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How Inspections Outcomes May Improve the Foresight of Operators and Regulators in Seveso Industries

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The Seveso III Directive 2012/18/EU was implemented by Italy in mid-2015 (D.lgs. 105/2015), and it has been applied since 2016. With the new legislation, the inspection system has been improved, in three years all Upper Tier Seveso establishments shall be inspected at least once. During the inspections, several technical documents are examined, including those containing detailed description about the accidents, incidents, near misses and anomalies recorded in previous decade at the establishment. To understand the potential of those documents, they have been organized into a repository. A method to extract knowledge from this collection has been developed to support foresights or intuitions about the safety of process industries. The paper describes the methodology and provides some cases of its application.

1. Introduction

A lot has been done in Europe, in recent decades to prevent chemical accidents. Through the Seveso Directives, implemented in national legislation, a very complex system has been defined, which includes authorization, inspections, verification and planning. The activities are in charge of Authorities, Regulators and Control Bodies. The establishments involved are relatively few, but very important for the strategic role they have, as well as for potential dangers. In this context, foresight is a very important quality. Competent Authorities should understand in advance the weaknesses of the System and the emerging risks arising from technological, economic, social, and organizational developments.

For this purpose, an instrument, envisaged by the Directive, is the database of major accidents. The information that comes from the database is very useful for companies and regulators. The accidents recorded in the EU database are very severe and, fortunately, quite rare. These is certainly very useful to react effectively to old and new problems, but it is more difficult to use this information to foresee and anticipate emerging risks. The question is, therefore, how to grasp the weak signals of emerging risks and act before they are manifest through severe accidents. In order to answer this question, it is important to stress that the Competent Authorities must have and act a plan of inspection at Seveso establishments on a regular basis. According to the Italian implementation of the Seveso Directive, the Upper Tier UT establishments must be inspected every three years, at least. The inspection team includes experts form environmental agencies, the national fire corps and INAIL the workers' compensation authorities.

Different types of documents results from inspections; the Italian Legislation requires the establishment operator to provide the inspection team with detailed information about the accidents, incidents, near misses and anomalies recorded in previous decade at the establishment. The operator is furthermore required to provide, for each top event recognized in the Safety Report, a brief summary about the related preventive and protective barriers.

The paper discusses the potential of these documents. Section 2 discusses aims and objectives, Section 3 describes the documents used in the research. Section 4 discusses in the detail the proposed method to handle the available documents. Section 5 presents a number of cases, where the proposed method has been experimented to verify a few supposed emerging safety issues in the Italian chemical industries.

2. Aims and objectives

The aim of the paper is to find out how to use the documentation resulting from Seveso Inspections, to exploit it for several purposes that includes improving the inspection activity, addressing the training activity, identifying criticalities and opportunities in relation to technological innovation. The most ambitious goal, perhaps daring, is to use information hidden inside documents to increase foresight, which is an essential capability for Authorities and Regulators, who have to make decisions over a longer period, promoting foresight in the prevention of chemical accidents. The objectives of the research is to understand the potential of the inspections' documents, to organize a repository, to develop a method to extract knowledge from this repository, so that to support foresights or intuitions about the safety of chemical industries.

3. Documents resulting from Seveso Inspections

Seveso inspectors collect many types of documents; two of them are essential for inspectors' activities:

- Operative Experience (OE) Sheets. For each event occurred in the recent past, the operator provides the commission with a form containing a short description of the event, the failed, missing or misapplied technical or procedural barriers, those that stopped the escalation and recovering actions, including the adoption of new technical systems and the implementation of procedures;
- Technical Systems (TS) Sheets. For each top event recognized in the Safety Report, the operator provides the commission with a form within an outline of the preventive and protective barriers, both technical and organizational, adopted to prevent the event and mitigate the consequences.

