

LEARNING FROM PROCESS SAFETY INCIDENTS[†]

John A Hare^{1,*}, Michael P Johnson¹, Brian Fullam²

¹Health and Safety Laboratory, Buxton, UK

²Health and Safety Executive, Leeds, UK

*Corresponding author: john.hare@hsl.gov.uk

The process industry and the health and safety regulator both have a need to learn the lessons from process safety incidents. In the UK, the Health and Safety Laboratory is undertaking operational research and analysis of data from process industry incidents to inform the Health and Safety Executive's decision-making, prioritization and trend analysis. Sources of data are discussed. A preliminary incident analysis is provided: Process industry dangerous occurrences are reviewed for 2008 with explosive manufacturing having most incidents followed by oil refining. For a sample of 19 incidents from 2006 and 2007 direct causes, underlying causes, safety management failings and "mitigation against escalation" are all discussed. Inadequate isolation was the most prominent direct cause. Operating procedures and hazard analysis/risk assessment were significant underlying causes. Planning and implementation followed by organising/competence were significant safety management failings. Process stopped and none/unknown were the most frequent "mitigation against escalations". Ways to improve the HSE incident data recording system are identified.

INTRODUCTION

Learning from incidents is necessary to help prevent future recurrence. Both the regulator and the chemical industry need to learn the lessons. HSE uses the analysis of incident data as one of its operational intelligence streams to better plan its interventions and to ensure resources are targeted where they can be of most benefit. It also provides part of the evidence base to steer operational policy decisions and resulting guidance. This paper describes work, which is still in progress, to provide analysis of process safety incidents and to advise on better ways of capturing data for future ongoing analysis.

Within the process safety community in HSE and HSL a number of knowledge hubs have been set up. The HSE/HSL process safety community are experts in process safety issues who also have access to an internal website. The process safety knowledge hubs manage knowledge and promote a consistency of approach between HSE process safety specialists in key areas. Incident analyses are therefore of interest to these knowledge hubs, to other specialist disciplines in HSE, and to wider HSE initiatives such as the Remodelling Control of Major Accident Hazards (COMAH) programme, which is reviewing the way in which the COMAH Competent Authority regulates under the COMAH Regulations. The work carried out on process safety incident analysis was informed by discussions with HSE staff representing the process safety and other specialist disciplines.

SOURCES OF DATA

CURRENT HSE DATA SOURCES

Incident investigation reports by HSE inspectors are currently stored on HSE's data storage systems (EDRM and COIN). Both regulatory inspectors and specialist inspectors

would contribute to the investigation. The regulatory inspector, using a template, normally completes the investigation report, which summarises the main investigation findings. Other more detailed reports will also be available.

The regulatory inspector records causal analysis of incidents. The causal analysis is in conformation to an HSE semi-permanent circular (SPC/Enforcement/132) (HSE, 2004c), which requires incident causes and activities to be recorded after April 2007. Specialist inspectors may only need to be consulted on the more complex larger incidents. Figure 1 shows the available causal categories from SPC/Enforcement/132.

The companies who have the incidents are legally required to report injuries or dangerous occurrences under RIDDOR (Form F2508, HSE 2009). There is an HSE website which stores these reports. HSE staff can arrange to search and download any RIDDOR report. There is often an historical description of the incident. Other useful information includes the Dangerous Occurrence (DO) Type, the Standard Industrial Classification (SIC) and the Process Environment (PE) code (the Chemical Engineering operation or other work process) (The Stationary Office, 2003). Figure 2 defines the relevant and possible DOs, SICs and PEs. These three types of information can be used to sort the data. Data can easily be extracted from the RIDDOR website and put into spreadsheets for further analysis. The quality of the RIDDOR incident data is also likely to vary.

PREVIOUS AND OTHER HSE DATA SOURCES

HSE used to produce annual sector reports covering the onshore oil and chemical industries, based on RIDDOR data (HSE, 2003b; HSE, 2003c; HSE, 2004b; HSE, 2003d; HSE, 2003e; HSE, 2003f). These reports were

[†] © Crown Copyright 2009. This article is published with the permission of the Controller of HMSO and the Queen's Printer for Scotland.

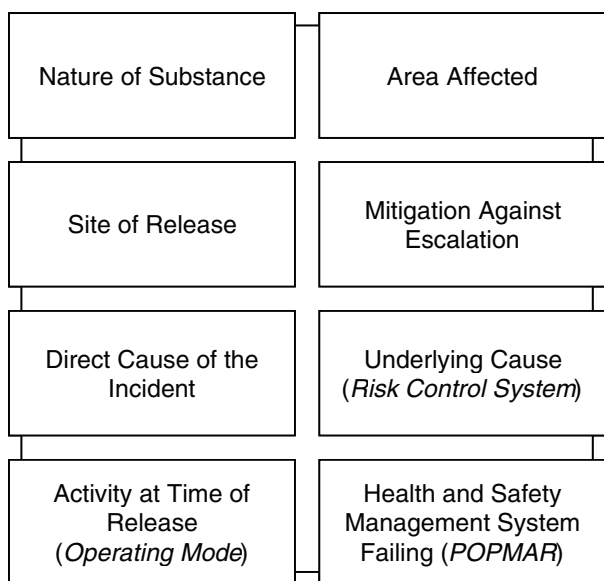


Figure 1. Available causal categories

useful as RIDDOR was searched using SICs and information on trends including DO type and Process Environment was presented. There would be some merit in the annual reports being reintroduced.

