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Seveso Accident Analysis and Safety Management System: a Case Study

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According to Seveso Directive the analysis of accident and near miss has be performed in order to identify which elements of the safety management system (SMS) should be reviewed. In this paper, a real accident in a chemical depot has been analyzed to investigate which aspects of safety management system should be improved. Both occupational safety and health (OSH) aspect and major accident hazards (MAH) about the accident have been considered by using two specific methods: the Infor.Mo. and the Root Cause Analysis. A comparison between the results obtained by application of two methods has been made to individuate useful information about occupational and major accident aspects and to harmonize them in a SMS.

1. Introduction

The analysis of a major accident has to considered part of a management process; starting to collecting information related to the causes of the event and its dynamic, preventive measures necessary to avoid its recurrence and significant elements to improve and develop an appropriate safety management system (SMS) have been identified.

1.1 MAH and OSH harmonization

The general approach to study accidents has changed over time; in fact, compared to a negative attitude to cover up the truth that has caused an increase in the frequency of accidents, it has been recognized the need for accident forecasting, consequences assessment and development of up-to-date emergency preparedness and disaster management plans (Khan, 1999).
Surely benefits are evident by the adoption of an SMS in all industrial sectors especially in the beginning, when, to implement management system, the working procedures are documented and the roles within the organization are defined (Bottani et al., 2009).
Interesting studies are related to the investigation between injuries and accident or in general between OSH and MAH. The most recent papers include Bellamy et al. (2013), which investigated 118 recorded incidents and accidents at establishments subjected to Seveso Directive in Netherlands, Bellamy et al. (2014), which analyzed some 20.000 occupational injuries and Lisbona et al. (2012) which examined a dataset of 975 incidents.
Furthermore, it should be considered studies of OSH' risks in Seveso establishments where the focus is on technical system such equipment, devises and control. As discussed by Bragatto et al. (2015) SMS-MAH is usually integrated with SMS-OSH and reflects the same structure; but it is more demanding because the extent of accidents is much larger, the consequences much more severe and the control by authorities compelling. The authors stressed this aspects about small and medium sized enterprises end consider that the "real" safety system is made by equipment, materials, instruments, instructions, procedures, documents, plans and workers with their knowledge and experience. Agnello (2013) makes a comparison between occupational Regulation (Italian Decree 81/08) and major accident Regulation (Italian Decree 334/99 now abrogated and replaced by Decree 105/2015). The report shows that health and safety Regulations have a point of view defined person-centric, as it is based on protection of worker, while major accident control

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Regulations is plant-centric, as it is based on all plants including unit of work, process and every components and devices. As discussed by Hopkins (2009), a fundamental distinction is made between process and personal safety and there are really distinctions between different types of hazards.
Bellamy (2015) explores the relationship between big and small consequences accidents, fatal versus non-fatal occupational accidents being one subset and major and occupational accidents being another and high lines that analysis of occupational accidents can help in addressing major ones proving it is restricted to the same hazard type, contradicting the view that personal and process safety are totally unrelated.

1.2 Accident analysis: MAH and OSH approach

In compliance with Seveso Directive, operators must adopt procedures for reporting accident and near misses, particularly those involving failure of protective measures and the investigation and follow-up on the basis of lessons learnt (Basso et al., 2004). The Seveso Directive stipulates that Member States must exchange information on major accidents and, to this end, a register and an information system called MARS (Major Accidents Reporting System) has been realized. In Italy, the Competent Authority draws up an inspection to inform the European Commission about a major accident occurred at Seveso establishment. These information are collected during a mandatory audits at establishment from a multi-disciplinary team and by using a specific procedure and simple format. One of the main methodology used to investigate a major accident is the Root Cause Analysis (RCA) that identify the primary causes of the event, as reported in Italian Guide Lines about post-incidental analysis in activities at risk of a major accident (2005). Health and safety European Regulation (Directive 89/391/EEC) requires to define methods and procedures for collecting and compiling data about occupational accidents, so to compare accident statistics between the EU Member States, therefore in Italy the method "We learn by our mistakes" ("Sbagliando s'impara" in Italian and thus SSI hereafter) has been implemented (Campo et al., 2006). The model Infor.Mo. has been developed starting from SSI model and it a part of the so-called "National System of epidemiological surveillance of (fatal) workplace injuries aimed at researching causes". Infor.Mo. focuses on each injured worker by going back to the dynamic of events of the incident which leads to the injury.

