Technological Emergency Planning Through An Ontology Oriented Approach.

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Abstract

Having access to the right information before and during an industrial emergency could save organizations and keep them safe and sustainable. Accident databases among other are used to provide such accesses. But, usual accident databases are lacking to provide enough emergency knowledge. This paper tries to improve the current process accident databases information retrieval through developing a process accident knowledge base (PAKB). Technological accident concepts and subconcepts were identified. Then, the relevant taxonomy for each concept was developed and the relationships among all concepts were formalized. This collection was transferred into the protégé software for more formal interpretation and representations. The established PAKB could improve information retrieval processes, reduce query time and fault results. Despite customary databases, it can disclose the hidden relations among different stored data. The accident knowledge base imagines knowledge epresentation and concept relationships that could help to understand the hidden relations among the needed data. Such features are vital in the emergency management.

Keywords: Databases, knowledge base, Emergency management, Process Accident, Emergency Plan

I. Technological emergencies and Business Continuity

Chemical process industries face many potential risks inherited in their entities. Such risks can lead to emergency situations that interrupt organization continuity, endanger their lives or even surrounding communities. Many organizations use emergency management systems to control threatening events in dangerous contexts.

To keep business safe and uninterrupted, many organizations plan to prevent and control technological emergencies as a known business interrupting cause. Emergency plans employ various approaches and strategies to manage the threats. Regardless the selected approach, planning for managing technological emergency needs a thorough approach to the risks data collection, analysis, communication and distribution (Pasman, 2009). So, it is necessary to have enough domain knowledge to manage the technological emergencies. Any domain knowledge is manageable through knowledge management (KM) process (Ly, Rinderle, & Dadam, 2008). Knowledge management refers to a systemic and specific frame to capture, organize, communicate and disseminate domain knowledge (Kim, Zheng, & Gupta, 2011).

Thus, the KM can form a sound basis for emergency management planning and its subsequent implementation. It could be declared that these days, organizations are becoming aware the KM could help them survive in the threatening contexts (Simone, Ackerman, & Wulf, 2012). KM provides mechanisms allowing the right knowledge to be at the right place, right people and the right time (Oztemel & Arslankaya, 2012). Then, having emergency domain knowledge could ease the emergency control and business continuity.

Process accident databases are the most known information resources for the technological accidents (Tauseef, Abbasi, & Abbasi, 2011). They are common tools to record the emergency information and are designed to collect and represent data, manage the experiences, serve the KM process and retrieve the required information for emergencies prevention and control purposes. But, these resources do not provide comprehensive domain knowledge for process accidents. The variables in an accident database are vectors whose parts comprise script data or strings of bits (Palamara, Piglione, & Piccinini, 2011).

Normally, an accident database represents an expandable keywords list and then finds the most related stored cases. Emergency situation information are not related linearly. Any data might be correlated with many other data. For example, the cause consequence relation, chemical and equipment involved in the emergencies, time of occurrence, human factor role and so on are interrelated together.

Dealing with these seemingly discrete, but actually interrelated data in a linear data presentation medium of common databases is a difficult task. In the current data mining procedure many mismatches are expectable (Batzias & Siontorou, 2012). Also, data mining in the common databases represents data and not the required knowledge. Considering the potential consequences of emergency situations, multiple needed data type and intertwined relations among the emergency concepts, the traditional ways of information management do not seem so suitable to provide the required knowledge at the new times. It implies that they are lacking for application in the emergency planning purposes (Batres, Muramatsu, Shimada, Fuchino, & Chung, 2009).

In the emergency planning phase, planners need to have access to the emergency domain knowledge of concerned risks as well as existing data. So, designers need to know the relations among data and information as well as the recorded data of previously occurred emergencies. Ordinary databases present discrete data for technological accidents and do not provide the required knowledge. For example, one may need to know about the credible consequences of a special threat, its probable causes, reliable preventive measures, response and recovery plans and the needed resources control and so on.

Obviously, such knowledge collections are not presented together in a routine database. Also, because of the lack of comprehensive knowledge resources for technological emergencies and a huge volume of unrelated information that could harden finding the right information; the current data mining approach is incapable to meet the emergency planning knowledge needs.

Considering the needs to have comprehensive knowledge resources, complex interrelations among the emergencies information and knowledge related limitations of databases, an improved emergency knowledge resource can help plan for a reliable emergency management system.
To achieve this goal, an ontological approach was used to develop a process accident knowledge base (PAKB). This KB would be useful in the emergency planning process. The following sections explain the steps to build the PAKB.