A further useful document is the Inspection Final Report, drawn up by the inspectors' team, according to a specific checklist filled by operator. The Report contains details about the site, the company organization, the stored dangerous materials, the production activities, the emergency procedure, and the visits of the inspection team at the establishment. Those details are essential to understand the TS and OE sheets.
Starting from the 2016 campaign, for each inspection, Inail systematically gathers those documents, organizing them into a repository. The OE collected are the core of the search activities described in the following sessions.

4. Methods

Remarkable researches have been developed on near miss NM management, including classifications and models for analysis. Gnoni et al. (2013) provide a method to classify NM's by computing their distance from the incident or top event. This method is suitable for measuring the effectiveness of a near miss management system, as shown by Andriulo et al. (2014). A more general approach is proposed by Gnoni et Saleh (2017), where NM are classified and interpreted in light of general principles, underlying the safety systems. Zhou et al. (2017) propose a method for NM analysis based on complex networks.
The proposed methodology starts with the collection of common opinions provided by the inspectors themselves or by panel sessions of experts. The aim is to look for such judgements in the OE repository using a semantic search engine. The Figure 1 shows flow-chart of the method used for analysing those beliefs and checking if they have a match in the collected OE's. The procedure illustrated in Figure 1 is a general framework but the main activities and the types of conditions are fully described.
The first activity is to extract those concepts that best represent the belief. Advanced and semantic search is the applied method including the automatic control of synonyms, compounds, redundancies, and context dependency. The tool adopted is IBM OmniFind Yahoo©, which has many search capabilities including generating automatic summaries, based on input keywords, and computing semantic similarity. As described by Ansaldi et al. (2016), the proximity of the documents, with respect to the query used for the search, adopts a "min-hash"-based algorithm, defined as follows:

$$\mathrm{P_{D-Q}} = \left(\frac{\mathrm{K^D} \cap \mathrm{K^Q}}{\mathrm{K^D} \cup \mathrm{K^Q}}\right) \quad (1)$$

Where $\mathrm{P_{D-Q}}$ is the proximity of a document D with respect to the query Q; K^D and K^Q are the key sentences singled out, respectively, in the document D and in the query Q by the search engine. Based on the proximity, the distance $\mathrm{MHdist_{D-Q}}$ is defined as complementary:

$$\mathrm{MHdist_{D-Q}} = 1 - \mathrm{P_{D-Q}} \quad (2)$$

$Dist_1$ and $Dist_2$ in Figure 1 are the measures, in the space of the sentences, defining, respectively, the area of relevance and the zone in which it is not possible to make a decision, so-called gray area. The area of relevance contains those documents that are appropriate to the search. A set of outcomes is qualified to be a cluster of a certain zone if the number of documents is meaningful.

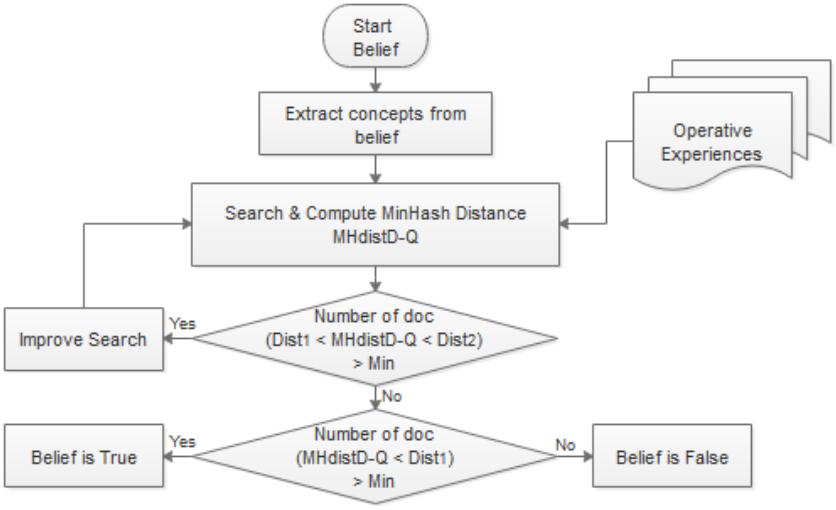

Figure 1: Flow-chart describing the methodology adopted.