2. Objectives

The analysis of causes of near miss or accident provides a fundamental contribution to improving prevention and protection measures and to implement adequate safety procedures.
As discussed by Bragatto & al. (2014), the prevention of major accident has to be integrated within the OSH management, so the study of near-misses and the internal audits could be considered the start point evaluate technical and management aspects in all plants in which workers applied instructions and procedures.
Starting by a real accident event in a Seveso chemical depot, the main causes have been investigated to individuate the critical elements of the SMS on the base of the results obtained through the use of two specific methodologies. Both occupational and major accident methods have been considered to analyze the technical and organizational reasons of accident. A comparison between the results of two methods has been made to obtained useful information to integrate OSH and MAH aspects through an harmonized safety management system.

3. Methods

The real accident was analyzed by using two different methods: the Infor.Mo. model and the RCA method. The first method is has been developed specifically in the field of employment, the second one is traditionally used for the assessment of causes of accident event in Seveso establishments. In the Infor.Mo. context, the word "accident" is used in accordance with the international standard BS OHSAS 18001 and means "an incident which has given rise to injury, ill health or fatality". Anyway, to avoid ambiguity in wording with Seveso Directive perspective, the term injury will be used.

3.1 Root Cause Analysis (RCA)

As reported in mentioned Italian Guide Lines, RCA is a structured survey which aims to identify the root causes and contributing factors to the occurrence of an accident or a near miss in order to prepare the necessary actions to eliminate them. The analysis is based on a cause-effect approach. The goal of RCA is to find out: what happened (finding), why it happened (root cause analysis) and what can be done to prevent the problem from happening again (brainstorming on possible remedial action). The RCA does not just identify the error closer to the event, but analyze the whole process that generated by searching the deep reasons behind the concatenation of circumstances for which the event occurred and on which it is possible to avoid that happen again.

The method includes: the determination of human, technological and infrastructure factors, the determination of process and related systems, the analysis of underlying systems of cause and effect, identifying risks and their determinants, the determination of the potential improvements in processes and systems. The application of method requires a few of rules: cause-effect relations must to be clear, use of negative attribute to explain the phenomena has to be avoided, every human error should be associated with its cause, every deviation from the procedures must be associated with its cause and only the actions formally provided must be considered. At the end of this process, the possible cheaper corrective actions can be defined to promote change by working on structural factors, procedural, organizational, motivational and behavioral.

3.2 Infor.Mo. model

The model Infor.Mo. examines in a systemic, standardized and interpretative way the injury dynamic, that is the sequence of events and circumstances leading to the accidents. It is a multi-factorial and multi-axial causal tree model operating through the logical-chronological scheme that connects accident, contact (energy transfer) and damage. Relying on information available about the event, chains and links of the circumstances are described, by going back in the sequence and providing an explanation or cause of the accident (Campo et al., 2006). The pivot of the model is detection and investigation of dangerousness of the energy produced or transferred when the incident occurs. There are two kinds of energy transfer. The first is the exchange of energy: it’s a fast and unintentional release or transfer of energy. The second is the exchange of interface between the environment and the worker: in this case, there is no change in the energy situation but there is a rapid and unintentional application of energy which is inappropriate. The model methodology goes ahead with identification of determinants and modulators: a determinant (accident risk factor) is any factor that contributes to causing an accident by increasing the probability of its happening. A modulator is any factor that, whilst irrelevant for the probability of whether the accident happens or not, can however impede, attenuate or even worsen the biological damage that follows. For each factor (determinant or modulator) various information are recorded: its safety problems, comparison with the standards, connections with risk assessment document and its classification in “state” or “process” factor; any element that was pre-existing when the accident occurred and which remains unchanged during the event is defined as a “state” factor; any element that represents something that happened during the accident is defined as a “process” factor”.
The recording has a graphical side: every state factor is represented by a square and every process factor by a triangle. At the end of data-entry, by reading from the bottom upwards, the graph shows the relationship between all the identified factors in the reconstruction of the event (Figure 1). Every factor has its own modalities and its connections to the others, on the basis of the logical-chronological links of the dynamics. In this way, the multi-factorial model makes it easier to research the causes of the accident (Campo et al. 2006).

