

Behaviour in emergencies on COMAH sites: Challenging predictive assumptions about likely fatalities based on actual behaviours in emergencies.

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This paper questions the current assumptions made in risk assessments and ALARP demonstrations about the likelihood of people evacuating a major hazard site during an alarm condition. Inherent in predictive assessments is the assumption that people will not behave in a way that might compromise their safety; they will seek escape and evacuate by the safest route as quickly as possible. Risk assessments rarely take into consideration the requirements in emergency procedures for early detection, investigation and remedial measures such as performing manual isolations on plant to reduce the size of release. The authors have evidence that in an incident (e.g. explosion or loss of containment), some workers will to go towards the hazard to investigate what has happened. Qualitative analysis of ten dangerous occurrences that have been investigated in the last five years, showed that in half of the cases, emergency response behaviour was inadequate. While acknowledging the small sample size and opportunistic nature of the study, the authors encourage others (duty-holders) to explore the topic in more detail and make sure their arrangements are as robust as they assume them to be.

Introduction

In 2010, an upper tier Control of Major Accident Hazard (COMAH) site in the North East of England experienced a significant loss of containment of a toxic material following a runaway exothermic reaction. Alerted by the noise created by the volume of vapour being released, the managers of the establishment left the office building (a toxic refuge) to run across the site to determine what was happening. The Shift Manager, who was in the control room at the time of the incident (another toxic refuge), left the control room without appropriate protective equipment to alert people he thought were on the plant, only being deterred by the noise made by the volume of material being released. In the same year, the HSE published, on its Human Factors web page, a video showing operator response to a loss of containment of petrol from a road tanker at a storage site (Health and Safety Executive, 2020). Groups of site personnel gathered standing in the pool of petrol to discuss what to do about it, whilst bicycles, fork lifts, vans and tankers passed within meters of the spill. In 2015, during an HSE inspection at site, alarms were heard sounding on an adjacent plant to signify a release of toxic material, followed within a minute by a loud explosion coming from the same direction. All bar two of the employees on site ran towards the explosion to investigate what happened, the remaining two leading the inspectors off site. These are just three of the examples experienced by one of this paper's authors of how people behave during a major incident. To these examples can be added experience of numerous emergency procedures, the first step of which is to send someone to the origin of an alarm to find out what is going on. This anecdotal evidence is the driver for this paper, which raises a question about the way in which quantitative and qualitative risk assessments on oil, gas and chemical sites estimate the likely presence of individuals in the vicinity of an accident.

Regulation 5(1) of the Control Of Major Accident Hazards Regulations (2015) (COMAH Regulations) requires Operators to "take all measures necessary to prevent major accidents and to limit their consequences for human health and the environment", and this has been interpreted in the guidance provided by the regulator as the requirement to reduce risks as low as is reasonably practicable (ALARP). COMAH Regulation 5(2) further requires Operators to demonstrate that they have done so. Understanding, assessing and predicting the risks associated with major accident hazards is a full-time occupation for some specialists including probabilistic safety assessors, predictive safety, process safety and quantified risk assessors who are engaged in trying to demonstrate that risks have been reduced ALARP. This includes time spent modelling evacuation predictions, vulnerability and survivability time factors.

The indicative human vulnerability criteria for offshore sector risk models are based on the type of fire, the distance from the fire and the time of exposure. Guidance states, *"On an offshore platform it is believed that personnel will be exposed to a fire for a longer period because of the time needed to escape from the seat of the fire or evacuate the platform. Typically, average escape speeds will not be expected to exceed 1.5 m/s because of the complexity of the installation lay out and presence of equipment"* (HSE: SPC/Tech/OSD30). This is generally considered to be different onshore where arguably the greater space available might mean less complex layouts of plant and equipment in less dense configurations, and there are in theory at least more places of safety within reach. The reality is that accretion of plant and equipment over decades at some sites, can lead to complex densely packed plant onshore as well, and onshore sites are frequently constrained by security considerations e.g. impenetrable fencing with only a few, guarded access and egress points. However, this paper is focusing on the assumption that people will try to escape in the first place, rather than on how long it might take them to do so.

Inherent in predictive assessments both on and offshore is the assumption that people will not behave in a way that might compromise their safety; they will seek escape and evacuate by the safest route as quickly as possible. Those who are not killed or injured will run away, and those who are already in a place of safety will stay away from the danger zone. It is assumed that these safety behaviours will reduce exposure/ threat to life. Risk assessments rarely take into consideration the requirements in emergency procedures for early detection, investigation and remedial measures such as performing manual isolations on plant to reduce the size of release. Yet, research by Woodcock and Au (2012) to explore the Human Factors issues in emergency responses at high hazard installations (focused on offshore installations) showed that, typically, the first step in an emergency scenario is investigation and diagnosis. Intuitively, this is essential for decision making and appropriate emergency response; a plant cannot be abandoned in every abnormal situation, the cost and associated additional risks from abandonment is disproportionate and in most cases it will not be necessary. Many scenarios are recoverable and with timely action, will not lead to a major accident.

