Process Safety in the Water Industry

Safety & Loss Prevention and Water SIG Collaboration Webinar

1st March 2023
Welcome

Presenters

- **Kirsty McCall** MSci, CEng CSci MIChemE, Regional Process Discipline Lead, MWH Treatment
- **Christopher Taylor**, Senior Process Engineer, United Utilities Group PLC
- **Ken Patterson**, Member of IChemE’s Major Hazards Committee and Loss Prevention Panel
- **Peter Marsh** BSc, CEng MIChemE; Director of XBP Refining Consultants Ltd.
- **Steve Murphy** PhD, MIChemE; Head of Process Safety for Syngenta Group.
Housekeeping

- Questions – in chat box, or in person during the designated question times?
- We will leave space at the end for questions
## Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Agenda Item</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Start / Welcome</td>
<td>5 mins</td>
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<tr>
<td>09:05</td>
<td>Process Safety in the Water Industry (Kirsty McCall)</td>
<td>5 mins</td>
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<tr>
<td>09:10</td>
<td>Municipal water disasters – a role for process safety (Ken Paterson)</td>
<td>15 mins</td>
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<tr>
<td>09:25</td>
<td>Q&amp;A</td>
<td>10 mins</td>
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<td>09:35</td>
<td>Incidents in the water and other industries (Peter Marsh)</td>
<td>10 mins</td>
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<td>09:45</td>
<td>Hazard spotting with study 1- applies to a change and links to other 5 stages (Steve Murphy)</td>
<td>15 mins</td>
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<tr>
<td>10:00</td>
<td>Q&amp;A</td>
<td>15 mins</td>
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<td>10:15</td>
<td>Finish</td>
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</table>
Process Safety in the Water Industry

Why is process safety important?

Personal safety
- Low severity
- High frequency
- Slips, trips & falls

Process safety
- High severity
- Low frequency
- Plant (hardware), process (systems), people

"Process safety hazards are less intuitive, so hazard identification techniques need to be structured."

P. Eames, The Chemical Engineer, December 2018

Image credit: IChemE Fundamentals of Process Safety training course, presented by Tracey Kelly & Andrew Hudson, 2017
Process Safety in the Water Industry

Process safety incidents within the water industry

Abbeystead (1984) – methane explosion - 16 fatalities

Camelford (1988) – contamination of final water – 20,000 homes affected

Avonmouth (2020) – sludge tank explosion – 4 fatalities
Process Safety in the Water Industry

What are the biggest risks to process safety?
Top risks (as identified by the Water SIG membership):

1. Consequences of abnormal operation and identifying suitable safeguards
2. Lack of maintenance and knowing when to react
3. Change management (lack of)
4. Handling chemicals

How can we prevent process safety incidents?
- Carry out the appropriate hazard studies at the right time with the right people
- Share examples of when things go wrong!
What can Process Safety do for the Water Industries?
Harare & Flint Water disasters

Dr Ken Patterson
Harare and Flint Water Disasters
In IChemE’s FOPS course we define Process Safety as:

“A systematic framework for the management of the integrity of hazardous processes”

We think of “Hazardous Processes” when we think of Major Accidents: Flixborough, Chernobyl, Toulouse, Deepwater Horizon - and we don’t think of water supply or disposal as “hazardous processes”.

However, urban society is totally dependent on service supply, and the effects of maloperation can be huge, which suggests a change to the definition:
Process safety

The extended definition could have significance more generally.

Society is increasingly reliant on services to function:

- Loss of electrical power takes out light, heat and communication
- Loss of gas takes out heat and power
- Loss of internet connection makes smart houses and “the internet of things” in-operable

Across the world, water system failures have probably killed more people than Process Safety failures in this century.