HSE’s Hazardous Installations Directorate Inspectors using both RIDDOR and Incident Investigation Report Data

produced a database (FIREX). Only Fire and Explosions were considered, as DO types. All fires and explosions were searched for not just those on chemical plants. The extraction process was quite time consuming. Runaway reaction incident data was particularly difficult to extract (Fowler & Baxter, 2000; Bradley & Baxter, 2002).

HSE has to report any large COMAH incidents every year to the EU (HSE, 2000a; HSE, 2001a; HSE, 2002a; HSE, 2003a; HSE, 2004a). There is a great deal of information on such large incident investigation as teams of HSE staff are generally involved. The reports could be used to identify large incidents for further study.

Large scale incidents are investigated by a team of regulatory and specialist inspectors. The data is likely to be of high quality with good incident history, causes and lessons to be learned. Examples include the Grangemouth and Humber Refinery Incident Reports (HSE, 2003g; HSE, 2005b).

An HSL report (HSL, 2003) and subsequent SPC (HSE, 2004c) tried to provide a causal analysis of incidents using incident investigation reports. The technique of relating the direct cause, release site, operating mode (activity at time of release) and primary risk control system (underlying cause) in the same table seemed to be a good one. The health and safety management system failings were also classified using POPMAR (ref HSG 65). Underlying causes also needed to be captured.

During 2004/05 the chemical industry was asked to provide their own simple causal analysis of incidents. A report (HSE, 2005a) on this voluntary reporting of loss of

Dangerous Occurrences		Process Environment	
02	Pressure System	0421	Bulk Transfer and Storage
05	Electrical Short Circuit	0422	Non-Bulk Transfer and Storage
06	Explosives	0423	Crushing, Grinding, and Drying
14	Pipelines and Pipeworks	0424	Mixing Without Reaction
19	Explosion or Fire	0425	Separation Processes
20	Escape of Flammable Substances	0426	Chemical Reactions
21	Escape of Substances		
Standard Industrial Classification Codes (SIC Codes)			
23200	Manufacture of refined petroleum products		
23201	Mineral oil refining		
23209	Other treatment of petroleum products (excluding petrochemicals manufacture)		
241**	Manufacture of basic chemicals: industrial gases, dyes and pigments, other organic and inorganic basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms		
24200	Manufacture of pesticides and other agro-chemical products		
243**	Manufacture of paints, varnishes and similar coatings, printing ink and mastics		
244**	Manufacture of pharmaceuticals, medicinal chemicals and botanical products		
245**	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations		
246**	Manufacture of other chemical products: explosives, glues and gelatine, essential oils, photographic chemical material, prepared unrecorded media, and other chemical products not elsewhere classified		
24700	Manufacture of man-made fibres		

Figure 2. Relevant dangerous occurrences, process environments and SIC codes

containment incidents has been published by HSE. There were also some anonymised incident descriptions. The report looks at both chemical and refinery incidents in separate sections.

Generally data varies in quality, detailed investigations of a few large-scale incidents generally provide high quality data whilst general incident data involving a high number of incidents may be variable in quality.

EXTERNAL DATA SOURCES

The IChemE's Loss Prevention Bulletin provides useful information on process incidents and lessons learned. The incidents described occurred in the UK and other countries. IChemE also ran a worldwide accident database, which has now been discontinued. Worldwide incidents can also be identified using regular literature reviews. The Major Hazards Incident Data Service (MHIDAS) (Fewtrell and Hirst, 1998), which was operated by AEAT on behalf of HSE, did this until the late 1980's/early 1990's. There may be a case for the reintroduction of such a service. The EU's Major Accident Reporting System (MARS) (EU Joint Research Centre) is a database containing all incidents reportable to it, under the Seveso Directive (implemented as COMAH in the UK). Both MHIDAS and MARS data is stored in a searchable database. In the United States, the Chemical Safety and Hazard Investigation Board (CSB), undertakes thorough investigations into large chemical plant incidents and produces useful reports on them. The CSB report into the Texas City Refinery incident (CSB, 2007) would be an example of such a report.

PRELIMINARY INCIDENT ANALYSIS

Some preliminary analysis of process safety incident data has been carried out or is planned within the project and is described here. As well as producing intelligence on process safety incidents, the process of analysis enabled issues and difficulties with the analysis of incident data to the identified and possible improvements to be suggested.

IDENTIFYING INCIDENTS USING RIDDOR AND COIN

Incidents may be identified from either RIDDOR or COIN. The search terms used for RIDDOR were firstly "loss of containment DO with relevant Process environment codes" and secondly "all DO in relevant manufacturing industries by SIC codes" for the calendar years 2006, 2007 and 2008. Figure 3 details the search terms used. The RIDDOR web pages were downloaded and the data transferred into a spreadsheet.

