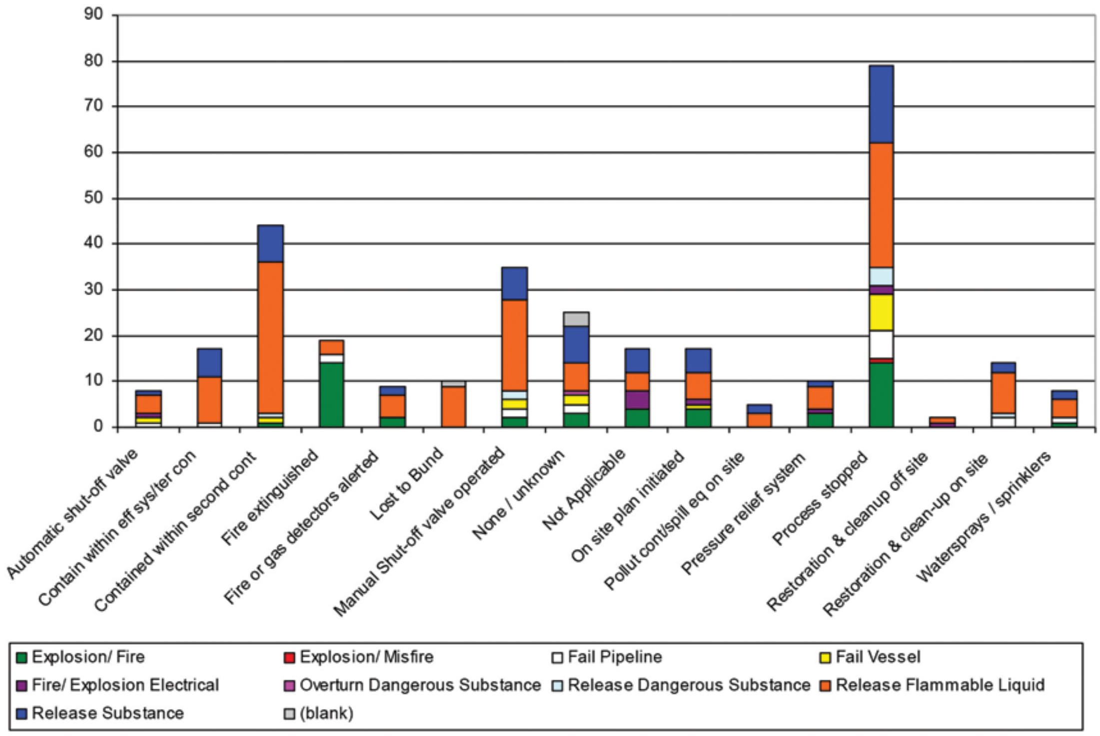
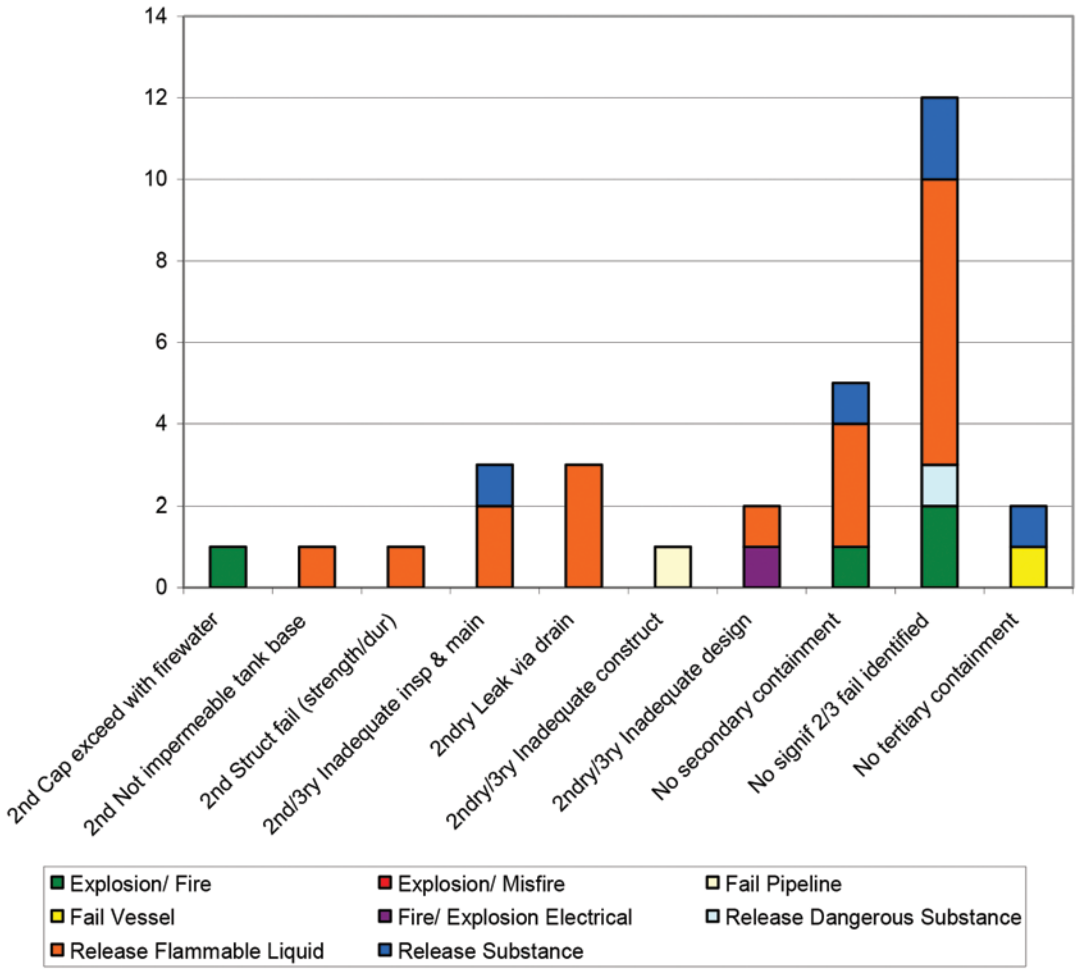
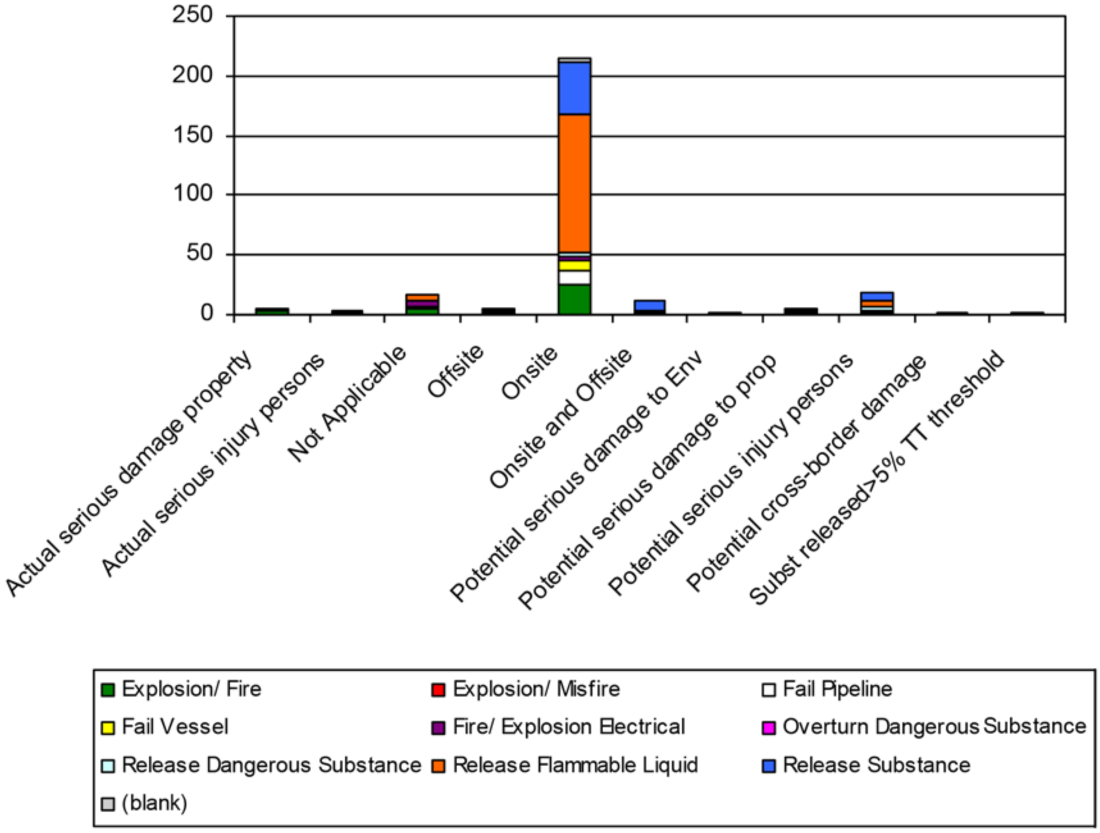
[1] *Report on the Application in the Member States of Directive 96/82/EC on the control of major-accident hazards involving dangerous substances for the period 2006-2008 [http://ec.europa.eu/environment/seveso/pdf/report_2006_2008_en.pdf]*