Thus, the first control of the procedure, illustrated in Figure 1, corresponds to check if the number of documents founded in the grey area is greater than a parameter Min. If this is the case, it means there is a relevant number of documents containing some of the search concepts but all of them are quite "distant" from the target. Therefore, the search clause needs some revisions, including adding new concepts or simply new synonyms. This improvement process of the search activity may loop several time, until the number of outcomes in the gray zone is irrelevant, that is less than Min. In the application of the test cases, the parameter Min has value equal to 3, this means that one or two documents (on a domain of about 900 documents) are not sufficient to judge the clause validity, if it is a true or false belief inside the Seveso establishments.
The second test of the procedure of Figure 1 means to count the documents in the relevance zone and check if the number is greater than the limit assumed (Min). A positive answer means the clause searched is valid (belief is true), because already occurred in industrial sites. On the contrary, i.e. negative answer, it can be deduced that the searched expression does not concern the domain of documents collected. The "false" value is a result relative to the current repository, thus it could change with subsequent inspections.

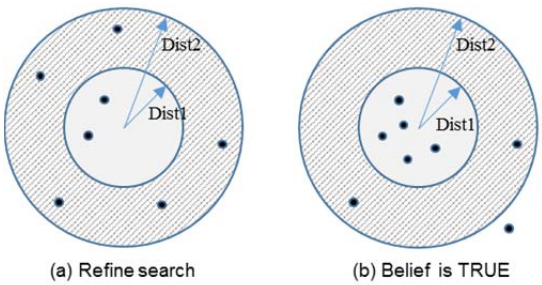

Figure 2: A graphical schema of the conditions for search refinement (a) or confirm belief validity.

The Figure 2 graphically simplifies the meaning of the results of the two tests described above. In both pictures, the white circle is the set of documents that are in close proximity with the belief searched, while the larger one corresponds to the grey zone. Thus, the case shown in Figure 2 (a) represents uncertain conditions and requires further efforts in finding concepts more appropriate for search operations. The second situation, shown in Figure 2(b), means the belief under examination has relevant occurrences in OE's, i.e. it is true.

5. Results

The test of the proposed methodology involved few of Seveso inspectors and used the technical documentation gathered in the 2016 campaign related to one third of UT Italian Seveso establishments. There

are currently about 1100 files; the collection of OE, which treats of the ten years earlier, takes about 900 documents. This section summarizes the outcomes of some common beliefs.

5.1.1 Common beliefs

The research started by interviewing few of Seveso inspectors, asking their more common beliefs. The topics faced cover a wide scope of subjects, including technological updating, environmental and social changes, and security needs. Further to the new and emerging subjects, it is also important to check what regards to the mature and usual situations, both from the point of view of equipment maintenance and usual working activities management to assess the recurrences of already known issues and to understand what is being done or to suggest improvements. The following sections show some of the beliefs identified, describing, for each, the semantic search made and the results obtained. The Tables 1-4 include the proximity value, the document identification and the dynamic summaries; the different colors highlight to keywords of distinct sets of concepts.

5.1.2 Level gauging system is a well-known setup

Search: Ansaldi et al. (2016) discuss the near misses involving level devices, due to their failure, lack or wrong operation. Thus, there is the awareness that level gauging systems installation is needful, thus their operation and correct maintenance play an important role in equipment safety.

Result: Only three documents state the lack of such a type of device, but all refer to a far period of time (2011-2013). In the same way, only two near misses refer to incorrect operation and maintenance, but both dated before 2011. Thus, this belief is true, i.e. these devices seems to be well setup and maintained.