II. Developing Process Accident Knowledge Base

2.1. The ontology approach to create the PAKB

Ontology is a formal and explicit specification of a shared conceptualization (Natarajan, Ghosh, & Srinivasan, 2012). In the other word, ontology defines knowledge as a set of concepts or classes of things within a domain and relations among those concepts. An ontology based process accident knowledge base can provide a common knowledge on the emergency domain knowledge for interested parties and share a common understanding among domain experts (Elhdad, Chilamkurti, & Torabi, 2013).

2.2. Ontology life cycle for the PAKB

Ontology lifecycle is a process that aims at producing ontology. To build the proposed PAKB the "Ontology Lifecycle" concept was followed (figure 1) (Poli, Healy, & Kameas, 2010). To build the PAKB, three phases were followed:

a) Phase 1: Process accident specification (compromises determination of the goals, scope and other general requirements for the PAKB).
b) Phase 2: The PAKB conceptualization (this phase contains the required knowledge getting process, its formalization and transferring into a computer program (protégé software) and
c) Phase 3: The PAKB exploitation (the final phase including the knowledge representation or reuses for further applications).

2.2.1. Pahse1: the process accident knowledge base specification and acquisition

If the lessons learned and gathered knowledge from the occurred emergencies and accidents disseminate effectively, it would be expected that accidents decrease or emergency scene being under control more effectively (Kidam & Hurme, 2012). Then, the PAKB aimed at creating a knowledge base for technological accidents to provide a reliable information repository applicable for preventing, controlling and responding to any industrial emergencies. The PAKB can promote adding, analyzing and spreading the relevant domain knowledge for emergency planners.

Essentially, any domain knowledge has three basic elements: concepts or classes, instances or individuals and properties or relations. The concept is a set of things that have at least one common feature (for example, exchanger explosion, dense gas dispersion and so on.). Table 1 shows the main concepts and their associated definitions. Property is a binary relation that correlates two concepts together. Indeed, a property defines a mutual relation between two concepts, subconcepts or individuals (Morbach, Wiesner, & Marquardt, 2009).

For example, the property "produces" connects two subconcepts "vapor cloud explosion" (as a subclass of "explosion" concept) and "overpressure" (as a subclass of "Process Accident Consequence" concept) to each other. Usually, property is a verb and the concept and subconcept is a noun.

Finally, the individual represents objects, real cases or things in the domain in that we are interested (Horridge, 2011). Usually, the individual is a real member of an asserted class (for example, fire at site ABC, company's ABC storage tank failure cause, etc.). The main and subconcepts and relations among them were identified through experts' opinions, reference checking and literature review.

2.2.2. Phase 2: the process accident knowledge base conceptualization and formalization

To build a supposed ontology one needs to setup taxonomies of its concepts (van Ruijven, 2012). Thus, the corresponding taxonomies for all main identified process accident concepts were built. A constructed taxonomy is a network of the "is a" relations among upper to the bottom layers of a special concept.

For example, figure 2 represents a taxonomy expansion for the "Process Accident" concept. For all other identified concepts such taxonomy was developed. Also, the real cases of occurred accidents were entered the package as "individuals" as well as concepts and subconcepts. In the present study, the CSB's (Chemical Safety Board) (CSB) investigation reports were used as the individuals. The same rules were followed for connecting the "individuals" and other concepts, for example, the case "explosion at ABC" *has surface cause* "PSV fail" and so on.

Next, the relationships among the eight main concepts were established. Then, the credible and detectable relations among all subconcepts were defined. Figure 3 represents an overview of the basic relations among the main concepts. After preparation of these collections, the relations among them were formalized.

The protégé software was employed in the knowledge formalization phase. Protégé software is probably the most commonly used tools to build ontologies. This software supports several languages and logic. The OWL (Ontology Web Language) is the latest language that is developed by the W3C (World Web Consortium) (Glimm, Horrocks, Motik, Shearer, & Stoilos, 2012), therefore, the OWL was accepted as the ontology language.

2.2.3. Phase 3: the process accident knowledge exploitation

2.2.3.1. *Knowledge* reuse

After preparation of the main frame and transferring knowledge into the protégé, it got ready to further knowledge exploitation including emergency management planning. In this phase the previously gathered knowledge would be represented as requested. Obviously, the usefulness of the collected accident knowledge depends on the comprehensiveness of the ontology life cycle construction phases. Process accident knowledge representation might be used for both real "instances" and "needed knowledge".