Harare - thousands & Flint - hundreds(?)
Harare - background

- Capital of Zimbabwe
- Water system (clean & foul) built for pop. of 150,000
- Extended to give capacity for ~600,000
- Current pop. 1,500,000 - 2,200,000
  - Significant part of the population is “informal”
- City is at ~1,450m, has surrounding hills & some rivers
- Majority of the water supply comes from 2 large lakes (reservoirs): Chivero - 35 km away and 100m below the city; & Manyame - 50 km away & 125m below city
- The City’s sewage system runs into the rivers which feed the lakes
Harare - surroundings

Picture from Google Earth dated March 2019
Harare - problems

1. The area surrounding the lakes is agricultural, run off from this can be rich in phosphate

2. Sewage system has frequent overloading, allowing untreated effluent to flow into the rivers & lakes
   → Algal bloom, water hyacinth, poor water quality

3. Economic collapse (GDP -10% pa), inflation 10⁹% pa

4. Water supply breakdowns & “diversion”
   → Shallow wells dug, lack of sanitation - polluted wells
   → Lack of treatment chemicals; prolonged plant outages

5. Lack of clean water even to hospitals
   → 2008 Cholera: 10,000 cases, 4,000 deaths
   → 2012 Typhoid: 3,000 cases; 2017 Diarrhoea: 50,000 cases
Flint - background 1

- Home of General Motors, 80,000 jobs in the car industry
- City develops from early 1900s, services built as city grows, prosperous until 1970s, pop ~200,000
- In the 1950s, clean water supply switched to Detroit system ~100 km away. Existing plant mothballed
- Flint severely hit by contraction in car industry, jobs fall to 8,000 by 2000, population falls to ~100,000
- By 2000 Detroit also has financial problems and price of water begins to rise
- Flint population now smaller & poorer but the City has all the existing municipal debt and services to pay for. Flint becomes effectively bankrupt by 2010
Flint - background 2

- “City Manager” appointed by the State Governor in 2011
  - Powers to over-ride council
  - Remit to cut costs - including cost of water
- As an interim measure decides to re-start mothballed plant, which takes water from polluted, acidic Flint River
- No experienced personnel, responsible manager opposes re-opening, says plant is not ready to start
- Decision taken not to add phosphate inhibitor, to save $140 per day ($50k pa)
- Plant restarted in April 2014 …..
Case study: Flint, Michigan 2014

Video by VOX - 3:36: https://youtu.be/NUSiLOwkrlw
Case study: Flint, Michigan 2014
Flint - problems

1. Water produced is not colourless, tasteless & odourless
   ➡ Very large use of bottled water & installation of water filters

2. Lack of inhibitor means calcite scale on existing, old pipes erodes away
   ➡ Lead pipes begin to dissolve, rust inside cast iron pipes is attacked

3. Poor quality water now contains e-coli
   ➡ Chlorine addition increased, which in turn:
      ➡ Increases conc. of Pb in water; infant Pb exposure and increase in perinatal deaths
      ➡ Attacks rust in iron pipes releasing legionella, 10-100 deaths
      ➡ Leakage increases sharply, local distribution pipes destroyed
Flint - problems 2

1. General Motors engine plant has problems with rusting, traced to acidic water supply
   - GM switches back to Detroit water in October 2014
2. Residents complain of water quality
   - Advised to boil water from August 2014
   - Sept 2015: Virginia Tech study suggests 40% of Flint homes have elevated Pb levels in their water
     - Study says Flint water not safe for drinking or cooking
   - Sept 2015: paediatrician’s study shows sharp increase in the number of children with high Pb levels
   - Oct 2015: Flint switches back to Detroit water at a cost of $9.35m
Flint - aftermath

1. Loss of confidence in system & government
   ➡ Many residents still apparently refuse to drink Flint water (thought it is now safe according to current testing)
   ➡ Houses in Flint are estimated to have fallen in value by >$500m

2. Large part of Flints local water distribution system, including inside properties were wrecked and needed to be replaced
   ➡ On-going, current bill estimated to be >$500m (estimated up to $1500m)

3. Civil case against State of Michigan by residents of Flint
   ➡ Settled in December 2021 for $626m

4. Criminal indictments against Michigan Governor Snyder el al, and against the City Managers; also against officials of Michigan Department of Environmental Quality, The US EPA, Michigan state Health Authority, and against officials of the Flint municipal authority.
A role for Process Safety?

- The problems in both Harare and Flint should have been clear to competent people with experience in the water supply and sewage treatment industries:
  - There does not seem to be any “new knowledge” which comes out of either case
  - I guess most people in the water industry will be thinking: “How could they do that?”
- These are only 2 cases but the number of deaths probably dwarfs the number killed by process industry process accidents since 2000
- Common process safety techniques; Hazid/Envid and Hazop studies, Management of Change control (mandatory under the Seveso 3 directive), and What-if techniques should all have held up “red flags” about the actions (proposed to be) taken
- Should we implement a PSM system for Water? How should/could we do it?
There is a Loss Prevention Bulletin paper on Flint and Harare: “Municipal water disasters - a role for process safety?”, in the June 2020 edition. The article contains a number of references to the source material on both events. LPB is free to access for all IChemE members.

