Lessons learned about the role of human factors in chemical accidents

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Outline of presentation

Who we are

Chemical accidents and the human factors “dirty dozen”

Human factors in chemical accidents are overpresent and understudied

Human factors dimensions of lessons learned from emergency response

Recommendations to improve risk management of human factors on hazardous sites

The Major Accident Hazards Bureau (MAHB) project

The **Major Accident Hazards Bureau (MAHB)** is an office within the **European Commission's Joint Research Centre (EC-JRC)**. We provide scientific and technical support for policy associated with **chemical safety and security**.

We work with European Union (EU) policy entities within the EC, especially the **Directorate General – Environment (DG-ENV),** to implement the **EU Seveso Directive** for the control of major chemical accident hazards.

We work with EU policy leaders in the area of disaster risk reduction and crisis management (DG-ECHO) to support impact analysis (DG-ECHO) related to accident scenarios as well as real time events and capacity building for CBRN risk management in EU neighbour countries and third countries **(DG-DEVCO and DG-NEAR)**

We collaborate with **the OECD Working Group on Chemical Accidents for over 35 years** to support improvement in chemical accident prevention and preparedness globally, as well as other international organisations, especially **UNECE** and **UN Environment**.

We manage EC obligations to collect and analyse EU Member State **data on chemical accidents to support lessons learning** and also manage reporting of information on **EU hazardous (Seveso) sites**

For more information, visit
https://minerva.jrc.ec.europa.eu/en/minerva

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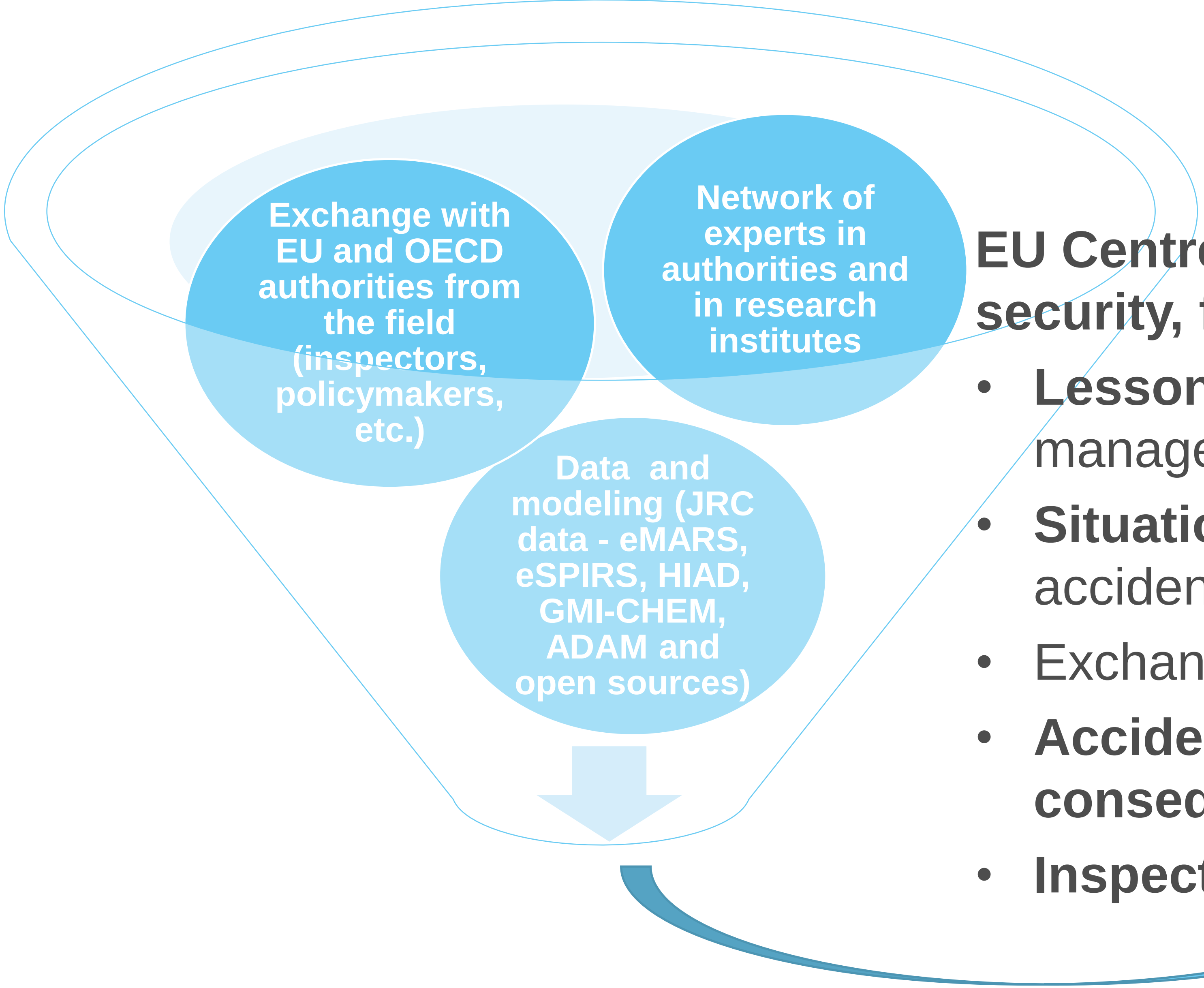