The HSE COIN data mining team was also asked to provide information on all Dangerous Occurrences assigned to HSE Hazardous Installations Directorate Chemical Industries Division (HID CI) between 01/04/2006 and 31/03/2008. This should capture many onshore process safety dangerous occurrences. The DO type, Process environment code, regulatory inspector, HIDCI team details and incident

description were all provided. The HSE COIN data mining team were also asked to provide information on all Dangerous Occurrences assigned to HID CI between 01/04/2008 and 31/03/2009.

RIDDOR ANALYSIS GRAPHS

Percentage bar charts were produced for each year (2006, 2007 and 2008) showing the numbers of each LOC dangerous occurrences on each bar for each relevant Process Environment and manufacturing SIC. Examples are provided for the year 2008: Figure 4 shows the Process Environments and Figure 5 shows the manufacturing SICs. Figure 4 shows that incidents involving chemical reactions can result in explosive dangerous occurrences. This is likely to be in the manufacture of explosives and Figure 5 shows that most dangerous occurrence incidents occur in the manufacture of explosives, but this industry is known to be particularly hazardous. A significant number of dangerous occurrences incidents also occur in the oil refining industry.

RIDDOR AND COIN SPREADSHEETS

The incidents identified using RIDDOR were arranged in a spreadsheet in order of Dangerous Occurrence, Process Environment and SIC. The incident spreadsheet supplied by the HSE COIN data mining team can also be arranged to show relevant Dangerous Occurrences or Process Environments, but not SICs, using a data filter. These spreadsheets enable incidents of interested to particular HSE Process Safety Knowledge Hubs and other inspector disciplines (Mechanical Engineering and Electrical/Control and Instrumentation (C&I)) to be easily identified. Table 1 suggests which particular codes may be most relevant to the various hubs and disciplines. An improvement to COIN would be to also record the SIC.

DATA ANALYSIS USING HSE INVESTIGATION REPORTS

For the years 2006 and 2007 a selection of RIDDOR incidents were identified and searched for on COIN using the ICC number. If a standard HID Investigation Report was available, it was noted and saved. The information from the HID investigation reports has been collected into a spreadsheet with headings based on the investigation report template. If the causal analysis drop down menu had been completed this too was noted and saved. The causal analysis was introduced by SPC/Enforcement/132 and would be expected after April 2007. A similar process will be done for the 2008 incidents identified with RIDDOR. Thus information from RIDDOR, the HSE investigation report and causal analysis results can be stored in the same spreadsheet.

HSL plans to also undertake a full analysis of all process safety incidents, but only where HSE investigation reports are available, for the years 2006, 2007 and 2008. The analysis will be based on both the HSE investigation report and the RIDDOR report using SPC/Enforcement/132 causal categories (Figure 1), but more than one cause will be recorded.