- The Flint water disaster was discussed in one episode of the National Geographic TV series “Disasters engineered”.

- There are a number of other short Vox videos on YouTube which discuss the Flint water crisis and especially the political implications of what happened.

- KJ.Patterson@NTLworld.com
Questions?
Peter Marsh
Learning From Past Incidents
Learning From Past Incidents

Peter Marsh BSc CEng MIChemE

1979-1980 Process Systems Engineer, Esso Fawley Refinery (UK)
1981-1982 Process Engineer, BP Isle of Grain Refinery (UK)
1982-1986 Process Engineer, BP Grangemouth Refinery (UK)
1987-1988 Operations Supervisor, BP Grangemouth Refinery (UK)
1988-1991 Lead Process Engineer, Davy McKee Pacific (Australia)
1995-1998 FCC Principal Specialist, BP Kwinana Refinery (Australia)
1998-2003 Technical Support Engineer, BP Coryton Refinery (UK)
2003-2004 Process Development Leader, BP Coryton Refinery (UK)
2005-2015 Advisor - Reforming/Isomerisation, BP Sunbury (UK)
2015-Now Director, XBP Refining Consultants Ltd (UK)
2017-Now Committee Member, IChemE Safety & Loss Prevention SIG
Learning From Past Incidents

**Abbeystead**
- 16 killed
- 28 injured
- HazID (CH₄)

**Milwaukee**
- 69 killed
- ~403,000 sick
- Process design

**Bethune Point**
- 2 killed
- 1 injured
- HazID (MeOH)
Learning From Past Incidents

“It might seem to an outsider that industrial accidents occur because we do not know how to prevent them. In fact they occur because we do not use the knowledge that is available.

Organisations do not learn from the past or, rather, individuals learn but they leave the organisation, taking their knowledge with them, and the organisation as a whole forgets.”

Kletz: “Lessons from Disasters. How organisations have no memory and accidents recur.” Institution of Chemical Engineers. 1993 ISBN 0 85295 307 0
Learning From Past Incidents

- Maintain corporate memory
- Raise awareness
- Share lessons
- No shame in sharing
- Improve risk management
- Improve safety performance
- Avoid recurrence
- Save lives, prevent illness or injury
## Learning From Past Incidents

### Abbeystead 1-Pager

<table>
<thead>
<tr>
<th>Incident Title</th>
<th>Water Pumping Station Explosion</th>
<th>IChemE Lessons Learned Database</th>
<th>Incident Summary</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident Type</td>
<td>Fire/Explosion</td>
<td>IChemE Lessons Learned Database</td>
<td>Summary Details</td>
<td>Cost</td>
</tr>
<tr>
<td>Location</td>
<td>Abbeystead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>11th January, 2023</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>A fire occurred at a water pumping station in Abbeystead on 11th January, 2023, resulting in an explosion. The explosion was caused by a failure in the water pumping system, leading to a rapid release of stored energy. The incident involved the loss of life and significant property damage.</td>
<td></td>
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</tr>
<tr>
<td>Lessons Learned</td>
<td>Safety protocols and maintenance were not in place, leading to a failure in the water pumping system. Immediate action was taken to prevent similar incidents in the future.</td>
<td></td>
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<td></td>
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</tbody>
</table>

### Milwaukee 1-Pager

<table>
<thead>
<tr>
<th>Incident Title</th>
<th>Water Supply Interruption</th>
<th>IChemE Lessons Learned Database</th>
<th>Incident Summary</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident Type</td>
<td>Communication Failure</td>
<td>IChemE Lessons Learned Database</td>
<td>Summary Details</td>
<td>Cost</td>
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<tr>
<td>Location</td>
<td>Milwaukee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>14th July, 2023</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Description</td>
<td>A communication failure led to a failure in the water supply system in Milwaukee on 14th July, 2023, resulting in a large-scale water supply interruption. The failure was caused by a software issue in the water supply system, leading to a disruption of service for a significant portion of the city.</td>
<td></td>
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</tr>
<tr>
<td>Lessons Learned</td>
<td>Communication systems and procedures were not properly tested and maintained, leading to a failure in the water supply system. Immediate action was taken to prevent similar incidents in the future.</td>
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<td></td>
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</tbody>
</table>