EU Centre for chemical safety and security, focus on:

- **Lessons learned** & good risk management practice
- **Situation awareness** – chemical accident monitoring
- Exchange/analysis on **emerging risks**
- **Accident scenario building** & **consequence analysis** modeling
- **Inspection** and risk governance

Our recipe: EU level mandate, scientific and analytical competence, data driven, an EU & global network, modeling and analytical tools

Chemical accidents and the human factors “dirty dozen”

Lessons learned from human factors

In aviation, they say “**Avoid the dirty dozen**”

Lessons learned about human factors and chemical accidents

The dirty dozen are relevant for all technological disasters, including chemical accidents

Several elements of the “dirty dozen” cannot immediately be “learned” from studying accidents, e.g., stress, fatigue, pressure, because of their chronic nature.

However, studying chemical accidents shows that several “dirty dozen” elements play a fundamental role in accident causality, especially:

- Lack of communication
- Lack of knowledge about procedures
- Lack of awareness
- (Unsafe) Norms
- Complacency
- Distraction

“They didn’t know”

Lack of communication = failure to tell someone something important to preventing an unsafe (or more unsafe) situation (situation-specific)

- No information,
- Partial information
- Wrong information

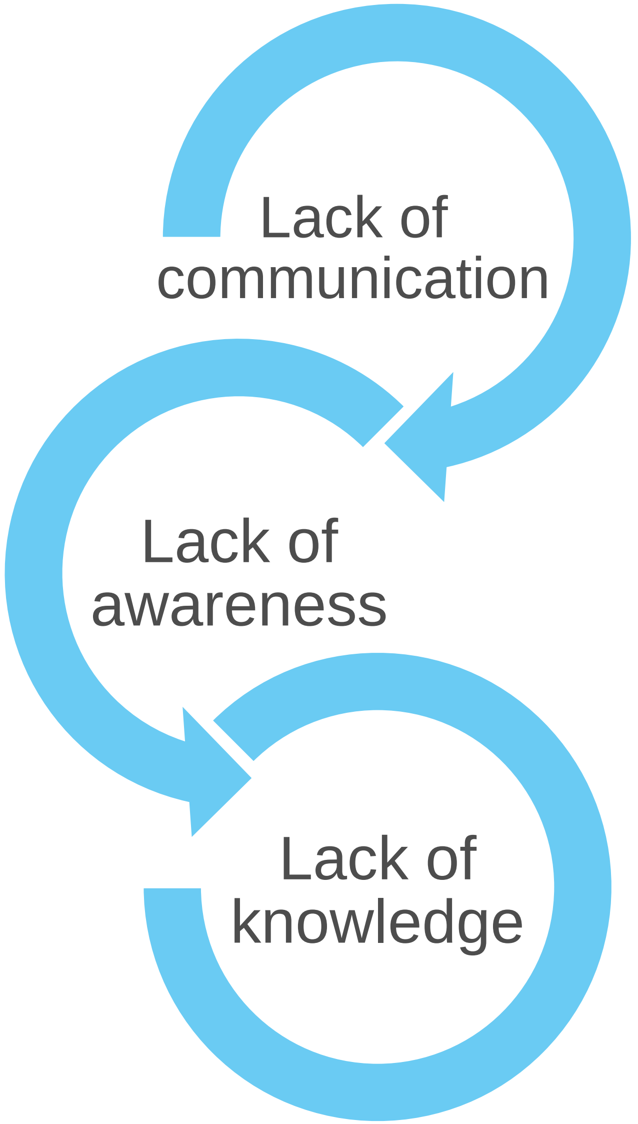
Lack of awareness = ignorance of critical information, including

- Ignorance of high risk environment
- Failure to recognize risk escalation
- Failure to notice potential risk impacts of change (small and large)

Lack of knowledge = not having sufficient information, including

It includes

- Lack of competence
- Lack of instructions and documentation
- Lack of training



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“They weren’t paying attention”

(Unsafe) Norms = Workplace habits that undermine safety, such as:

- Acceptance of deviation (e.g, from process pressure/temperature/volume norms)
- Routinely making up rules when the established rules are not producing the desired result

Complacency = False confidence leading to unsafe behavior, such as:

- Routinely violating rules and taking shortcuts (e.g., not wearing personal protective equipment)
- Not taking action when safety is compromised (e.g., postponing repairs to safety equipment)

Distraction = Working conditions routinely risk taking attention from safety,e.g.