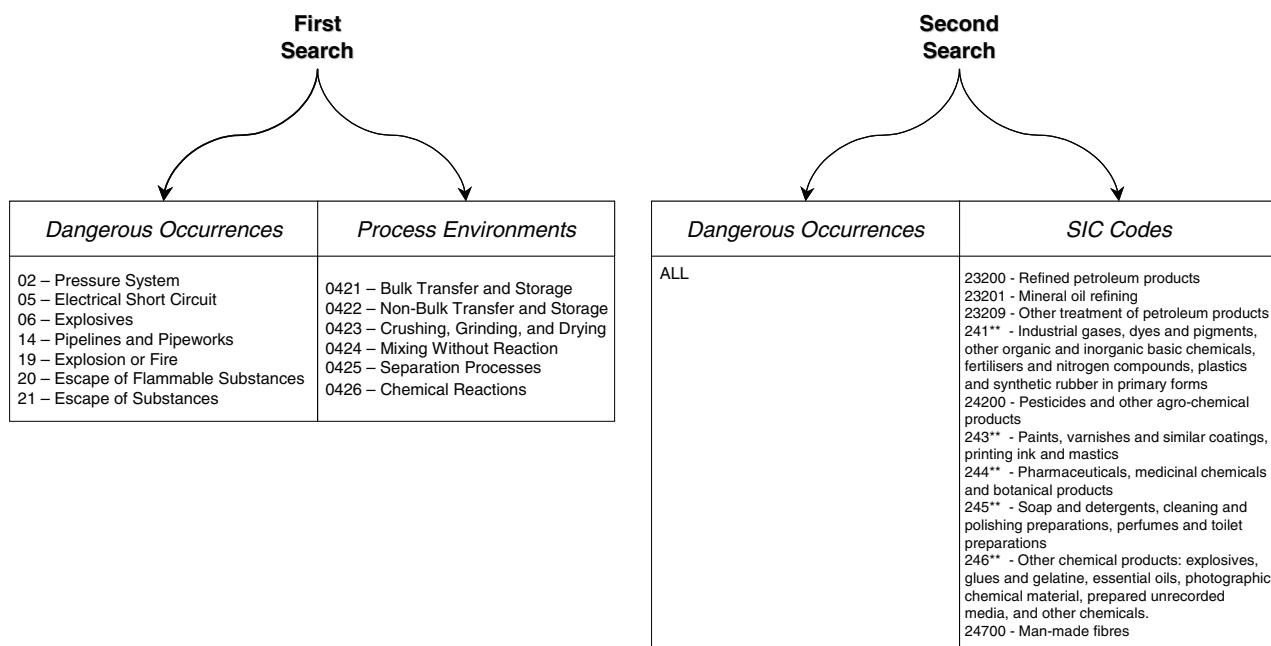


Figure 3. Search terms used

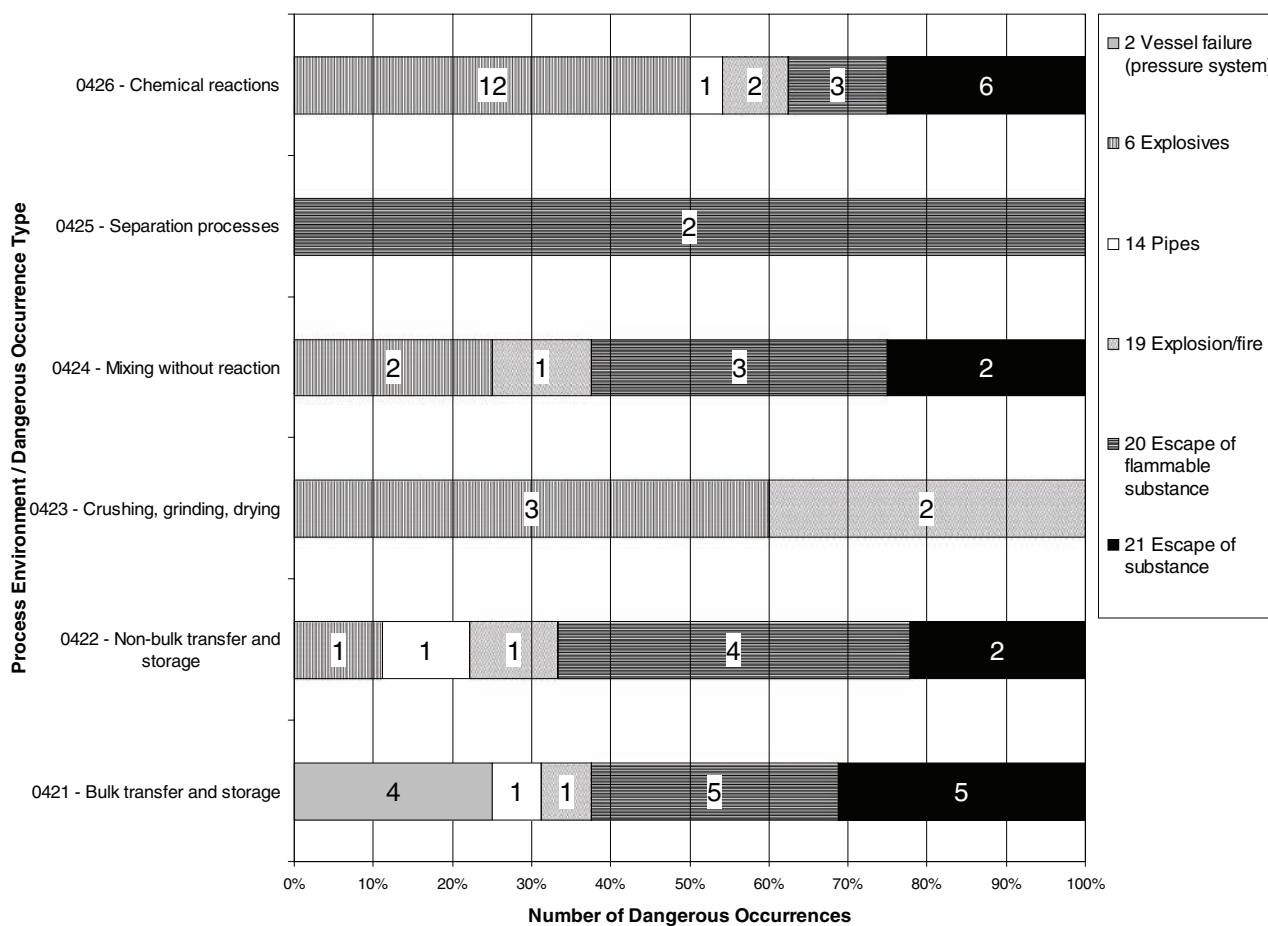


Figure 4. Percentage bar charts for relevant Process Environments for Dangerous Occurrences in 2008