2.2.3.2. Searching through the PAKB

In comparison with routine databases, searching in the PAKB is more intelligent and conscious. The reasoners elaborated in the ontology based KBs (including protégé) enables understanding relationships among seemingly discrete, but interrelated concepts. Searching through the PAKB enables users to find the needed knowledge as the required past information. Despite the traditional databases, KBs could represent knowledge besides past data. For example, we can ask for:

- has cause some Probable gasket failure causes
- has consequence some dens gas dispersion consequences
- need response plan some response tactics for a pool fire
- need training some training for a hazardous material release control team
- And so on.

Also, the reasoners embedded in the PAKB can correlate concepts and individuals together intelligently. This feature reduces representing redundant results following any search. Such a semantic feature is lacking within the custom databases, so such a shortage might produce many unwanted search results.

Essentially searching through common databases would represent all of its contents having typed keywords even though unrelated ones. For example, searching the common database to find accidents about "crude oil that leaks from distillation columns," represents results of which only 40% is answers to the query (Batres, et al., 2009). But, in the knowledge bases including PAKB, composite query offers more special and exact query than routine databases, for example:

- "Heat exchanger rupture" and "has cause some corrosion" and "has financial losses some moderate losses"
- "Heat exchanger consequences" and "more than 3 killed" and so on.

Obviously such an approach cuts out many unrelated results and could increase information retrieval power. In these cases, a reasoner explores the previously stored information contents, imagines the relationships, extracts the proper responses by fitting interrelated correlations and would present the exact defined relation as requested.

Obviously, searching promoted by KBs are more convenient and user-friendly and could refine and remove redundant finding through the searching process.

2.2.3.3. Case study

As an example; suppose a user wants to plan for a chlorine release. The relevant query was carried out in the PAKB. The presented results depict a two-dimensional picture: first, the general knowledge that could be about such an event in general (knowledge reuse) and the second feature is the previously recorded cases for the chlorine release event (database feature). Both cases are searchable through the PAKB content. Figure 4 presents some selected and defined concepts, properties and an individual for "chlorine release" concept.

III. The Outstanding PAKB Features for Emergency Planning

The KBs are computer systems using a formal mechanism to represent or simulate specific aspects of human knowledge, and apply these representations in actual problem situations (Hendriks, 1999).Ontologies can be employed to mark-up the textual descriptions of accidents and emergencies, so they could enhance the efficiency in the information retrieval process of technological accidents (Batzias & Siontorou, 2012).

As it was noted above, searching for a concept like "chlorine release" in the customary databases would represent the previously recorded cases in chlorine release, but searching in the PAKB would represent the required knowledge as well as recorded cases. Among other information, the required preventive and mitigation actions, probable causes, credible consequences, needed resources or even the training needs to control such emergencies are obtainable through the PAKB. This feature is beyond the current accident database characteristics and expectations.

In contrast to the common databases, newly emerged knowledge bases could summarize and refine the searched queries. Current databases are keyword processing engines that find questions according to searched keywords. Searching through custom databases may lead to many unnecessary and redundant results for any interested keyword, which may not have any factual association with other keywords. But in KBs there is semantic search ability for understanding keyword relations which make the search results more conscious.

Technological emergency usually faces conditions that need to precede customary databases common features. These situations have their user's requirements and expectations. To meet such expectations, any knowledge resource for emergency planning should have certain features. Adrian L. and Sepeda (Sepeda, 2006) have listed the required contributions as: Accessibility, User-friendly, Accuracy, Sufficient volume, Standardization, Query system/search engine, Data security and confidentiality.

Employing such KBs could help the emergency planners to develop their plans. Time stress, knowledge representation limitations, inability to provide the required knowledge, needs for more interrelated information, etc., enforce the emergency managers to welcome more improved knowledge repositories.

As well as the discussed characteristics, the following notes are notable:

i. ***Process Accident Knowledge Representation*:** the PAKB would represent the domain knowledge and explains the relations among domain knowledge concepts as well as the data presentation feature of usual databases. This feature is provided through semantic search capability embedded in the ontological approach (Garrido & Requena, 2012).

ii. ***Process Accident Knowledge dissemination*:** ontology can create a common knowledge about the intended domain for users and can provide a common understanding among domain experts. The PAKB enables users to get and add gathered knowledge off-line and online.

iii. ***Process Accident Knowledge Visualization*:** depicted relations among concepts and instances are illustrated by PAKB and an understanding of the interactions is possible.