- Failure to limit interruptions during critical tasks
- Unreasonable workload, e.g., one person has to do too many tasks at the same time

Complacency

Norms

Distraction

Everyone is vulnerable, but some are more vulnerable than others

Factors that can increase vulnerability to human factors include:

- Contractors
- New and replacement staff
- Downstream industries (chemicals are not their main business)
- Ageing sites
- Maintenance staff, especially hot work
- Loading and unloading
- Construction work, or temporary maintenance, on a part of the site
- Night shift and holiday periods
- Seasonal illness (e.g., the winter flu) or major epidemics (Covid)
- Sites in financial difficulty
- Small sites
- Sites with poor safety culture
- Emergency response
- Loading and unloading

All hazardous sites have more than one of these vulnerabilities at all times

Human factors in chemical accidents are overpresent and understudied

Initiating Direct Causes from 97 major accidents and 39 near misses in 2016 – 2021 as reported to eMARS

#1 Wrong procedure (29) Hot work (7) -- (Several other cases where wrong procedure did not initiate the incident but failed to stop the sequence or caused a worse consequence.)

#2 Corrosion (12) / Mechanical integrity (18) / Error in maintenance (4)

#3 Process miscalculation (14) – That is, something went wrong in the process

#4 Electrical ignition source (11) Unknown/unexpected ignition source (9)

#5 Power failures (11)

 # 6 Natech (11)

 # 7 Waste management (6)

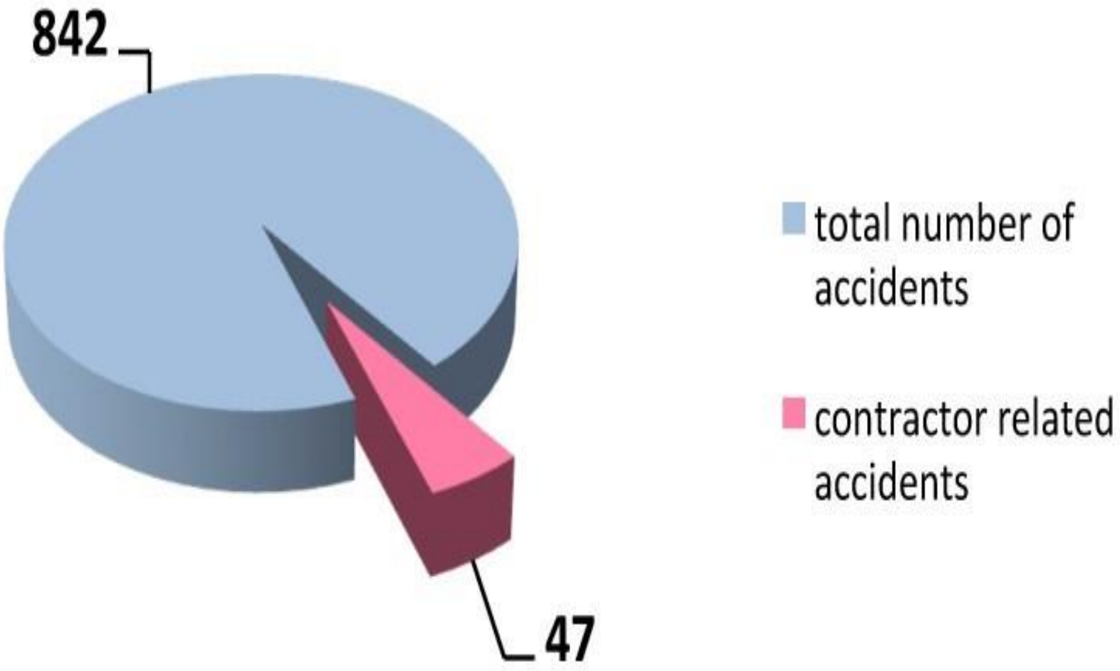
#8 Detection system failure (4)