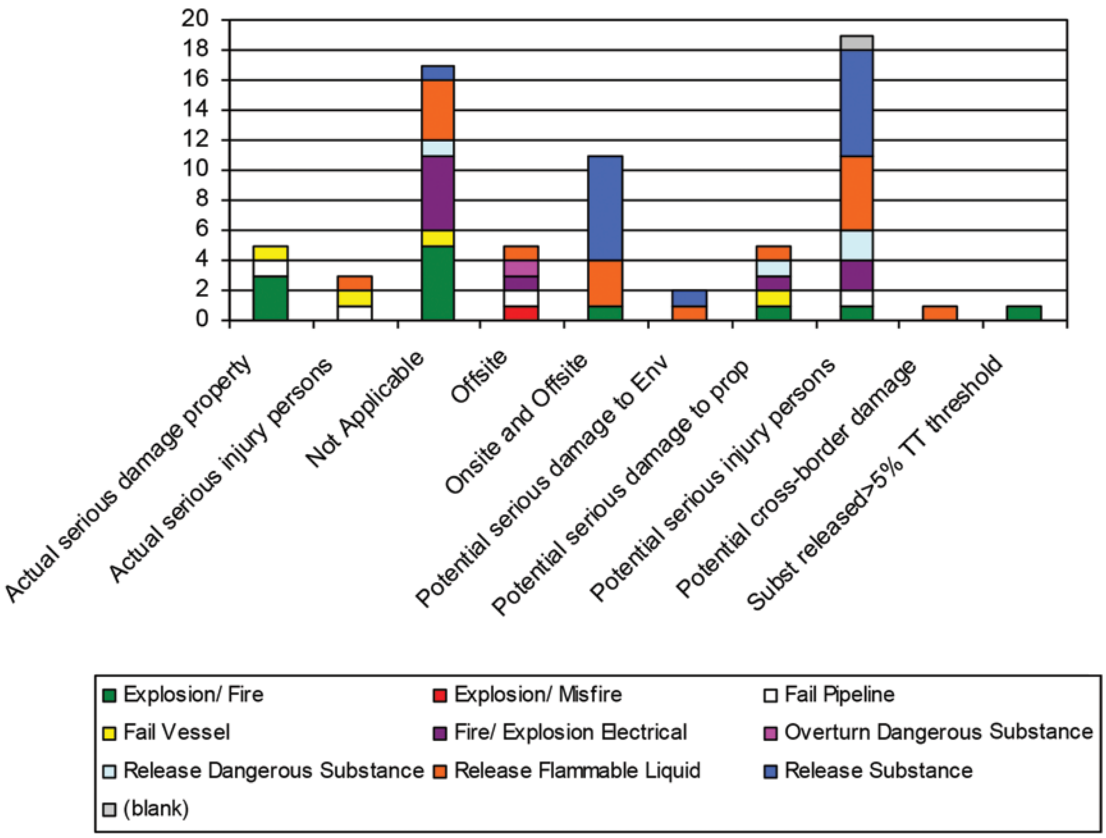
Graph 1: Mitigating measures used to stop the progress of incidents