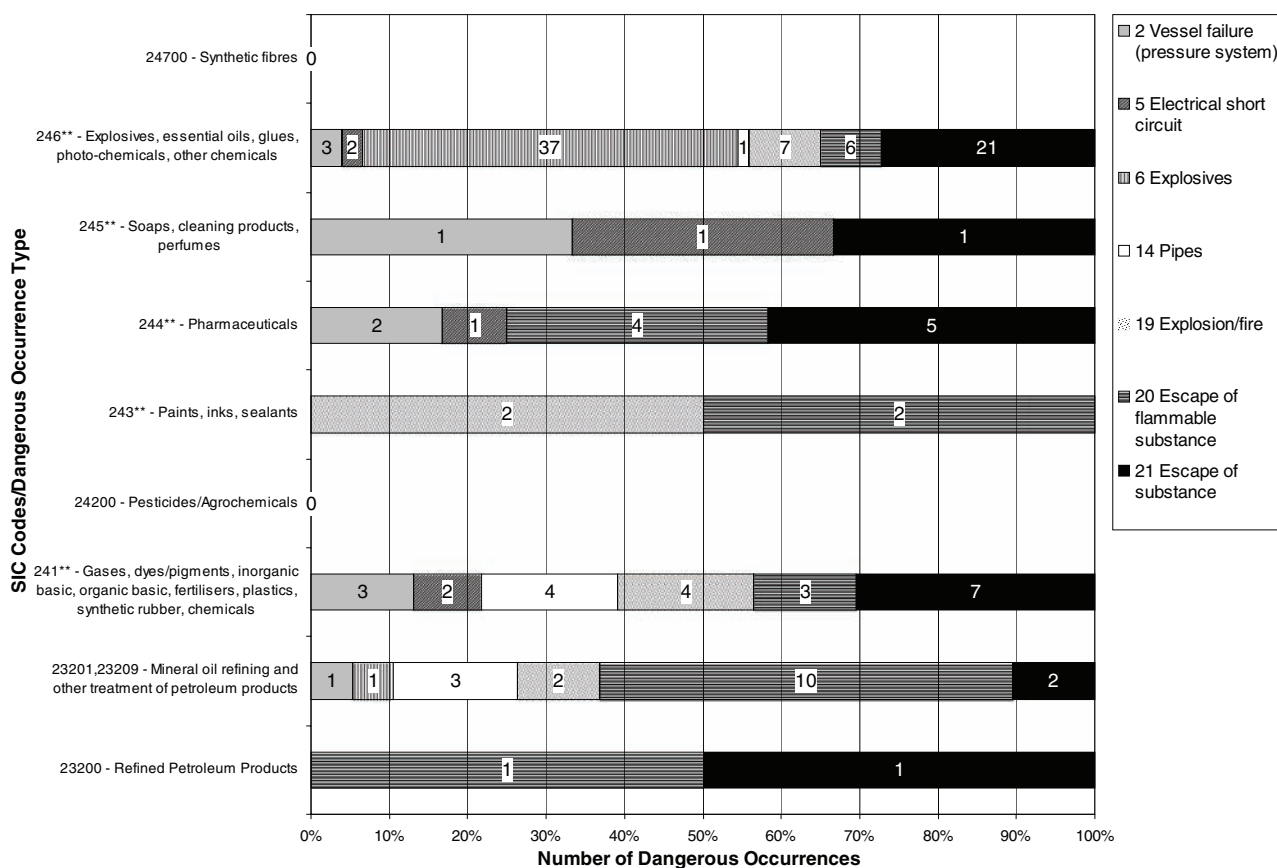


Figure 5. Percentage bar charts for relevant SIC Codes for Dangerous Occurrences in 2008

Table 1. RIDDOR codes most relevant to particular knowledge hubs and disciplines

Hub/discipline	Dangerous occurrence	Process environment	SIC
DSEAR & Petroleum licensing Refineries	19 Explosion or Fire	0421 Bulk transfer and storage 0422 Non bulk transfer and storage	23200 Refined Petroleum Products 23201,23209 – Mineral oil refining and other treatment of petroleum products
Bulk Toxics LFG & Fire	21 Escape of Substance 20 Escape of Flammable Substances 19 Explosion or Fire	0421 Bulk transfer and storage 0421 Bulk transfer and storage	
Exothermics & Energetics		0426 Chemical reactions	
Mech Eng	02 Pressure System 14 Pipelines and Pipeworks		
Elec/C&I	05 Electrical Short Circuit		