While there is evidence that predictive assessments are conservative about the survivability of workers in the immediate vicinity of an event, they also assume that others will move away and that emergency response procedures will be correctly enacted. Statements made in COMAH safety reports include,

"People will see the fire and will escape to safety without injury"

"It would take a significant amount of time to develop… and therefore, it is expected that the site would have been evacuated before any further escalation occurs."

"Those outdoors would be expected to escape".

The authors' experience suggests this assumption needs further consideration. To what extent do the opposite behaviours, which have been observed above, prevail in the major hazard industries? This paper seeks to explore this question.

Literature review

Excluding the work to model evacuation from offshore facilities, the focus of the emergency response literature is on crowd behaviours at events where most people are strangers to the location and are experiencing novel situations (e.g. Pan et al, 2006), members of the public escaping from high rise buildings (e.g. Lovreglio 2014a; Gerges et al, 2017), or evacuating in response to natural disasters (e.g. Huang, et al, 2012). There is a knowledge gap regarding emergency behaviours for people working in high hazards industry where they have responsibility for the safe operation of high value assets and the welfare of staff – this refers to both managers and employees who share responsibility and understanding of the risks associated with the hazards they work with. The available research into human behaviour, and particularly during emergencies, combined with the extensive literature on decision making and risk perception does provide consistent findings that are relevant to the major hazard environment.

Psychological short cuts, or heuristics, are essential for a functional life. They help us to understand our environment without the need to undertake a systematic analysis of every situation each time we encounter it (Kahnman, 2011). The influence of these short cuts in decision making can also lead to errors when the situation is misinterpreted. For example, research consistently reports that under-reaction is more of a problem than over-reaction in an emergency; a significant proportion of people will not react to a fire alarm where they assume it to be part of a drill or false alarms are a common occurrence because they perceive the threat to be low. Individual tend to assume the status quo and ignore the more subtle cues of a real incident. This potential underestimation of risk can be explained by anchor heuristics and / or availability heuristics. These heuristics result in people making decisions based on limited information to the exclusion of contrary signs and the remembered situation(s) where the event did or did not occur (Kinateder at al, 2014).

Availability heuristics will also tell people who work in major hazards contexts that most of the time, they can work with flammables, explosives and toxics without any ill effects (see also normalisation of the risk). If people feel that they are in control of or should be in control of a situation (see illusion of control, Thompson, 1999), they are likely to try to bring the situation under control long after they should have evacuated (see optimism bias, Sharot 2011).

If people do evacuate, and many won't, they take familiar and known routes (the way they came in) rather than the shortest route to the exit. People show herding behaviours and 'follow-my-leader', and they become more conformist (Lovreglio 2014b). On the whole people in emergencies show more altruistic behaviours than at other times; however, if there are bottle necks and the perceived threat level is increasing, people may panic if not reassured that they have time to escape (Drury and Cocking, 2007).

Where the threat level is perceived to be extreme, people experience acute stress and at such times they exhibit cognitive tunnelling, shutting out any perceptual data that is not relevant to escape. Survivors of disasters usually cannot recall sound, smell or colour and sometimes recall seeing their escape route as a tunnel they are progressing along. In such circumstances, the existence of rules, learned or otherwise, becomes irrelevant as reported by the operators who survived Piper Alpha and Macondo by ignoring mustering rules (Skogdalen et al, 2012).

Where people identify there is a threat, but information is in short supply, they experience threat anxiety and therefore, we suggest, are more likely to investigate even when toxic alarms/ explosions are occurring in order to reduce the anxiety. The behaviour of people who work with major hazards daily is likely to be affected by a normalisation of the risk. This describes a situation where, the safer things appear to be, the more risks people will take. This is strongly affected by culture and group norms – so if the group you identify with are happy to work at height without safety harnesses, you are likely to conform to the group; likewise, if everyone else runs towards a hazard, you are likely to do so too.

Work by Kobes et al (2010) summarises the influences on emergency behaviours as,

- Individual factors including personality, knowledge and experience, powers of observation, powers of judgement, powers of movement and competence.
- Social features including affiliation (e.g. family and colleagues), role/responsibility for others.

- Situational features such as awareness of the situation, plant condition, familiarity with layout.
- Organisational features such as arrangements for command and control, management/leadership, procedures, communication, the safety management system, and work practices.

It is reasonable to expect that the emergency behaviours of operators at a COMAH site will be influenced by this same wide range of factors and that the assumption that people will run away from a hazard, is too simplistic.