In summary in comparison with traditional DBs the proposed PAKB has the following features:

- Represent the needed emergency knowledge as well as the recorded data
- Provide the inference possibility for further queries
- Could relate the emergency and threat data and concepts together
- Could be built on more rapidly
- Collect and represent the formal available knowledge for emergency planning
- Could refine the search process

Using the PAKB enables users to understand the emergency knowledge behind the stored data. It is possible to upgrade the required knowledge by representing and improving (Batzias & Siontorou, 2012). Finally, using the knowledge management approach could be suggested for other fields of the safety and health domain.

IV. Conclusion

This paper proposed the knowledge management process for setting up a process accident knowledge base by ontology approach. To keep businesses safe and uninterrupted before and during an emergency, it is necessary to keep them aware about the threats. To meet these goals, we need domain knowledge that is provided thorough knowledge bases. Process accident knowledge extraction could be improved by using ontology based KBs. It could resolve some limitations of custom databases and provide a good foundation for knowledge dissemination. Employing KBs also would improve domain knowledge access alongside previously collected data. This paper suggested applying the knowledge management process for a technological emergency domain thro

Table 1 - the main concepts related to the process accidents and their definitions

Concept	Definition
Process Accident Cause	Probable causes for any occurred process accident
Process Accident Consequence	Credible outcomes for any occurred process accident
Process Accident Example	Includes the real case of process accidents with their features
Equipment Involved Characteristic	The characteristics of equipment which the accident occurred inside or about it
Chemical Characteristic	Physical /chemical/ toxicological or other characteristics of chemicals involved in occurred accident
Mode of Operation	Status of the activity of the plant while accident has occurred
Process Characteristic	Process parameters or operational properties while accident occurs
Process Accident	Type of process accident