Graph 2: Analysis of secondary and tertiary containment failures



Graph 3: Area affected during an incident



Graph 4: Analysis of offsite effects

Appendix

Appendix B: Major environmental incidents

Year	Place	Accident	Substances	Amount released	Impact	Costs (not today's value)	Lessons
1976	Seveso, Italy	Seveso	Dioxin	1 / few kg	10 square miles land and vegetation contaminated. Many animal deaths, 600 people evacuated, 2000 people treated for dioxin poisoning	>$10 billion clean-up and compensation	Seveso Directive
1986	Switzerland	Sandoz warehouse fire	Flammables, toxics & R50/53, pesticide and firewater	Estimated <30 tonnes dangerous substances (out of 680 tonnes total) in firewater	Extensive cross border to Rhine killing most aquatic life over 100s km and many years recovery	90M Euro total (24M Euro remediation, 27M Euro compensation, 39M Euro damage to premises)	Pollution could have been reduced by: - Sprinklers (reduce volume of water) - Better containment (warehouse and drainage) - Firewater management plans Seveso Directive
1989	Prince William, Alaska	Exxon Valdez (tanker)	Crude oil	38,000 tonnes	Pollution of 1,090 miles coastline, large kill of otters and seabirds. Long term recovery (half species recovered after 10 years)	$1–2 billion clean-up $100 million ecological recovery	United States introduced ban on single wall tankers in US waters.
1992	Bradford UK	Allied Colloids fire	Oxidising and flammable raw materials warehouse and external drum store	Some of the 16M litres of firewater runoff	10–20,000 fish killed over 50 km stretch of river		New warehouse – high fire prevention standards, sprinklers, segregation. New £4M water supply, drainage and containment system installed with boundary walls and retention basin
1996	Milford Haven UK	Sea Empress (tanker)	Oil & fuel	72,000 tonnes crude and 370 tonnes of heavy fuel oil	Pollution of 200km coastline. Beach closures, temporary fishing bans. Wildlife recovery within 2 years	$60 million total, $36 million clean-up	
1998	Portugal	Porto refinery spill, followed by flow off-site and ignition on beach	Crude oil	230 cubic meters	One fatality, human injuries, water contamination	20 million Euro (material loss)	Motorise block valves to reduce response times, Improve onsite drainage systems and procedures to minimise risk of hydrocarbon release through outfall
1998	Spain	Aznalcollar tailings dam, Donana lowlands	Tailings, acidic & heavy metals	5–7 million cubic metres (including 2 million cubic metres of mud)	5000 ha agricultural land destroyed Aquatic life killed over first 40km of spill (30 tonnes of dead fish)		
2000	Sweden	Gällivare, Tailing dam failure	Tailings		Material loss, ecological harm		
2000	Romania	Baia Mare tailings dam	Included cyanide	100,000 cubic meters tailings water	Extensive cross border >1,000km rivers, 1,240 tonnes dead fish in Hungary alone, drinking water interruptions to 2.5 million people		
2000	France	Haguenau, Large fire in a glues and resins factory			Ecological harm	>15 million Euro (material loss)	