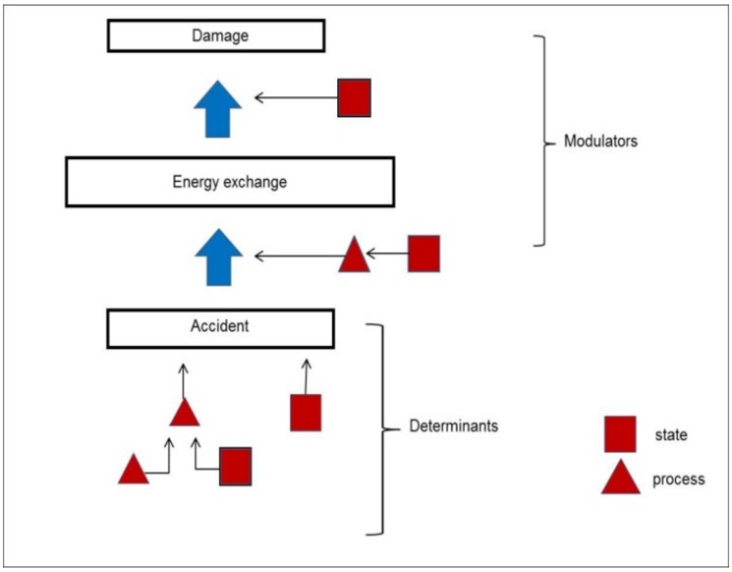

Figure 1: General injury dynamic according Infor.Mo. model (Campo et. al, 2006).

4. Case study

The case study is about an explosion occurred following the contact between the sodium hypochlorite and an oxidizing. It involved a fatal accident, material and environmental damage. The explosion resulted in the death of a worker. Accident is related to a chemical depot subjected to Seveso Legislation so it is recorded into MARS. Also the event has been analyzed through Infor.Mo. method. In this paragraph the dynamic of event has been reported according the two models.

4.1 Event's dynamic according to Seveso

The event occurred in the area reserved for the storage of combustible solids inventory where it was stored sodium hypochlorite crystalline powder. This substance was stored and manipulated according to the information in the Safety Data Sheet provided by the supplier; therefore, sodium hypochlorite was stored inside a polythene bag placed in metal drums iron from 50 kg each, sealed and placed on pallets of plastic.
Two warehouse workers were standing in the lane for the transit of the hangar, each on board his truck, positioned in front of the deposit of sodium hypochlorite. On the basis of evidences related to the accident, it was able to establish that, following a handling error, an operator inadvertently crushed reverse pedal carriage going to brute force drums hypochlorite with the rear of his truck and making some fall when he has subsequently moved forward with the same. The fall of the stems had determined the leakage of sodium hypochlorite with training and lifting a small cloud of dust with a glow inside. The two operators had dropped immediately from their carts to go to the fire-fighting, but there was a first explosion which then set off a devastating chain reaction. One of the operators was screened outside the warehouse, falling into the courtyard; the other was crushed by the collapse of the structures falls following the explosion. The explosion, in fact, determined by the involvement of all the material present in the combustion zone of the oxidizing depot, led to the partial collapse, almost immediately, and the same damage to the adjacent warehouse.
The event was reported to Local Command of Firefighters and the company had implemented the Internal Emergency Plan.

4.2 Event's dynamic in Infor.Mo. model

The case examination starts from the description of the workplace which the event occurred in storage of chemicals and the description of the task being performed by the victim (warehouse forklift driver). Next, the action undertaken by the worker at the time of the accident is examined. In that circumstance, when he was enlivening some pallets, the injured worker accidentally bumped a pallet holding drums of sodium chlorite powder. As a result of impact, one of the drums, falling to the ground, cracked and caused spill of the substance that burned and produced several explosions, shed collapse and the worker's death for his crushing. In this data-entry, it is an additional inquiry and was reported; in fact, it was deduced the fire grew up because of the presence of peracetic acid on the floor, produced in the nearby department and inadvertently conveyed by the forklift wheels. The chemical reaction between peracetic acid and sodium chlorite powder resulted in fire and explosions that involved the warehouse. The accident dynamic graph for that case according to the Infor.Mo. has been represented in Figure 2.

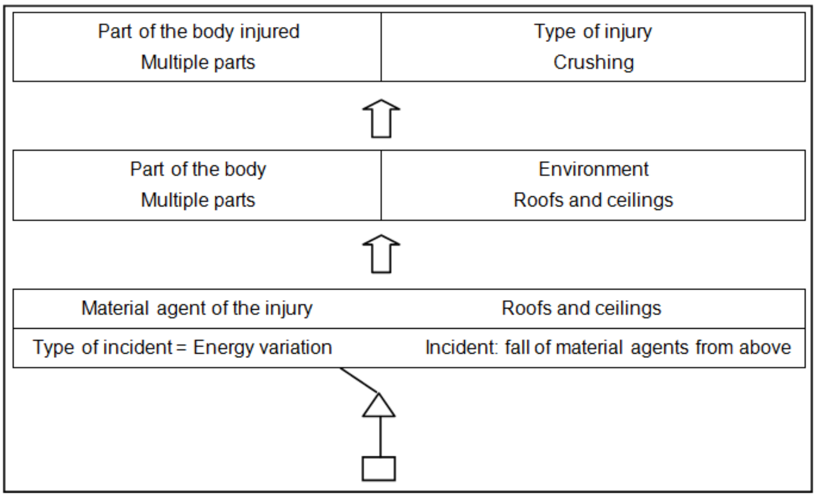

Figure 2: Injury dynamic concerning the analyzed case.