5.1.3 Severe weather phenomena stress safety systems

Search: One of the common beliefs is that, due to climate changes, severe weather phenomena cause stress to safety systems. The search looks for the exceptional weather events, including sudden violent rainstorms (cloudburst), increase of number of lightning in a storm, freezing rains, heavy snowfalls, and ice.

According to the Seveso III decree, in the safety report the operator must already gather the historical information related to the meteorological, geophysical and hydrogeological events of the site. This search instead deals with extreme events that go beyond the historical series. For example, the amount of rain fallen in a short time is equal to that recorded in a long period.

Result: Following the proposed procedure, all results in the Table 1 show only one type of severe weather events. That is the exceptionality of heavy rains caused overfilling of tanks used for collecting meteoric waters.

Table 1: Result related to severe weather phenomena.

Prox	ID	Result
94.39	B2.1	… heavy rainfall has filled the tank for collecting water potentially polluting from hydrocarbons coming from the basins of ... Following an electric blackout the pumping system for emptying the tank has been blocked with consequent overflow of the polluted waters from oils on the surrounding square. Due to the exceptionality of the rainfall it has not been possible to avoid dragging of water contaminated with oil in ... The emergency procedure did not provide equipment for a further reduction of damage due to exceptional temporary diaphragm events…
93.46	B2.2	…during the preceding and temporal phase characterized by copious rains. ... which had been activated in substitution and maintenance one and a lack of control by the shift workers who took turns in the previous 36 hours. Lack of a high level reporting system. Poor general attention and in particular due to the rains Failure to compare any levels detected in the field…
91.42	B2.3	... meteoric tank used for the storage of waste water with consequent leakage on the pavement of the basin. As a result of the heavy rains, the water collected in the basin flowed to the waste water tanks …

5.1.4 Foreign workers jeopardize knowledge and communication base

Search: This belief deals with the presence of foreign workers that can arise problems in communication and misunderstanding during daily operations.

Result: During audit, the inspectors usually ask the number of foreign workers inside the establishment and the activities done for their integration, including the language adopted and the training actions. Indeed, some final reports positively outlines that there are not communication problems with foreign workers. Thus, the outcome of this search clause in the operative experience documents is empty.

5.1.5 Criminal acts treats both safety and security

Search: One belief is that criminal acts are increasing and deal with both safety and security systems. It is a widespread problem for oil pipelines, but they are out of scope of Seveso Directive. The search query looks for criminal acts, including intrusion, robbery, and sabotage.

Result: The results in Table 2 show three cases of attempt of robbery and malicious damage but without severe consequences. Two of them (B4.2 and B4.3) occurred during the weekend or out of daily working time, one B4.1 was discovered during an inspection activity. The low number of such events may be because all the major accident hazard establishments are fenced and equipped with guardian, thus malicious acts are more difficult.

Table 2: Result related to criminal acts search.

Prox	ID	Result
91.88	B4.1	Intrusion during an inspection a technician saw two intruders walking near the formaldehyde plant. When the intruders were discovered, they escaped outside the fence. No theft was committed but part of the perimeter wall was demolished…
91.62	B4.2	… Attempt of theft diesel breakage of the north side secondary entrance gate Improve surveillance during the week end by guardian …Approve project cameras and anti-intrusion system ...
90.69	B4.3	…Theft attempt with LPG release … Out of normal working hours an unauthorized person entered the warehouse to steal the LPG ..…

5.1.6 Effects of work related stress

Search: Often accidents are related to the workload that in some cases may be excessive compared to the number of personnel available.
Result: All OE's deal with workers behavior, including psychophysical stress (B5.1), excessive confidence and poor attention (B5.2), especially at the end of the shift (B5.3).

Table 3: Result related to effects of work related stress.