Figure 1- process accident ontology life cycle

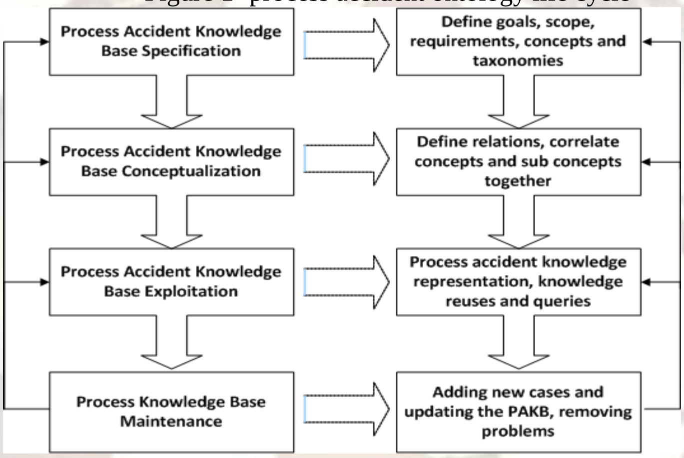


Figure 2. Some section of the basic taxonomy of process accident

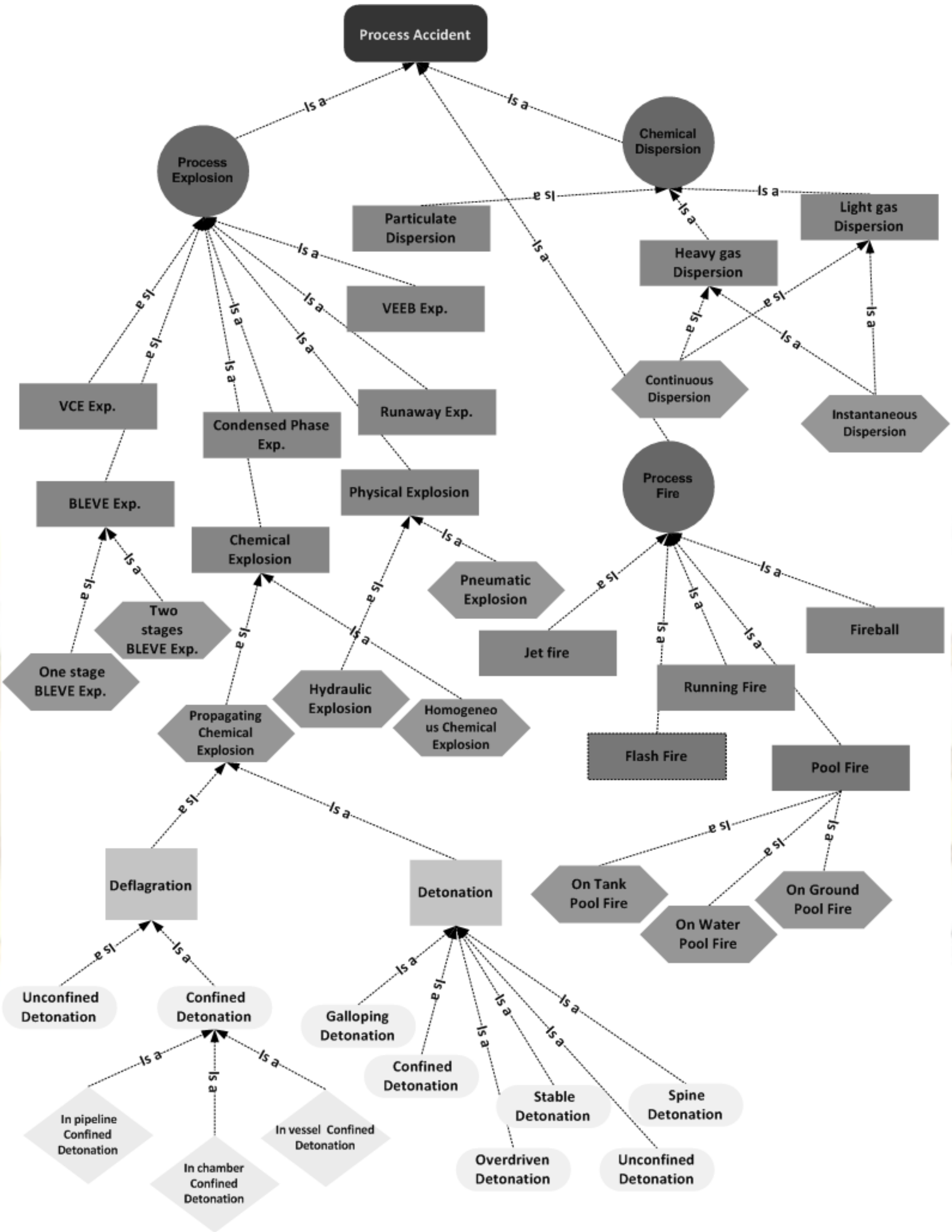


Figure 3- An overview of the basic relations among the main concepts of process accident