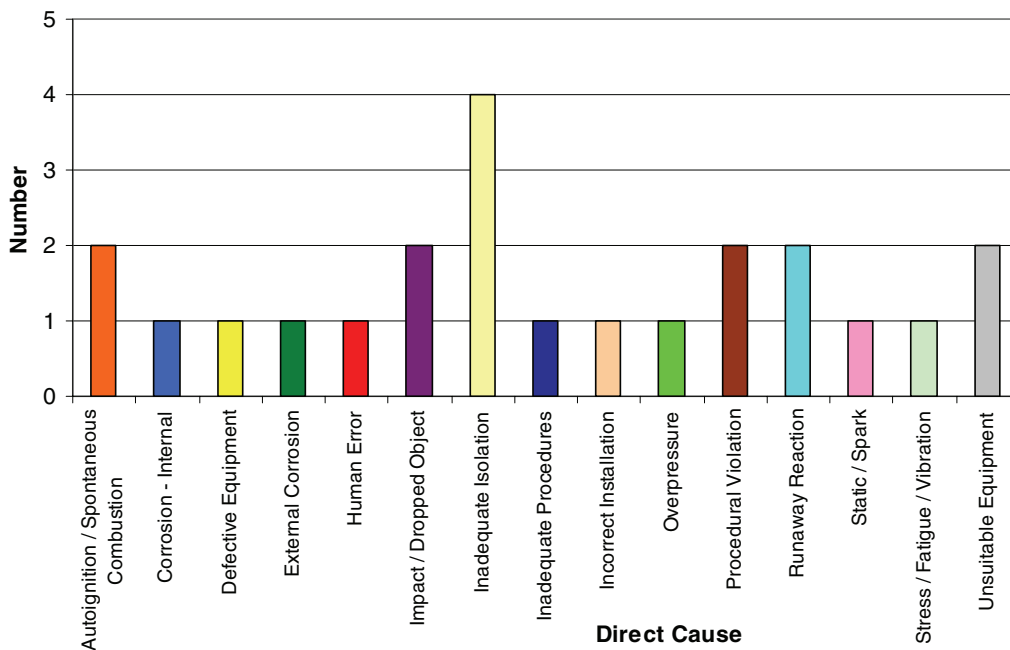


Figure 6. Direct causes of the 19 sample incidents from 2006 & 2007

The analysis, including causes and activities, will be reported in the HSE Research Report, to be produced on this project.

To illustrate the data analysis process, a sample of 19 sample incidents, will be discussed here. Figure 6

shows the direct causes of these sample incidents. The direct causes seem to be variable but inadequate isolation does seem to be most prominent. Figure 7 shows the underlying causes (risk control system) of the sample

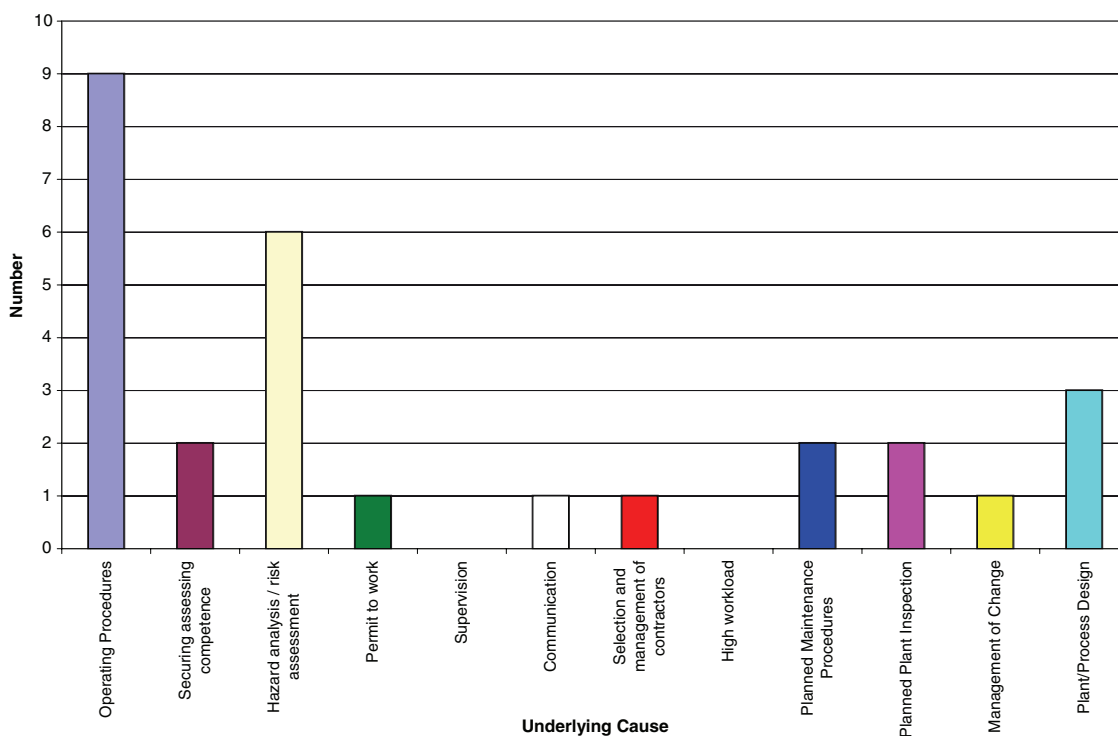


Figure 7. Underlying causes of the 19 sample incidents from 2006 & 2007

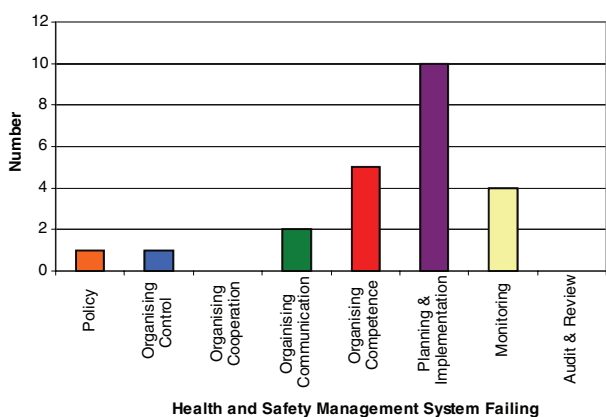


Figure 8. Health and safety management system failings of the 19 sample incidents from 2006 & 2007

incidents. Problems with operating procedures and hazard analysis/risk assessment seem to be highlighted here. For the sample incidents, the activity at the time of release (operating mode) was generally normal operation. However the reasons for the incident may have started previously during planned maintenance, shut down, start-up or plant modification. For the sample incidents the site of release varied but “valve open end” and “pipe body” did seem to be more prominent than other release sites. Figure 8 shows the health and safety management system failing of the sample incidents. Planning and implementation is the most prominent with organising/competence also significant. Figure 9 shows the “mitigation against escalation” for the sample incidents. “Process stopped” and

“none/unknown” were the most common mitigation methods. However a variety of other mitigation methods are also employed, as shown in the figure.