Source: JRC Analysis of eMARS incidents presented at OECD, 2021

From a study of nearly 900 eMARS accidents involving contractors

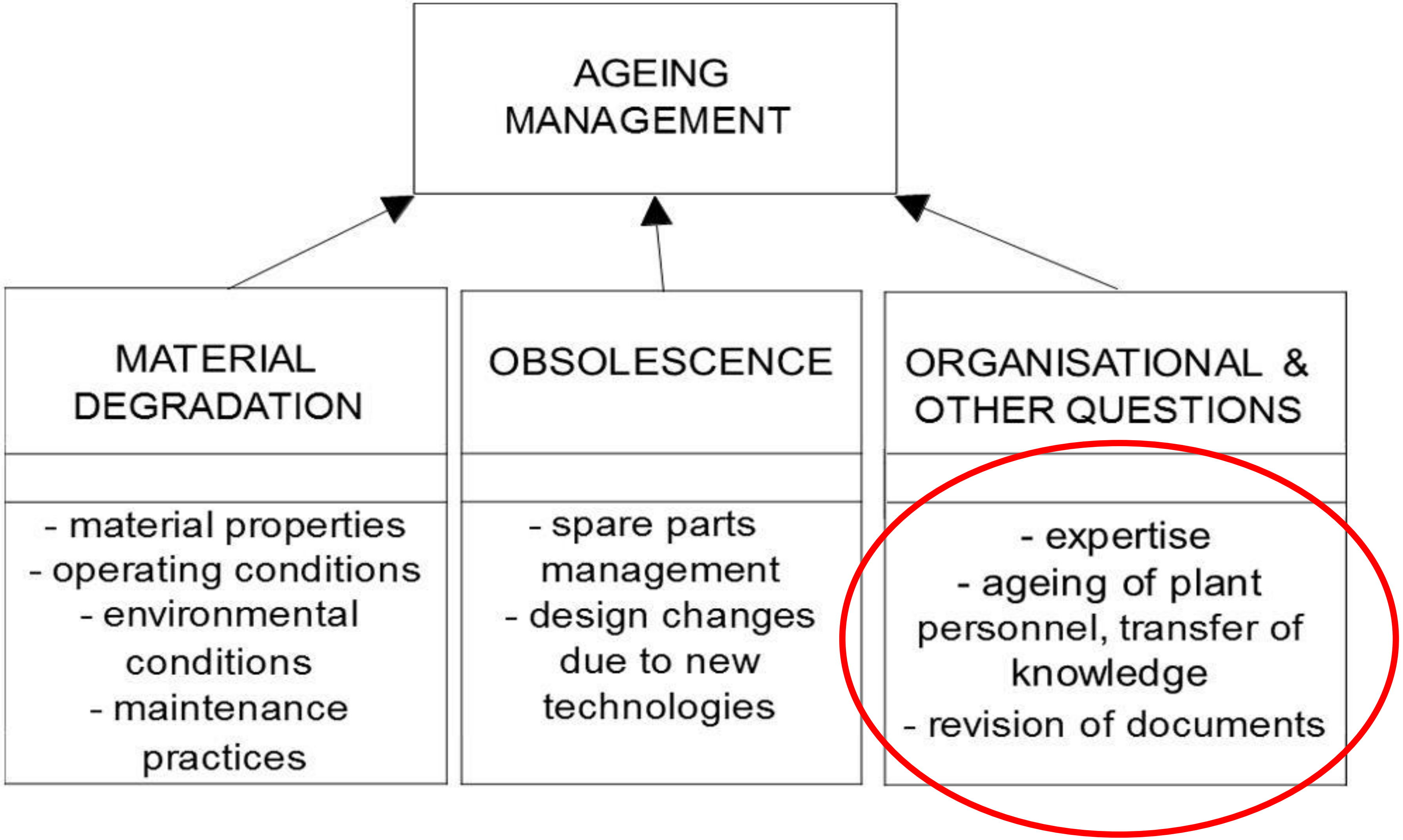
Common factors associated with accidents **involving contractors**:

- **No permit-to-work** issued
- **Insufficient training** of contractors
- **Insufficient communication** between the operator and the contractor
- **Insufficient oversight** of the work and working conditions
- **Lack of adherence to safety requirements**
- **Deviation** from job procedure
- **Inattention** to warning signs.



Source: [JRC - Lessons learned from major accidents involving contractors, 2012]

Lack of knowledge linked to ageing sites



Currently, we need better methods for investigation and analysis of chemical accidents that help us to more easily identify the human factors associated with causes of accidents on ageing hazardous sites.

