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Learning (and unlearning) from failures: 30 years on from Bhopal to Fukushima an analysis through reliability engineering techniques

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ABSTRACT

Reliability engineering techniques such as failure mode effect analysis (FMEA), fault tree analysis (FTA), and reliability block diagrams (RBD) have been used to analyse the case of the Bhopal disaster (Labib and Champaneri, 2012), and subsequently used in the analysis of other disasters (Labib, 2014b), where it has been shown how such techniques can help in building a mental model of describing the causal effects of the disaster. The same case study of Bhopal was also investigated (Ishizaka and Labib, 2014) and a new logic gate in the fault tree method was proposed for analysing disasters and the benefits of using hybrid techniques of multiple criteria and fault analysis to evaluate and prevent disasters were demonstrated.

In this paper an analysis of learning, and un-learning, from failures is carried out using a comparison between Bhopal and Fukushima, although they occurred in different industries, by comparing them we observe many similarities. This is followed by a compilation of different models based on FTA and RBD analysis of the Bhopal disaster which were an outcome of a series of workshops that were carried out to investigate the Bhopal disaster. This approach shows how the same case study can be viewed from different perspectives although the same modelling techniques were used. The paper then explores few interesting research questions such as how to evaluate different models? Do multiple models lead to better understanding of the case study? And are there any practical guidance to follow when studying root cause analysis?

1. Introduction

Bhopal, Minamata, Deepwater Horizon, and Fukushima are examples of disasters that have common features. They all show that in their struggle to maximize their profits, major companies and industries have tended to compromise safety. They also demonstrate an attempt from those responsible to initially hide the extent of the impact of the disaster and in doing so, many lives have been lost due to late response. They also illustrate how man-made disasters can have a far reaching impact on the neighbouring communities and the environment. Finally, they remind us, as also proposed by others (Mohagheg and Mosleh, 2009; Taniguchi and D'Agostino, 2012a,b; Taniguchi, 2012), that disasters are not just a technological problem but there is a need to study socio-technical factors, and to adopt a trans-disciplinary approach that incorporates social and natural scientists, practitioners, and policy makers.

Bhopal occurred 30 years ago, before many of today's engineers were born, and so it may be worth summarizing the incident. In the midnight of December 2, 1984, the tank 610 (one of three tanks) containing methyl isocyanate (MIC), which is an intermediate compound in the production of a highly toxic pesticide called cevine, got contaminated with

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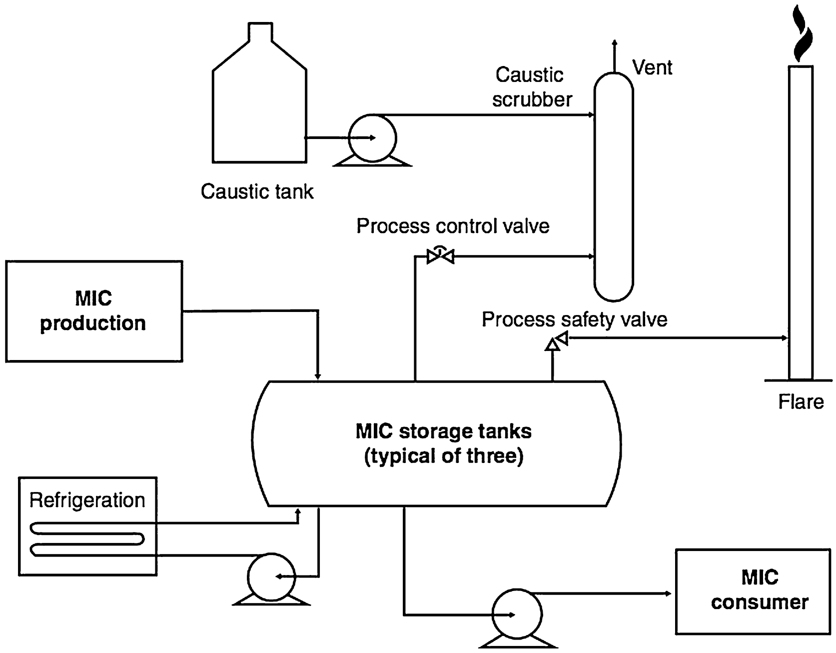

Fig. 1 – The process at the Bhopal Plant Ref: Adapted from SPE http://www.spe.org/news/article/what-caused-the-deadliest-industrial-accident-in-history.

water. The source of contamination whether intended or unintended is still questionable. This led to the initiation of an 'exothermic reaction' (a type of chemical reaction where the energy needed for the reaction to occur is less than the total energy released, so heat is generated as an output which in turn is used as an input to speed the chemical reaction and generates more heat). This reaction turned into a violent 'runaway' which is a term used to describe an accelerated and uncontrollable chemical reaction. This leaked to the atmosphere by-passing safety barriers such as the vent gas scrubber (VGS) which is a device designed to serve as the last line of defence in the eventuality of this deadly gas leak. Apparently the VGS was not well designed to be capable of handling such mount of leak, and to make matters worse, it was unavailable as it was under maintenance during the incident. There was also a catalogue of safety breaches through operational errors such as shutting the refrigeration unit which was designed to keep the temperature below 5 degrees centigrade and the unavailability of the flare tower. The process at Bhopal can be illustrated as shown in Fig. 1. The consequence of this disaster was the killing of around 3400 people, and injuring around 200,000. It is also reported that 3000 cows were killed and vegetation died over an area of 40 km^2.

Fukushima disaster occurred on March 11th, 2011, when Japan suffered from one of its worst ever recorded earthquakes of magnitude 9.0 Richter scale, known as the Great East Japan Earthquake. This was then followed by a massive tsunami, which swamped the Fukushima site and took out the AC electrical power capability. Due to these two double jeopardy events, the cooling capability of the four nuclear reactors at the nuclear power plant was lost, a phenomenon known as the 'ultimate heat sink'. This together with hydrogen built up caused an ignition that led to a nuclear melt-down. This disaster was classified as a level 7 of the International Nuclear and Radiological Event Scale (INES), the highest severity level which is only shared with the Chernobyl disaster. For more details about the analysis of Fukushima, the reader can consult Labib (2014 a,b), and Labib and Harris (2015).

2. Learning (and unlearning) from failures—Bhopal versus Fukushima

2.1. *Bhopal vs. Fukushima*

Although there are similarities between Bhopal and Fukushima nuclear power plant disaster as mentioned above, there are also subtle differences. Bhopal was a perfect storm (Pate-Cornell, 2012) or an accident waiting to happen (Chouhan, 2005), whereas Fukushima is claimed to be a 'Sotegai' (a Japanese word that means beyond hypothetical expectations) or a black swan (Taleb, 2010).

So, why was Bhopal a perfect storm? In all, or most, major accidents, we see a similar pattern of multiple things going wrong simultaneously. The list of things that went wrong at Bhopal is striking, including:

- Many safety related devices where not well designed to handle such major gas leak, with no redundancy, and to make things even worse, most of these devices (such as the VGS, flare tower, and cooling refrigerator) were not available at the time of the disaster.
- The plant was losing money, which resulted in staff and maintenance budget cutbacks.
- A social system that dismissed safety culture and created extreme tension between management and workers to the extent that one disgruntled worker was willing to intentionally ruin a batch of MIC (SPE, 2014).
- The plant was to close permanently, which, no doubt, significantly affected operator morale and contributed to the lack of maintenance and the bypassing of safety systems.
- The complete failure or lack of an emergency response programme.
- Ineffective treatment of the injured.
- The people outside and inside the fence had no idea how hazardous the plant was. There was no citing or any awareness of the dangers of this plant.