Prox	ID	Result
84.13	B5.1	... occurred during loading the tankers at 8.30... At the end of a loading operation before having proceeded to the disconnection of the loading arm ... release of LPG... excessive confidence among people and non-observance of the roles and responsibilities…and by conditions of psycho-physical tension due to particular intensity of rhythms of work in the peak season…
79.17	B5.2	… During normal working hours during loading ... the driver unrolled about a meter of the hose to try ... The pistol detached itself from the hose and fell to the ground. ... The confidence between factory staff and drivers has probably led to a lack of control over the work …
79.01	B5.3	…It was almost 19 o'clock on Friday evening at the end of the week and of the normal working hours and the attendant had just started the transfer operation, having connected to the tanker loads of about 20 tons of propane only the loading arm of the liquid phase when suddenly a large continuous release occurred. …

5.1.7 Increasing the effects of the corrosion in special condition

Search: Corrosion, erosion and creep are the most frequent mechanisms of damage that cause accidents or near misses (Bragatto 2013, 2015). The Seveso III decree requires the owner to monitor the risks associated with these phenomena through a monitoring plan.

Table 4: Result related to corrosion's effects search.

Prox	ID	Result
82.33	B6.1	... at the base of the tank due to the lack or damage of the seal of the trench on the base of the tank that has caused infiltration and stagnation of rainwater with consequent corrosion initiation. The spill has remained circumscribed in the reservoir containment basin which is separated from the ground by asphalt mantle and bounded by perimeter walls in reinforced concrete critical technical systems crusher tank cracking for corrosion …
80.47	B6.2	… acetoncianhydrin loss from tank... the first washes were started with water to make the tank safe. ... Solution: The tank has been placed on a layer of bitumen to reduce rainwater infiltration, which could cause corrosion and reduce the mechanical stress of the bottom…
78.56	B6.3	About 1 m3 of fuel oil leaking from the recirculation pipe ... pipe for corrosion from the outside determined by water stagnation that caused the leakage involving the channel for the supply of cooling water in the section of intersection with the pipe Critical technical systems pipeline…
78.29	B6.4	From a more accurate check, the operator has signaled a hole on the roof plate and a very marked corrosion at about 10 cm from the hole itself. ... they did not allow to foresee the hole caused by external corrosion like pitting due to stagnation of water on the roof…

However, the documents collected by the inspectors during the 2016 audits reveal the lack of monitoring plans set up to control the risks associated with aging and degradation of the equipment, mostly due to corrosion. Thus, the focus is onto special conditions that may increase or accelerate corrosion phenomenon, for example the acidity of water or rain.
Result: The Table 4 shows four results describing losses of containments of tanks or pipeline due to corrosion. B.6.1, B.6.3, and B.6.4 refer to corrosion related to the stagnation of rainwater. B.6.2 describes a tank with corrosion on the bottom and the solution adopted for isolating it by the ground avoiding possible infiltration of water.

5.1.8 Outcomes from common beliefs

The Table 5 summarizes the results (relative to 2016 inspections' campaign) obtained by applying the proposed methodology to some common beliefs. The second column contains the number of relevant documents found in the search. The first clause conveys a positive concept, while the others state some problems. To sum up, severe weather events, work organization, and increase of corrosion under special conditions are concepts to be monitored in next inspection campaigns. Right now, the presence of foreign workers seems not to be a criticality.

Table 5: Result applying the methodology to common beliefs.

Common beliefs	Relevance zone	Result
Level gauging system is a well-known setup	none	True
Severe weather phenomena stress safety systems	3	True
Foreign workers jeopardize knowledge and communication base	none	False
Effects of work related stress	3	True
Increasing the effects of the corrosion in special condition	4	True

6. Conclusions

The test results show the potential of the proposed methodology to promote the foresight in the prevention of chemical accidents. The research is at initial phase and experiment described in the paper outlines some limits. Firstly, documents do not include Lower Tier Seveso establishments that have a different inspection procedure. OE repository refers to 2016 campaign, but OE's of previous campaigns, even though Seveso Legislation was a bit different, could be useful to understand the changes in the years. The beliefs proposed were collected through informal interviews; the follow up is to structure a method to get the beliefs from experts' group.

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