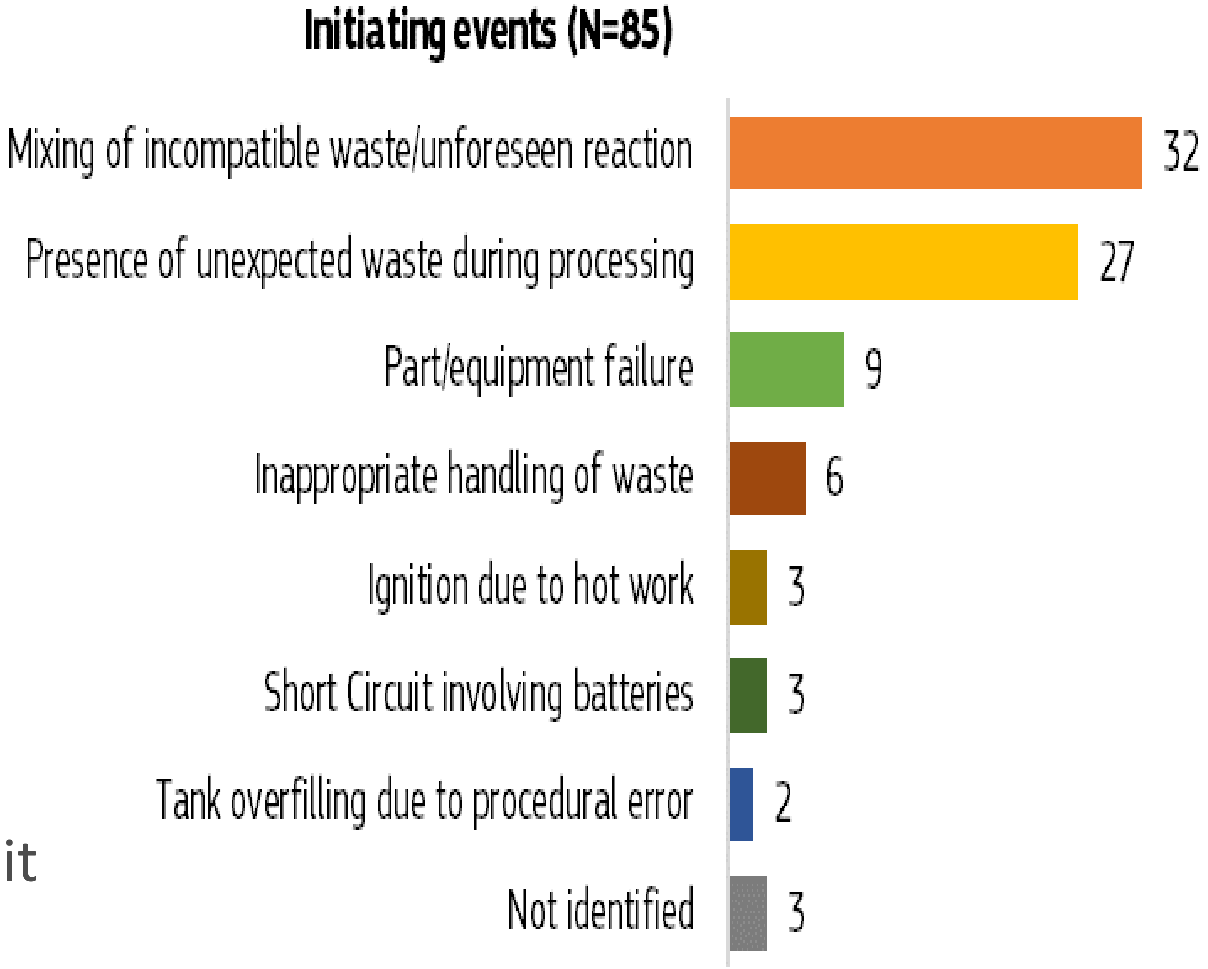
Source: JRC Lessons Learned from chemical accidents on major accidents related to ageing

Wrong procedure – A typical cause of many incidents

A study of chemical accidents caused by **runaway actions** found that **common causes** included:

- **an incorrect formula** (wrong recipe)
- the **operator forgot to start the stirrer** or **forgot to check the temperature**
- **water or reactant was added all at once** (instead of in small portions) **or in wrong concentration**
- the reactant stuck on the wall of the reactor and when the man-hole was opened it exploded.

Source: [Lessons learned bulletin – Major accidents from runaway reactions, 2016]

