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Process versus personal accidents within sociotechnical systems: Loss of control of process versus personal energy?

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ABSTRACT

Process safety and personal safety are often distinguished in literature and practice despite an acknowledged advantage in their integration. Degree of damage and type of hazard are advanced as factors that distinguish process and personal accidents. A damage production model based on a hazard systematically characterised by an energy is proposed. This distinguishes energies external to the victim and specific to process operation from energy related to the victim's movements. This development is based on six accident cases, of which three are consistent with common representations of a process accident and three of a personal accident. They are identified in the sea fishing and hospital sectors. This ensures broad coverage of different hazard types and resulting damage. The proposed model is capable of formalising the coexistence of hazards (i.e. energies) that are fundamentally different. It highlights different kind of energies to be controlled by a sociotechnical system. Our model also reveals practical difficulties of protecting an exposed target in relation to the type of energy causing damage. It is a tool useful for integrating control of process and personal energies, combining the aims adopted for managing process and personal safety.

1. Introduction

A distinction between process and personal safety is made in practice and in the literature (Hopkins, 2009; Grote, 2012) despite the advantage expressed for their integration (Fahlbruch and Wilpert, 2001; Carayon et al., 2015). Type of hazard and resulting damage are what clearly distinguish process safety from personal safety (Hopkins, 2009). It is our hypothesis that a model formalising the difference between process and personal accident, in term of hazard, could represent an advance towards integrating these process and personal safety.

Hazard is the element through which a risk is apprehended and its identification is the starting point of risk management. The hazard is characterised differently if it is a process accident or a personal accident. For example the bowtie model-based generic representation of an accident may be used for hazardous substance risk management under the Seveso III directive (Bragatto et al., 2015). In this representation, hazard appears as the “hazard top event”, one of whose modes is “overflow of chromic solutions into containment basin”. In this case, the hazard top event refers to loss of control of a chemical process. The bowtie model may also be used as a tool for comparing occupational accidents based on their seriousness (Bellamy, 2015). In this representation, hazard appears as the “accidental release of the hazard agent” whose modes mostly refer to how the injury is produced (e.g. contact with electricity, extreme muscular exertion or contact with machine moving parts) or else to loss of control of the victim’s movement (e.g. fall on the level). We note a different characterisation of the hazard when process or occupational accidents are concerned. We also note that in occupational accidents, hazard categories are neither mutually exclusive nor mutually consistent. Indeed, some injuries can result from contact with machine moving parts which can itself result from a fall on the level. In the case of a fall on the level, the injury can be caused by contact with the floor or an object in the physical environment. Why are we not consistent with other contact-related hazard categories by considering “contact with the floor” instead of “fall on the level”?

In short, the polysemic nature of the hazard concept leads to adopt labels of different natures to express the hazard. These items are neither comparable, nor always mutually consistent. This paper proposes an harmonized characterisation of hazard for every accident occurring in a sociotechnical system, whether it is a personal accident or a process accident. We develop a model of accident damage production - *the very final stage of damage genesis that involves the hazard concept* - based on a common energy-based hazard characterisation. This model focuses on the two types of energy involved in the loss of control with which the

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sociotechnical system must cope: energies specific to process operation and energy related to workers's movements.

This paper is divided into three sections. The first one examines the current status of the contents of databases, which capitalise on different accident types in sociotechnical systems. It allows to highlight the issue related to each kind of safety and the fuzzy perimeter between process and occupational accidents. It also emphasizes different types of hazard that are present and managed in these systems, before going on to examine the hazard concept. The second section of the paper describes development of a damage production model using a set of 6 accidents embracing the different types of hazard encountered in sociotechnical systems. In this model, hazard is systematically characterised by an energy. Finally, the third section of the paper is a discussion on safety management based on the developed model and on the literature.

2. State of the art

2.1. Process accidents/personal accidents: issues, perimeters and hazards

Examining the contents of databases, which capitalise on different accident types in sociotechnical systems, is a way of assessing the risks present and managed in these systems and of taking up the challenge represented by their prevention. We note that these accidents are covered by different surveys based on the targets jeopardised by them (workers, provided service beneficiaries, environment, installations, etc.) and on the type of declaration required by the system, (e.g. when work accidents occur).