Year	Place	Accident	Substances	Amount released	Impact	Costs (not today's value)	Lessons
2004	Italy	Ancona explosion and fire in a storage facility during loading			One fatality, three people injured, ecological harm	6.5 million Euro (material loss) 56 million Euro (costs for renovation, and disrupted production)	
2005	Milford Haven	Petroplus tank bottom leak	Kerosene	~650 tonnes	>1ha groundwater contaminated.	> £3 million clean-up	Pollution could have been avoided / reduced by: Inspecting to standards (API 653 / EEMUA 159) Impermeable tank bases Inclusion of tank bottom leakage as Major Accident Scenario
2005	Belgium	Kallo, major leak in a storage tank			Soil contamination		
2005	Buncefield	HOSL, Buncefield explosions and fire	Fuels	Thousands of tonnes of fuel and firewater (68 million litres used)	>1ha groundwater contaminated. Extensive damage to property on and off-site.	£1 Billion total, site clean-up estimated to be £30-50 million with ongoing remediation adding to this	Improved secondary and tertiary containment standards.
2006	Andoversford UK	Biolab fire	Swimming pool / water treatment chemicals	> 40 tonnes R50 involved	~2500 fish killed over 6km river with 4–7 yr recovery time predicted. Road closures and business disruption		Pollution could have been reduced by: better containment & knowledge of drainage pathways on and off site.
2006	Louisianna, USA	Huricane Katrina, Murphy Oil tank failure - flooding	Mixed Arabian Crude	25,000 barrels	City canals and over one square mile of neighbourhoods oiled	$50M fine $70M clean-up $30k per home compensation	Pollution could have been reduced by: filling tank before flooding so it did not float.
2007	France,	Ambes sudden oil tank bottom rupture	Light crude	10,800 tonnes, 2000 m^3 escaping bund, 50 m^3 to river	Pollution of ground, shallow groundwater and 40km river banks		No procedure in SMS to manage minor leak on previous day. Time lapse between scheduled inspections was too long: the last inspection in 2006 detected wall thickness losses attaining 80% in certain points [inadequate rejection criteria?].
2008	Dormagen, Germany	Ineos explosion & fire after pipeline rupture	Ethylene – escalation to acrylonitrile		On-site and environmental damage	3.2 million Euro (on-site & environmental damage) 40 million Euro (material loss)	

It should be noted that over the past three years (2010–2012) major accidents have continued to occur at UK COMAH establishments (in particular fires at refineries and chemical warehousing or production). These have caused fatalities and serious environmental harm. In some cases firewater runoff was contained, but in others it was released to the environment. These incidents are subject to ongoing investigation and will be reported by the CA in the future.

Appendix

Appendix C: Near misses

The table below collates information from a number of near misses identified by Environment Agency Officers. These resulted in formal enforcement action in the form of improvement notices.

Sector	Failings identified
Logistics	Firewater containment provisions inadequate / inadequately devised
Fuel storage	Inoperable drainage valves on secondary containment Inadequate storage tank leak detection Insufficient provision for prevention of tank overfilling
Logistics	Insufficient environmental hazard identification and likelihood / consequence assessment
Chemical manufacturing	Firewater containment provisions inadequate / inadequately devised
Chemical manufacturing	Material segregation for the purposes of fire escalation inadequate Secondary containment capacity not sufficiently assessed
Chemical manufacturing	Tertiary containment in poor state of repair
Chemical manufacturing	Broken drainage system Inadequate knowledge of drainage sizes and locations
Logistics	Insufficient environmental hazard identification and likelihood / consequence assessment
Chemicals manufacturing	Insufficient environmental hazard identification and likelihood / consequence assessment