### Bethune Point 1-Pager

<table>
<thead>
<tr>
<th>Incident Title</th>
<th>Fire at Water Treatment Plant</th>
<th>IChemE Lessons Learned Database</th>
<th>Incident Summary</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident Type</td>
<td>Fire</td>
<td>IChemE Lessons Learned Database</td>
<td>Summary Details</td>
<td>Cost</td>
</tr>
<tr>
<td>Location</td>
<td>Bethune Point</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>28th March, 2023</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>A fire occurred at a water treatment plant in Bethune Point on 28th March, 2023, resulting in a failure in the water treatment process. The failure was caused by a design flaw in the water treatment system, leading to a disruption of water supply for a significant portion of the city.</td>
<td></td>
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</tr>
<tr>
<td>Lessons Learned</td>
<td>Design flaws in the water treatment system were not identified and corrected, leading to a failure in the water treatment process. Immediate action was taken to prevent similar incidents in the future.</td>
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</tbody>
</table>

### Summary

- Incident summaries for all levels of organisation

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**ICHEME**

Water Special Interest Group

**ICHEME**

Safety & Loss Prevention Special Interest Group
# Learning From Past Incidents

**Major Process Safety Incident vs Root Cause Infographic**

![ICHEME Logo](https://example.com/icHEME_logo.png)

## Major Process Safety Incident vs Root Cause Map

<table>
<thead>
<tr>
<th>Year</th>
<th>Process</th>
<th>Location</th>
<th>Incident Type</th>
<th>Casualties</th>
<th>Cause</th>
<th>Root Cause</th>
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</thead>
<tbody>
<tr>
<td>2010</td>
<td>Reactor</td>
<td>USA</td>
<td>Explosion</td>
<td>10</td>
<td>Loss of</td>
<td>Inadequate</td>
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<tr>
<td>2011</td>
<td>Tower</td>
<td>UK</td>
<td>Fire</td>
<td>5</td>
<td>Flow</td>
<td>Design</td>
</tr>
<tr>
<td>2012</td>
<td>Storage</td>
<td>India</td>
<td>Leak</td>
<td>2</td>
<td>Chemical</td>
<td>Material</td>
</tr>
<tr>
<td>2013</td>
<td>Refinery</td>
<td>China</td>
<td>Blowout</td>
<td>75</td>
<td>Pressure</td>
<td>Operating</td>
</tr>
<tr>
<td>2014</td>
<td>Plant</td>
<td>Canada</td>
<td>Explosion</td>
<td>25</td>
<td>Equipment</td>
<td>Maintenance</td>
</tr>
</tbody>
</table>

*Note: Data is hypothetical and for illustrative purposes.*
Learning From Past Incidents

- Report incidents and near misses
- Conduct root cause analysis of incidents
- Share learnings with colleagues and networks
- Accelerate replication of good practices
- Contribute to improved safety performance

Resources:
- IChemE Lessons Learned Database at:
- IChemE Learning Lessons from Major Incidents eBooklet
Steve Murphy
Hazard Study 1 - early identification of hazards
Hazard Study Process

- Hazard Study is a staged process that identifies hazards and seeks to control them to an acceptable level and so ensure that hazardous process units operate safely.
- It is a key element of Process Safety Management; sometimes it is referred to as Hazard Identification and Risk Assessment (HIRA) or Process Hazard Analysis (PHA).
- Hazard Study is used throughout the high hazard industries (Oil, Gas, Fine Chemical, Pharmaceutical..)
- Clear evidence that assessing risks early in a change project maximizes safety and saves money.

- Developed by ICI in 1960’s and first published in 1970’s

- The Hazard Study Process, proven in use for the last 50 years
Early Stage Assessment- Study 1

- Change Projects often concentrate on HAZOP studies
- These happen late in the design stage
- Often we get “nasty surprises” during HAZOP- more complexity, lead times.