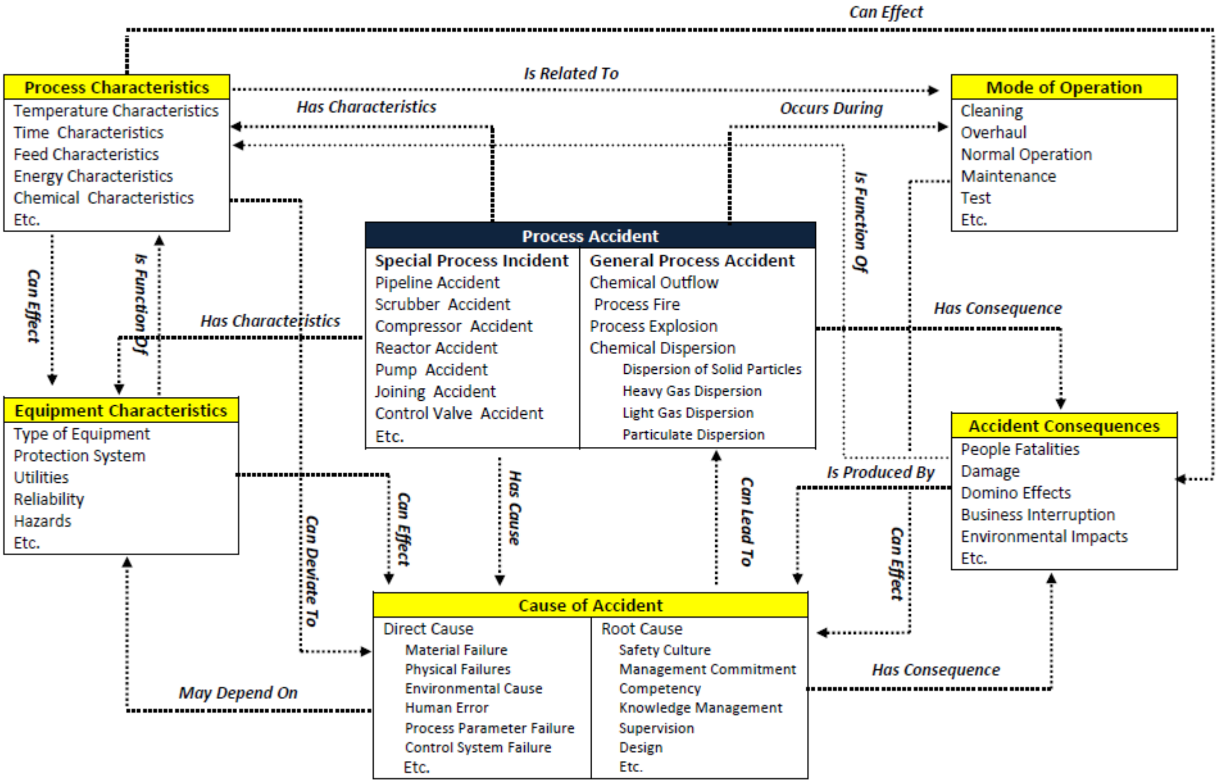
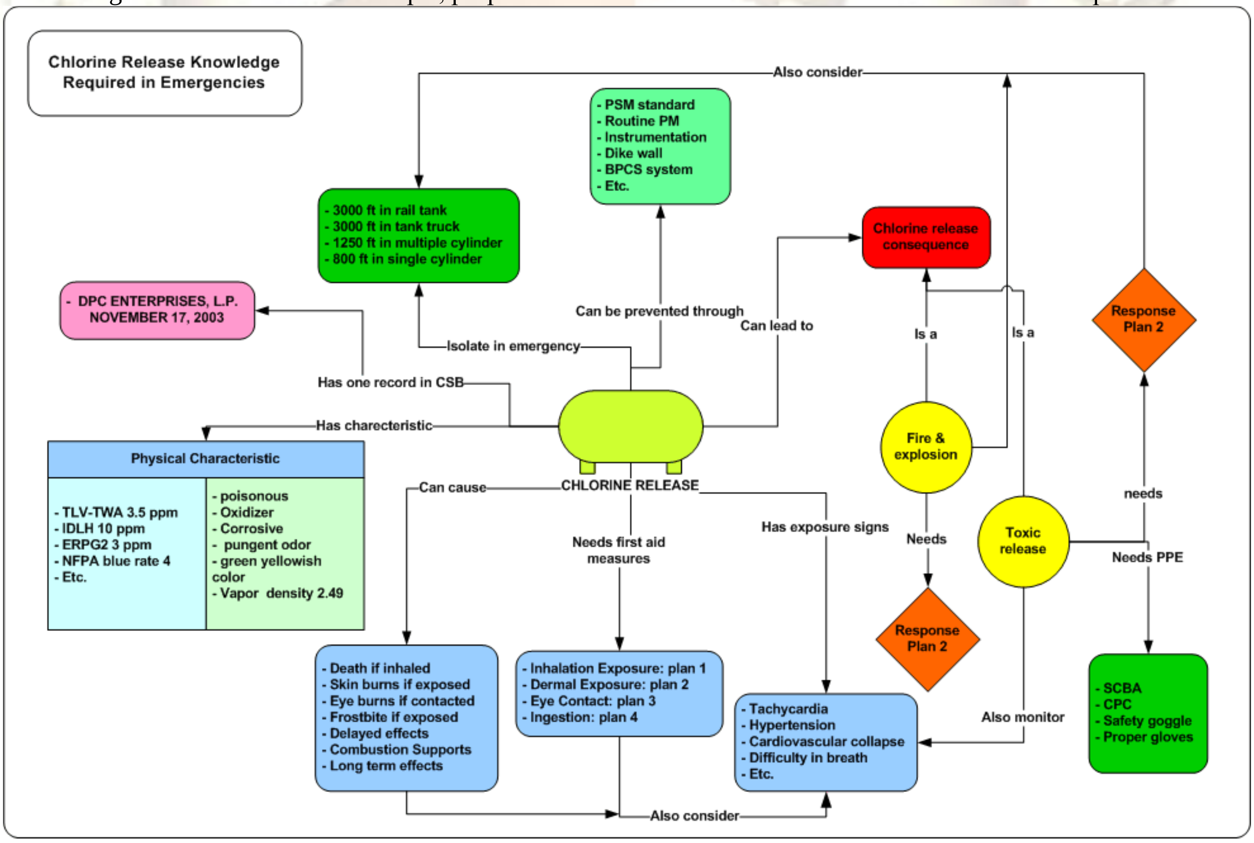


Figure 4. some selected concepts, properties and an individual for the "chlorine release" concept



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