Objective

The aim of this paper is to explore the idea that if there is an incident (e.g. explosion or loss of containment) on a major hazard site, some workers are likely to go towards the hazard to investigate what has happened. This was achieved by analysing the HSE Corporate Operational Information System (COIN) records and interviewing HM Inspectors who have investigated reportable incidents at COMAH sites. Recognising the limitations of the study, the ultimate aim is to encourage others (duty-holders) to explore the topic in more detail and make sure their arrangements are as robust as they assume them to be.

Methodology

This qualitative research was based on an analysis of semi-structured interviews with HM Inspectors who had investigated reportable incidents from COMAH sites in the past 5 years (2014 – 2019). HSE COIN records were scrutinised for reports of dangerous occurrences (incidents with a high potential to cause death or serious injury) where reference was made to 'emergency' action as part of the incident description.

The initial sampling identified 30 dangerous occurrences and of these, there were 19 cases that made specific reference to emergency actions, behaviours or response; at this stage, no judgement was made about whether the response was appropriate or not. The investigations into these 19 cases were led by 14 different HM Inspectors who were asked to participate in the study. Some inspectors were unable to participate, and others had since left the organisation, this meant that the final sample consisted of 10 investigations led by 7 inspectors.

The semi-structured interview was based around the COIN description of each investigation and asked the inspector to talk through the incident focusing on who was involved, how the scenarios developed, whether alarms were activated, if there was an explosion, how many people were in the area, how they dealt with the scenario, how management / supervisors responded, what they might have expected to happen and how it differed, if at all, to those expectations. Each interview took approximately 30 minutes. The interviews were summarised as narrative accounts and analysed for themes relating to emergency behaviours. The investigating inspectors (as Subject Matter Experts) were asked to make a judgment about whether the emergency response had been appropriate (good) or whether inappropriate behaviours had been evident, and the response considered inappropriate (poor) in terms of health and safety management.

Results

The information provided in the following section is a summary of the key points and respects the confidentiality of the data collected by HM Inspectors. Where specific detail is provided it relates to information that is already in the public domain.

The ten cases represent a range of routine activities (e.g. movement of chemical packages by fork lift truck, tanker filling, batch processing of chemicals), some cases of abnormal activities (e.g. commissioning of plant, mothballed plant) across a variety of operations involving toxic and flammable materials. The common characteristics were that the dangerous occurrence occurred at a COMAH establishment within the last five years.

The analysis identified five cases where there had been a poor safety response to the dangerous occurrence and five cases where the available information indicates that the response had been appropriate or, at least, did not warrant further investigation at the time.

Cases categorised as 'good'

Four of those considered to show 'appropriate' behaviours were in response to an incident that happened during routine activities and the operators, who were directly involved in the incident, raised the alarm. As they were directly involved, it seems likely that they understood the situation and had enough information to know what response was needed – in all four cases they raised the alarm and evacuated the area. In two of these four cases the operative was the immediate cause of the LOC (a fork lift truck collision and a tank overfill), and in the third, a fire broke out on the equipment being operated. In the fourth case**,** a leak was identified by the oncoming shift who reported the issue to the control room operator who then closed the necessary valves and initiated the clean-up. In this case, an alarm was not raised because they were the only people on site. Again, the operators had enough information to manage the situation and did so safely by removing themselves to a place of safety (the control room) and closing the valve remotely.

In the fifth case the emergency behaviours were in response to a toxic alarm and all staff went directly to the control room, which is the toxic refuge. The inspector stated that there were a small number of workers on site, and the operators were able to control the plant mostly from the control room. As the operators worked to bring the situation under control, operators had to go to the release area, but they did so as part of the emergency response and with appropriate PPE/ controls in place.

Cases categorised as 'poor'

The five cases identified as having a poor response, covered a range of activities; two incidents happened during routine operations; two occurred during the commissioning phase of new plant; and one during maintenance activity. There were very different influences on behaviour in each case.

In both commissioning activities something went wrong and resulted in people putting themselves in danger to manage the incident. In one scenario, the toxic alarm was heard and then an explosion which caused staff (including managers) to run towards the scene to investigate. There was no consideration of initiating emergency procedures or stopping to consider appropriate action. Those running towards the toxic release did not stop to don appropriate PPE or RPE. In the other case, operators went to investigate a smell that they had detected in the control room and subsequently identified a toxic leak. The employees who took remedial action upon discovering the LOC were not wearing suitable personal protective equipment to control their risk of exposure to the toxic material.

In the maintenance case, managers became aware of a leak and sent operatives to investigate. The local alarms had been deactivated to allow for the maintenance work, but the operators' personal alarms activated when they went into the area. The investigation indicated that managers had initially chosen not to hit the emergency stop because the cost implications for shutting down the plant were considered too high.

The two examples that occurred during routine activities were very different. In the first, an alarm and explosion were heard in an area where control room operators knew a colleague was working; they rushed in, putting on their kit as they were running towards the vapour cloud, resulting in minor chemical burns. In addition to the initial behaviours, the case identified issues around the company's emergency response generally including the lack of access to procedures, preparedness and access to emergency equipment.