The ARIA (Analyse Recherche et Information sur les Accidents) database was developed by BARPI (Bureau d'Analyse des Risques et Pollutions Industriels[1]) to record process accidents occurring at "Installations Classées Pour l'Environnement" (ICPE), environmentally classified facilities in France, and those involving transport of hazardous materials, gas distribution and domestic usage, mines, quarries and hydraulic structures. These are accidents that have caused (or could have caused) damage to targets such as company installations, the environment, surrounding populations and/or company personnel. Such accidents result from loss of control of hazardous materials or technical equipment, so the term process is here used to characterise technical equipment and hazardous materials and does not include the associated personnel. Data on French accidents listed on the ARIA database come from different sources, in particular, public authorities, the press and sometimes professional bodies. Moreover, a number of international organisations also provide information on accidents outside France. Finally, the ultimate aim of creating the ARIA database was to ensure that prevention could benefit from experience feedback.

With regard to occupational accidents, databases have been drawn up using compulsory declarations made by companies for each employee injured at work; the ultimate purpose of these surveys being to ensure redress on the part of the victims.

We note that these surveys are performed neither uniformly nor exhaustively. On the one hand, there are overlapping areas in their records: for example, an ARIA database accident causing so-called major damage, which has inflicted bodily injuries on several workers, appears as many "personal accidents at work" database entries as there are worker victims. On the other hand, an accident revealing loss of process control, whose resulting damage is qualified as minor and limited to the company, is not systematically listed on a process accident database. It will appear on the database that lists occupational accidents in the form of as many events as there are victims among the workers. It should also be stated that the ARIA database does not only include accidents that have occurred in France and that the database consolidating occupational accidents at companies belonging to the French general social security system only covers approximately 75% of French employees. Despite these limitations, it is still interesting to examine the frequencies of the accidents recorded on these two databases. Since 1992, the ARIA database has been enriched with a total of 43,976 accidents and incidents. 37,586 of these are in France, of which 26,368 involve classified facilities. 899 accidents were recorded in 2013; each of these gave rise to an intervention by public emergency services and a declaration to the French classified facility inspectorate. These accidents had consequences, in particular environmental in 251 cases and human in 160 cases. There were 7 fatalities, 19 serious injured victims and 158 injured victims. At the same time, over 600,000 occupational accidents with days lost, over 500 fatal occupational accidents, over 40,000 occupational accidents leading to permanent disability and over 18,000,000 days lost due to temporary disability are recorded each year for companies belonging to the French general social security system employing more than 18 million people nationally (CNAMTS data). Around a quarter of these accidents resulted in injuries caused by an element, with which any contact or closeness will cause injury (high voltage source, corrosive chemical, certain moving parts of a machine, etc.). The remaining three-quarters resulted in injuries prompted by falling more or less from a height, collisions, jamming, elements that give way when the person exerts actively forces on them or appearance of pain, especially during handling operations (Leclercq et al., 2015). These accidents most frequently reflect the victim's loss of control of his/her movement without involving systematically hazardous materials or technical equipment in the production of injury.

The nature of the various risks to be confronted by a sociotechnical system is strongly dependent of the activities developed by these systems. While the so-called "high risk" only exists at certain companies, the risk of an accident caused by movement disturbance is effectively present in all sociotechnical systems and can affect directly both company workers and provided service beneficiaries. Having said this, every sociotechnical system, whatever it may be, has to confront accident risks that involve hazards of different types affecting different targets. These different hazards are distinguished and sometimes qualified as process hazard or personal hazard, the latter causing most injuries and fatalities (Hopkins, 2009).

2.2. Hazard concept

The October 2005 glossary of technological risks defines a hazard as "an intrinsic property of a substance (butane, chlorine, etc.), a technical system (pressurizing gas, etc.), a provision (elevation of a load), a body (microbes), etc., likely to cause damage to a "vulnerable target"". The International Risk Governance Council (IRGC, 2005) stated that "Hazards describe the potential for harm or other consequences of interest. They characterise the inherent properties of the risk agent and related processes". Kjellén (2000) adopts the following definition of hazard: "a source of possible injury to personnel or damage to the environment or material assets".

Hazard is therefore frequently characterised by an intrinsic property of an element/agent likely to cause damage to an exposed target, which can be a human being and/or the environment. In most cases, these definitions refer, explicitly[2] or not, to an element that is external to the target and recognizable as harmful when assessing a priori the risk. For example, when mapping hazards, Koehler and Volckens (2011) project the intensity or concentration of a chemical agent onto a two-dimensional floor plan or workplace layout. In this case, the hazard is a chemical agent (a chemical energy carrier), which is external to the target and identified a priori as a clear possible cause of damage, if exposure occurs.

On the other hand, Rasmussen and Svedung (2000) consider hazard

[1] Industrial hazard and pollution analysis unit at the French Sustainable Development Ministry's General Directorate for Risk Prevention.

[2] In the International Classification of External Causes of Injury (ICECI, 2004) for example.