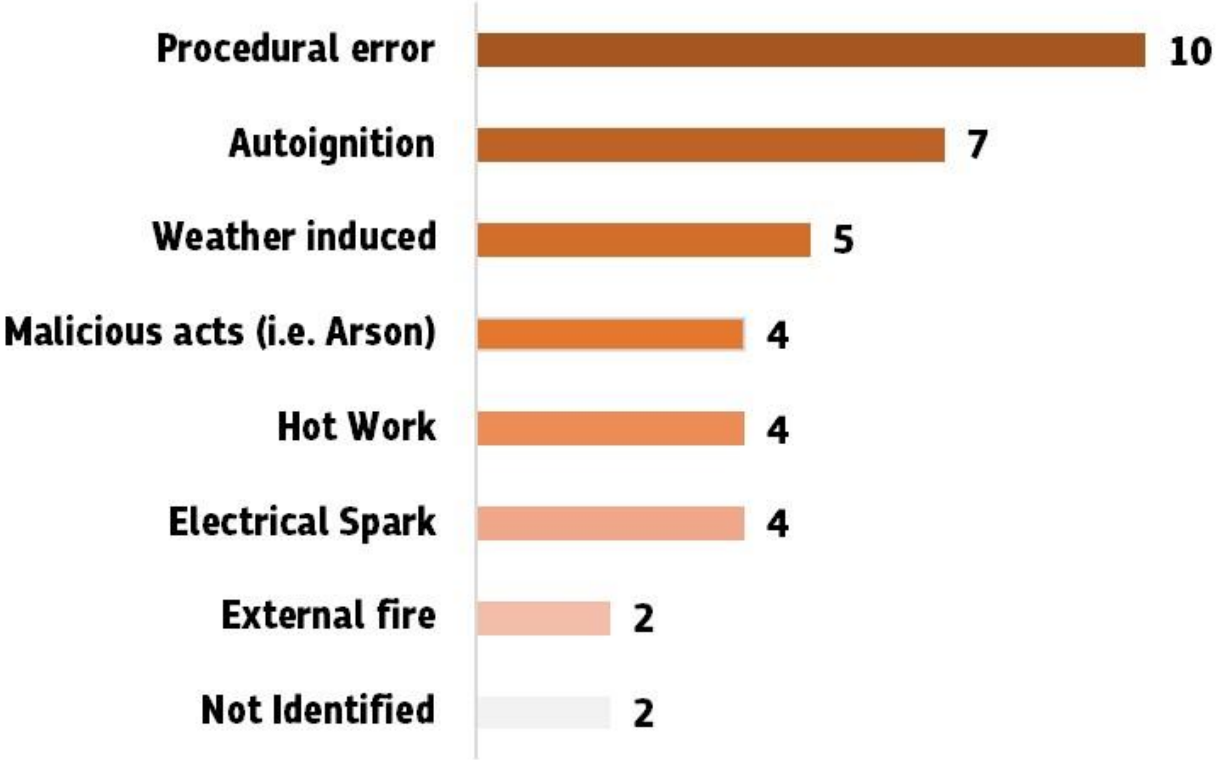


Source: [Lessons learned from accidents in waste management facilities, 2024]

Initiating events in warehouse accidents

Chemical accidents in warehouses, are often caused by human errors, especially:

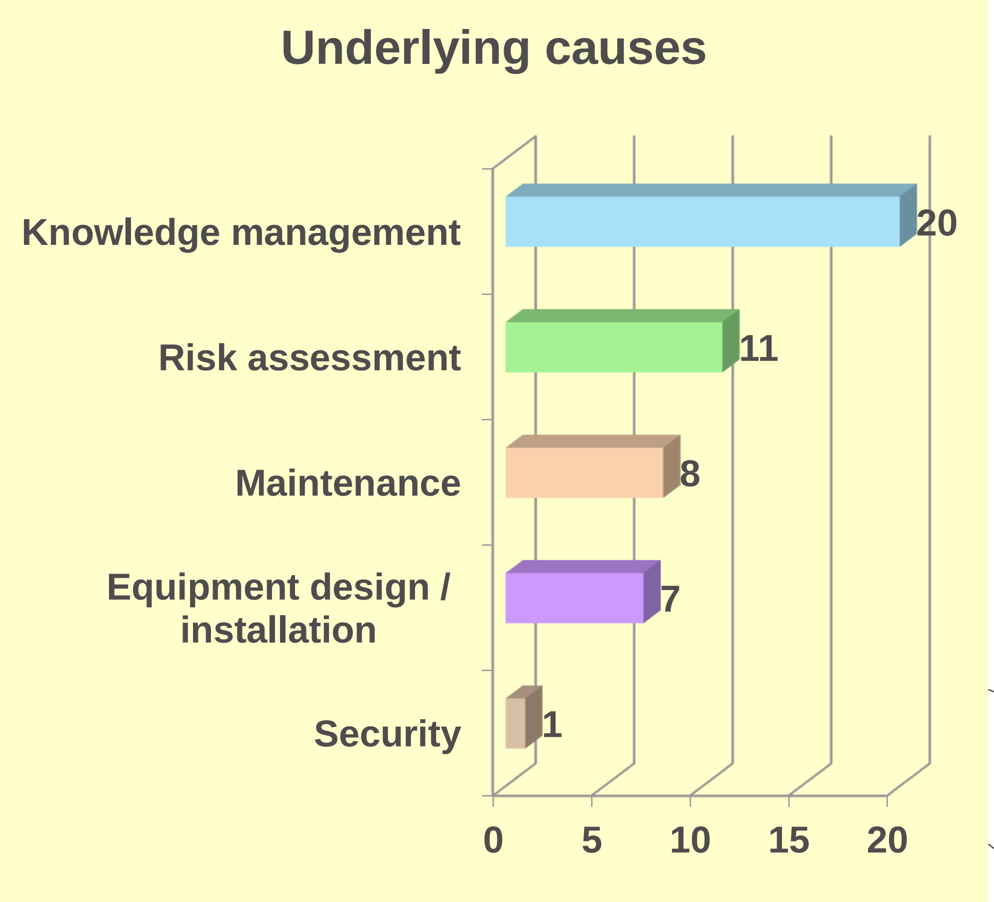
- **Acceptance of goods** without proper verification of contents
- **Mishandling of forklifts** while manoeuvring
- **Dropping a container** was from a certain height
- Improper **positioning and stacking**
- Improper preparation of **hot work**