The final example was a case where the operator was the immediate cause of the LOC but instead of raising the alarm and initiating emergency procedures, they tried to recover the situation themselves and did so in an unsafe way.

Limitations

The study is based on a small, opportunity sample and no consideration was given to the size or location of establishment, the complexity of operation or the nature of the hazard. The methodology relies on the memory of inspectors and, in most investigations, the focus is on finding and understanding the cause of an incident and not the response afterwards; emergency behaviours are not usually considered unless the response is so poor that it draws attention. This means that more information is available for those cases that were classed as poor than those judged to be good. Even so, with 50% of this sample demonstrating serious flaws regarding emergency behaviours, it is sufficient to raise concern and warrant further investigation.

Discussion

The analysis of the ten interviews identified five cases that were judged to have an inadequate response to the dangerous occurrence, and five were judged to have had an appropriate response – note the five 'poor' cases were identified because the response was sufficiently poor to draw attention and the information was included in the COIN records.

The cases identified here further illustrate that in emergencies people will be influenced by a variety of factors. The key difference between the way people behaved in the 'good' examples versus the 'poor' examples appeared to depend on their knowledge of events. Where people had a good understanding of what had gone wrong, i.e. they were directly involved in the incident, or had line of sight to the threat (discovering a leak), they were able to take appropriate measures to escape and evacuate.

In one of the 'good' examples, the appropriate emergency response did include personnel visiting the site of the incident, which was consistent with the findings of Woodcock and Au (2012). The personnel were properly equipped with PPE and sent on site to open a valve to a water feed system, which resulted in water suppression of a corrosive cloud and the incident was brought under control.

The reasons for people's behaviours in the 'poor' examples appear more diverse. They include:

- Behaviours consistent with threat anxiety, with employees going to investigate a situation about which they had no knowledge (in this case an explosion).
- Behaviours consistent with a weakened risk perception – investigating a 'smell' without donning appropriate PPE.
- Behaviours consistent with affiliation – seeking to rescue people we know and for whom we feel a sense of responsibility.
- Behaviours consistent with anxiety about blame – cleaning up in an unsafe manner.
- Behaviours consistent with inappropriate priorities – sending operatives into a dangerous area to avoid the costs of shutting down.

In all but one of these cases the people responding to the emergency had impoverished information about what was happening at the site of the incident.

Currently, HSE Human Factors specialists look at the usability of Emergency Response procedures. Simply put, inspectors ask operators to walk through the procedure on plant to determine if it is possible for people to carry out the task in the circumstances and time required. Too often we find that it is not possible to do what is asked. Some examples from the last 5 years include:

- References to plant and equipment that no longer exist e.g. press button X when button X had been deactivated;
- Inability to reach plant locations wearing proscribed PPE;
- Inability to access PPE without entering the danger area;
- Inability to carry out tasks in the required time scale;
- Impoverished information to allow people to make good decisions in the required time scale;
- No communications equipment (phones/radios) in toxic refuges despite procedural requirement to communicate as part of the emergency response including directing the work of the emergency services;
- Procedures inaccessible in the circumstances of the accident or under stress e.g. held on a password protected computer for which the operative couldn't recall the password.

Since these problems only come to light on inspection, during a walk-through of the procedure, this is telling us that they have not been practised on the plant. These issues are unlikely to be picked up by table top exercises (the most usual manner of practising emergency response), since they do not require people to demonstrate that they can actually do the task.

Enriched information would perhaps help people to respond in a safe manner by which we mean, removing themselves from the danger area and not entering the danger area if currently in a safe place. However, providing that information for all scenarios on a complex chemical plant is no easy matter. Therefore, assuring human performance in these situations may require training people to automaticity. That means training people until they are competent – they know what to do and when – and then continuing to train people until they perform the required action at the required time without thinking. It is probable that the certainty about what to do would counteract the threat anxiety provoked by impoverished information. This would still leave non-participants in the required emergency response, vulnerable. It is noted that in at least one example, the site management also put themselves at risk to investigate.

Conclusion

The exploration of this small number of dangerous occurrences indicates a need to better understand human behaviours in emergency situations. In the current situation, where we have reason to believe emergency response procedures are not practised at all, it seems unlikely that risk assessors can make any reliable assumptions about timely evacuation or about the numbers of people normally in the danger area. Moreover, assumptions that the persons exposed to the hazard are limited to those normally working in the area are invalid since others will go to investigate. Therefore, current assumptions made in risk assessments and ALARP demonstrations about the likelihood of people evacuating an area during an upset are brought into question. However, we must acknowledge the small sample size and opportunistic nature of the study. For this reason, the authors believe that further research is required in this area.

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