WAYS TO IMPROVE THE HSE INCIDENT RECORDING SYSTEM

DATA COLLECTION

Possible improvements to the incident recording system arose during the project, and are listed below:

- An improvement to COIN would be to also record the industry in which the incident took place using the standard industrial classification (SIC) code.
- Allow more than one causal type to be selected by the regulatory inspector from the drop down menu, this would improve SPC/Enforcement 132.
- There may be a case for the reintroduction of a database to record worldwide process incidents.
- Have all data come together in the same place so it can be searched and causal analysis examined. This avoids over analysing the data.
- Use supplementary forms for each chemical industry sector (e.g. chemical and onshore oil) to capture more detailed incident information. This approach is similar to the forms used on a voluntary basis by the offshore oil and gas industry (Form OIR12, HSE 2009) to record additional data on hydrocarbon releases.
- Involve specialist inspectors in causal analysis by way of supplementary forms for their discipline. The regulatory inspector would decide which specialists (generally those involved in any investigation) would assist with the additional forms.

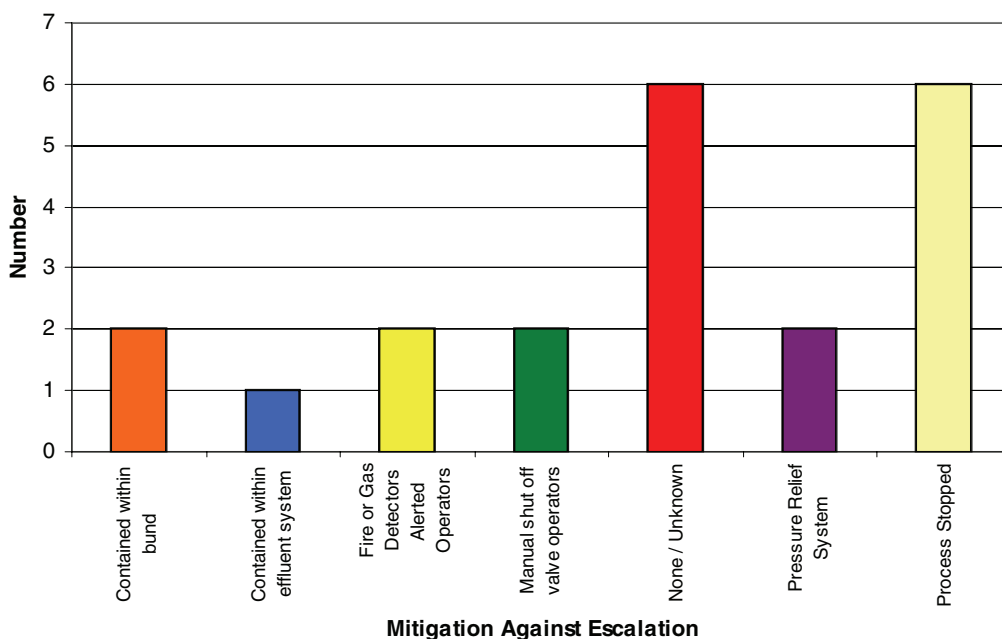


Figure 9. Mitigation against escalation for the 19 sample incidents from 2006 & 2007

- Encourage the regulatory inspector and the operating company to cooperate in the generation of RIDDOR and HSE Investigations Reports.
- RIDDOR reports could be amended to include incident causes once they have been determined.

INFORMATION EXCHANGE

A Process Safety Incidents page was created on the internal HSE Process Safety web community. It has project reports and power point presentations. Spreadsheets were provided which give information on incidents. It provides a focal point for information exchange with the inspector teams and knowledge hubs. Topics were suggested for the individual knowledge hubs to search on – Dangerous Occurrences (DO), Process environment and SIC manufacturing codes, see Table 1. Process incidents have been raised as an issue with all the knowledge hubs. The incidents page could also provide a link to incident reports. Changes to the page are generally notified to members of the internal HSE web community.

COMAH REMODELLING – OPERATIONAL INTELLIGENCE

Analysis of incidents is an important input into HSE's planning cycle. The planning cycle is the process used to assign priorities for HSE. HSE's COMAH remodelling – operational intelligence work seeks to make best use of all such intelligence – inspection, assessment and incident analysis in the planning cycle. This paper and its associated project will contribute to the redesign of HSE's operational intelligence system for COMAH.