Source: JRC Lessons learned bulletin on chemical accidents in warehouses, 2023

Small JRC study presented at Stockexpo (March 2021)

21 incidents involving tank storage



- Acceptance of deviation
- Wrong procedures
- Lack of documentation/ historical knowledge
- Poor training
- Permit to Work failure

- Management of change failure
- Insufficient barriers to wrong procedure

Insufficient secondary containment
Lack of detection equipment

Inadequate maintenance
Inadequate inspection regime

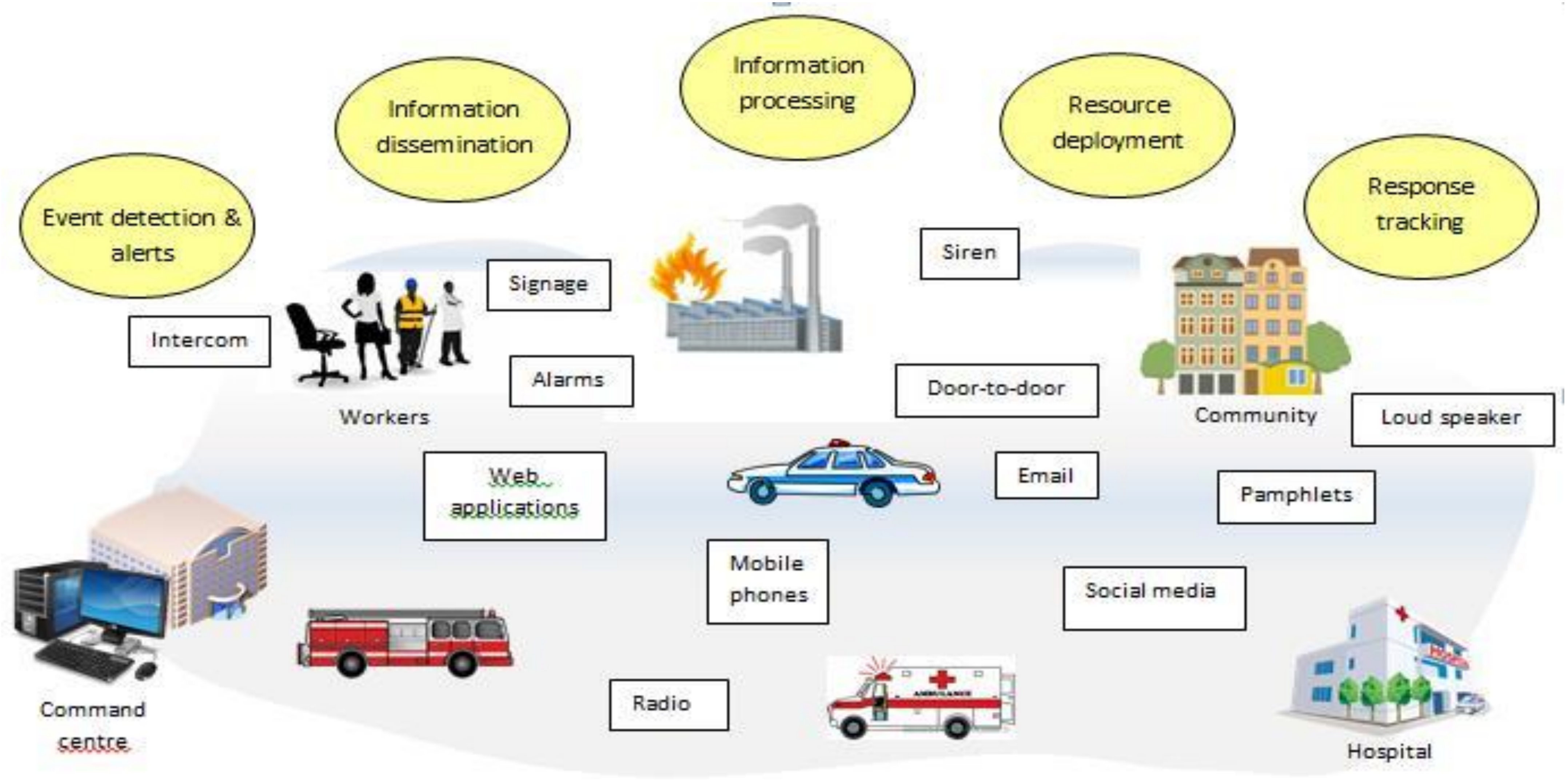
Poor valve design
Poor design of tank
Poor design/installation of safety equipment
Poor design of loading equipment