5. Results

5.1 Aspect related to major accident analysis

The application of the RCA has identified as the most likely cause of the accident trigger in the contact of two incompatible substances. The accidental collision of the truck with pallets meant that some drums of sodium

hypochlorite from falling to the ground, crystals were in contact with contamination of peracetic acid traces of which were present on wheels of the truck itself. In Table 1 principal errors and anomalies have been individuated and SMS's procedures that should to be improved have been investigated.
In the post-incidental analysis, based on the results obtained, it is possible to provide specific suggestions for changing procedures. In the case study the SMS needs changes primarily related to: updating staff training about the hazards of dangerous substances and the use of equipment; reorganizing the Company's personnel providing skilled one in the chemical industry; revising procedure for the risks assessment related to the use of hazardous substances and their storage.

Table 1: Results by RCA and SMS's procedures.

Mistakes and anomalies	SMS's Procedures
-The employee has inadvertently made a mistake operation causing the fall of drums of sodium hypochlorite on the ground -The staff enlivened substances not compatible with each other	Information, Education and Training
- Evaluation of dangerous substances stored in the warehouse is not complete - Substances not compatible with each other were stored in the same warehouse solids - Management procedures not adapted had been adopted	Risk Assessment
- The warehouse was not properly ventilated	Risk Assessment, Preventive actions
- Safety Data Sheets of some substances present in the establishment were outdated and sparse information about their possible reactions	Documentation and Reporting
- The use of PPE were not always appropriate during the handling of hazardous substance	Emergency Planning

5.2 Application of Infor.Mo. model
In Table 2, elements derived by the analysis carried out through the Infor.Mo. methodology have been showed.

Table 2: Results by the application of Infor.Mo. analysis.

Steps	Injuries' description	Detail of factors
Damage	worker's death for his crushing	
Contact (energy transfer)	between the material involved in the crash and the worker's body	
Type of accident	exchange of energy	
Accident	not directly due to the explosion, but it's a slip, fall or collapse of material agent from above (falling on the victim), caused by the explosion	
Factors of risk	two determinants identified (as described in detail column)	- activities of the injured worker: wrong forklift handling causing the collision - material: the presence of incompatible chemical substances

The research of the risk factors revealed that one of the causes leading to the incident was a wrong forklift handling performed by the worker: by hitting the drums, he caused first the explosions and then the warehouse collapse. Another risk factor identified is the improper storage of goods: drums of flammable material were in an area contiguous to another one where oxidizing material was and this increased the chance of the incident. By reading details concerning these two determinants, it's clear that risk assessment wasn't carried out in depth: the worker wasn't aware of the presence of oxidizing material on the forklift wheels he had to handle.
The comparison with the Regulation down by law (Legislative Decree 81/2008 art. 225 c. 4) showed that the employer didn't comply with provisions about technical and organizational preventative measures suited to operations performed in his firm, including storage, handling and segregation of incompatible chemical agents.

In particular, the employer would have had to prevent the presence of hazardous concentrations of flammable substances and hazardous quantities of chemically unstable substances. Among the preventative measures he would have had to take, there are the employees' training and information about all the chemical characteristics and the dangerousness of the materials handled and moved.
Moreover, in accordance with the law article mentioned above, the employer must take effective technical and organizational measures providing specific areas for storing various materials involved in the work process, thus avoiding the dangerous proximity of flammable and chemically unstable substances.

6. Conclusions

The accident's analysis by using OSH and MAH method has showed similar results. It is very interesting considering that it is analyzed the same case but with very different approach. In fact, the two methods are consistent, but not equivalent.
The method Infor.Mo. starting from the assessment of a fatal accident and from the recorded effects establishes what was the cause of the event on the base of an interpretative approach that is more simplified than the RCA analysis that is heavier.
Despite this aspect, it was found that the results confirm the consistency and robustness of Infor.Mo. also to manage complex events involving managerial, organizational and technical aspects.
This enhances its use in the field of major accident prevention by providing an effective investigative tool suitable for the integrated SMS.

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