- Early identification of the key HSE Hazards is desired
  - Identify hazards and their control
  - Allows time for ordering
  - Built in cost estimating early

- Hazard Study 1 (Initial HSE Assessment)
  - Part of 6 Stage Hazard Study- HAZOP still important
  - Often over-looked
  - Advantages to doing this well
Hazard Study 1 – When?

- Change Project Lifecycle
- Study 1 early in the Inception Phase
- Typically, Terms of Reference / project team formed
- Basic Design Information
  - Where, what, when
  - Block Flow Diagram
- Chemical hazards
  - List of chemicals
  - Scale
  - Safety Data Sheets (SDS)
- Do Not have / need
  - P&ID, Reaction Hazards, detailed process
Hazard Study 1 - Structured Format

• Hazard Study 1, Allows the Project Team to define HSE / Process Safety aspects
  • Typical project team
    ▪ Leader / facilitator
    ▪ Project manager
    ▪ Operations manager
    ▪ Process Engineer
    ▪ Other specialists

• It is broader and shallower than Study 2 or Study 3
  • Asks about Chemicals, Process, Location, Operation, Resourcing…

• Can be used to help identify other HSE assessments
  • COSHH, Environmental, Off-site impacts
Hazard Study 1 - Benefits

- All team together in one room to agree scope
- Gathering of corporate memory
- Identifying hazards and any Basis of Safety
- Identifies any legal requirements
- Agrees whether any further risk assessment required.
- Creation of P&ID
Hazard Study 1 - Structured Format

- HVAC System change at Laboratories
  - ID Need to change filters
  - Plan break-ins early

- Organizational changes at a Chemical site
  - Listed roles and tasks affected
  - Prelude to more detailed Risk assessment

- Change to mode of operation of Fire Water retention
  - Found early incompatibility of retention tanks
  - Allowed time for treatment of concrete

- New Chemical Production Plant
  - Assessed Fire Protection Concept
  - Allowed resource planning for Study 2 & Study 3

- Changes to an Effluent Treatment Plant
  - Changes to effluent pH - required controlled Neutralisation
  - Led to full HAZOP of dosing regime

Asks Question in a Structured Format
Hazard Study 1 - Typical Sections

Introduction

• Team; roles and responsibility
• Scope; When, why, what’s in and not in
• Legal requirements

Corporate Memory

• Learning from similar
• Any related incidents
Hazard Study 1 - Typical Sections

Chemical Hazards
- Listing all possible chemical hazards
- List all materials. Effluents, by-products, adjuvants
- SDS Reference

Key Hazard data
- H Phrase (H 301 Very Toxic)
- Flash point, MIE other fire /explosion data
- OEL/VME
- Physical form
Hazard Study 1 - Typical Sections

**Process Hazards**
- Define Major Hazards and their Basis of Safety
- Fires, Explosion (Dust/Vapour), Toxic Gas, Runaway Reaction, Pollution

**Basis of Safety**
- Basis of Safety is the high level preventative or mitigative control concept
  - E.g. Internal Fire or Explosion- Basis of Safety is control of flammable atmosphere with inerting
  - Toxic Gas release- BoS is Containment by correct choice of materials plus area alarms
<table>
<thead>
<tr>
<th>Location Aspects</th>
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<tbody>
<tr>
<td>• Transport issues</td>
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<tr>
<td>• Building codes</td>
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<td></td>
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<tr>
<td>People Aspects</td>
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</tr>
<tr>
<td>• Who is managing the change</td>
</tr>
<tr>
<td>• Human Factors in Design</td>
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<tr>
<td>What other risk assessments are required?</td>
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<td>-----------------------------------</td>
</tr>
<tr>
<td>• Fire</td>
</tr>
<tr>
<td>• Manual handling</td>
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<tr>
<td>• Human Health</td>
</tr>
<tr>
<td>• Area classification</td>
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<tr>
<td>Do we need any permits?</td>
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<tr>
<td>Are we following Company Standards</td>
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Summary

• It's called many things, at my Company it’s the Initial HSE Assessment
• It's part of the Project Process
• Fits in with other parts of 6 Stage Hazard Study
• Identifies and documents major hazards and their basis of safety
  • High level though enough detail to assess impact on project
  • Produces a written report stating early project thinking
• Identifies other HSE aspects important to the project
• Clear benefit to using Study 1 early in Design
• Been used for over 40 years
Questions?