Security failure

eMARS database 2016-2021

Human factors dimensions of lessons learned from emergency response

A significant portion of emergency response errors are communication errors



Source: *JRC Lessons learned bulletins 10, 11, 12, 2017-2018*

Checklist questions (extract) for emergency responders in chemical accidents - *Derived from a study of 763 eMARS accidents*

- **Do emergency responders have a site map** that illustrates the location of fire protection equipment, emergency exits and assembly points?
- **What means of communication are available** on-site for effective coordination between the on-site and off-site emergency teams? Have they been tested in joint exercises to evaluate their effectiveness and identify improvements?
- **Are communications maintained constantly** with all personnel operating on the scene as well as with plant operations personnel? Are radios intrinsically safe for use in certain industrial circumstances (ATEX)?
- **Are there efficient means of information handling** during the emergency and good critical communication arrangements available?
- **Are there arrangements for families to access to official information** about the firefighters involved in the emergency response operation or already been retained from the scene?
- **Are there arrangements in place for providing information to the public** and the neighbouring establishments relating to the accident and the behaviour which should be adopted?
- Has **the incident command system** considered the possibility of overcrowding on channels, different frequencies used, mobile telephone network overload problems?
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Case study #1: Warehouse false alarm

Sequence of events

In a warehouse facility, a fire alarm triggered the activation of the automatic foam extinguishing system

The local fire brigade was called in to respond. When the firefighters arrived, the warehouse unit had already been filled with foam up to the 10-metre-high ceiling.

A team of three firefighters, due to the presence of foam and possible fire, equipped with self-contained breathing apparatus (SCBA). Foam filled the access corridor, probably escaping from the cell through wall seams.

As the team advanced, the foam obstructed vision as well as acted as a sound insulator, preventing verbal exchanges (except for radio).

In the end, physical and radio contact with one of the firefighters, who was an experienced fire officer, was lost.

When the victim was found, she was in a coma, without her SCBA equipment and with her buddy rope unattached. She died in the hospital three days later.

Case # 1: Lessons learned for human factors

The accident was caused by the technical malfunction of the automatic extinction system. There was no fire in the warehouse

1. **WRONG INFORMATION.** The three firefighters decided to conclude a physical inspection on the situation because they thought there were flammable substances present, but this was incorrect.

- Apparently, there was a misunderstanding in relation to the ICPE (French)category classification versus the UN classification.
- As a result, the substance was identified as tetranitromethane, a toxic combustible product which accelerates fire, but in fact, there was no such substance in the warehouse.

2. **LACK OF AWARENESS.** When her fellow responders decided to turn back, they removed their backpacks.

The victim had been connected to her partner via the backpack (rather than the belt), so she was left alone, without any means of communication, disoriented, and short of air.

Recommendations to improve risk management of human factors on hazardous sites

Opportunities for Seveso inspectors

Consider how to improve human factors elements of the inspection. In particular, review checklists or other tools to identify whether there are more opportunities for human factors questions

Resources for improving tools include:

- Checklists from the JRC Lessons Learned Bulletins and Good Practice Reports

Developed in collaboration with the EU Seveso Inspections group (TWG 2) and available on the JRC Minerva Publications page

- Human Factors library of the Energy Institute – Human factors are a priority area for the Energy Institute and they have elaborated several elements of human factors for training purposes

- UK Health and Safety Executive: Human Factors and Ergonomics

- Sky Library: Article on the Human Factors Dirty Dozen

- ICSI: The Institute for an Industrial Safety Culture (French)

- In progress: TWG 2 Framework for Incorporating Human Factors in Seveso Inspections

Opportunities for networks of authorities, researchers, industry

- There are few resources to guide inspectors and operators on incorporating human factors in chemical disaster risk management.

- There are a few organisations, like the Energy Institute, that have developed resources on human factors that are freely available

- Most other resources are expensive and it is not clear if they are adaptable for all audiences

- Chemical process safety doesn't really have a "human factors methodology". Should it? Should there be a "dirty dozen" for human factors for preventing chemical accidents?

- Should there be a longer list of typical factors involved in chemical accidents? Can the new OECD project on lessons learning from incidents help with this?

- There is a lot of work to do here. Perhaps some feedback from your experience might motivate those networks and institutions to work on these issues.

Thank you

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