CONCLUSIONS

A method HSE can use to collect, attribute and analyse process safety incidents has been described. Collecting information on dangerous types, process environments and industrial sectors for process safety incidents also allows targeting of HSE's resources. Methods to attribute incidents to particular HSE topics and specialist disciplines have been described. Incident analysis needs to consider a range of causal factors (direct cause, underlying cause, health and safety management failing) as well as other factors (site of release, activity at time of release, mitigation against escalation). The incident analysis approach described could contribute, as one operational intelligence strand amongst others, to HSE's plans for future interventions on COMAH sites in Great Britain.

REFERENCES

Bradley P.L & Baxter A, "Fires, explosions and related incidents at work in Great Britain in 1998/99 and 1999/2000", *Journal of Loss Prevention in the Process Industries*, 15, (2002), 36–372.

EU Joint Research Centre, "Major accident reporting system" <http://mahbsrv.jrc.it/mars/default.html>.

Fowler, A.H.K & Baxter A, "Fires, explosions and related incidents at work in Great Britain in 1996/97 and 1997/98", *Journal of Loss Prevention in the Process Industries*, 13, (2000), 547–554.

Fewtrell and Hirst, "A review of high-cost chemical/petrochemical accidents since Flixborough 1974", *IChemE Loss Prevention Bulletin*, April 1998, no 140.

CSB, (US Chemical Safety and Hazard Investigation Board) "Investigation Report, BP Texas City, March 23 2005", Report No 2005-04-I-TX, March 2007. http://www.csb.gov/completed_investigations/docs/CSBFinalReportBP.pdf.

HSE, "COMAH Major Accidents Notified to the European Commission England, Wales & Scotland 1999-2000", 2000a. <http://www.hse.gov.uk/comah/eureport/images/1999-00.pdf>.

HSE, "COMAH Major Accidents Notified to the European Commission England, Wales & Scotland 2000-2001", 2001a. <http://www.hse.gov.uk/comah/eureport/images/2000-01.pdf>.

HSE, "COMAH Major Accidents Notified to the European Commission England, Wales & Scotland 2001-2002", 2002a. <http://www.hse.gov.uk/comah/eureport/images/2001-02.pdf>.

HSE, "COMAH Major Accidents Notified to the European Commission England, Wales & Scotland 2002-2003", 2003a. <http://www.hse.gov.uk/comah/eureport/car2003.htm>.

HSE, "Industry Sector Profile Chemical Production Industry 2002/03", 2003b. <http://www.hse.gov.uk/chemicals/chemprod02-03.pdf>.

HSE, "Industry Sector Profile Chemical Industry 2002/03", 2003c. <http://www.hse.gov.uk/chemicals/chemsect02-03.pdf>.

HSE, "Industry Sector Profile Paints and Coatings Industry 2002/03", 2003d. <http://www.hse.gov.uk/chemicals/paints02-03.pdf>.

HSE, "Industry Sector Profile Pharmaceutical Industry 2002/03", 2003e. <http://www.hse.gov.uk/chemicals/pharmaceutical02-03.pdf>.

HSE, "Industry Sector Profile Onshore Oil Industry 2002/03", 2003f. <http://www.hse.gov.uk/chemicals/onshoreoi02-03.pdf>.

HSE, "Major Incident Investigation Report BP Grangemouth Scotland 29th May – 10th June 2000", 2003g. <http://www.hse.gov.uk/comah/bprgrange/images/bprgrangemouth.pdf>.

HSE, "COMAH Major Accidents Notified to the European Commission England, Wales & Scotland 2003-2004", 2004a. <http://www.hse.gov.uk/comah/eureport/car2004.htm>.

HSE, "Industry Sector Profile Chemical Industry 2003/04", 2004b. <http://www.hse.gov.uk/chemicals/chemsect03-04.pdf>.

HSE, "Loss of Containment Incident analysis", SPC/Enforcement/90, 2004c. <http://www.hse.gov.uk/foi/internalops/hid/spc/spcenf90.pdf>.

HSE, "Findings From Voluntary Reporting of Loss of Containment Incidents 2004/05", 2005a. <http://www.hse.gov.uk/chemicals/vrlci.pdf>.

HSE, "Public Report of the Fire and Explosion at the Conoco Phillips Humber Refinery on 16 April 2001", 2005b. <http://www.hse.gov.uk/comah/conocophilips.pdf>.

HSE, "Investigation of loss of containment dangerous occurrences", SPC/Enforcement/132, 22, 2007a. <http://www.hse.gov.uk/foi/internalops/hid/spc/spcenf132.pdf>.

HSE, "HSE Forms – Incident Reporting", HSE, 16 January 2009. <http://www.hse.gov.uk/forms/incident/index.htm>.

HSL, "Loss of Containment Incident Analysis" HSL/2003/07, 2003 http://www.hse.gov.uk/research/hsl_pdf/2003/hsl0307.pdf.

The Stationary Office, National Statistics, "UK Standard Industrial Classification of Economic Activities 2003", UK

SIC(2003), London, 2003. [http://www.statistics.gov.uk/methods_quality/sic/downloads/UK_SIC_Vol1\(2003\).pdf](http://www.statistics.gov.uk/methods_quality/sic/downloads/UK_SIC_Vol1(2003).pdf)

DISCLAIMER

The views expressed in this paper are those of the authors and do not necessarily reflect the policy of the Health and Safety Executive or the Health and Safety Laboratory.