COMMON LESSONS LEARNED FROM AN ANALYSIS OF MULTIPLE CASE HISTORIES

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In recent years there has been increased emphasis on process safety as a result of major chemical incidents involving gas releases, major explosions, and environmental incidents. To prevent the recurrence of incidents, the application of most advanced technologies is strongly urged for optimization of designs, operations, managements, controls, and emergency response. On the other hand, spending some time to fix our eyes on the historical catastrophes of industrial processes is extremely necessary for process safety improvement.

While each case history presents an important foundation for understanding, identifying, and eliminating root causes, in order to prevent recurrence of these incidents there is a need to identify the common lessons learned. Root causes are usually deficiencies in safety management systems, but can be any factor that would have prevented the incident if that factor had not occurred. In this paper, multiple case histories were analyzed to understand the common similarities between process incidents. The objective of this paper is to focus on learning some common lessons from the historical incidents in order to prevent recurrences of similar incidents.

INTRODUCTION

Recent advances in science and technology have revolutionized the chemical production in process industry. Consequently, it has also generated a rapid growth of technological risks, which has been associated with chemical incidents in the past decade. Chemical incidents may result in fire, explosions, and releases of hazardous materials. These incidents could possibly occur during production, handling, storage, and transportation of chemical and petrochemical products.

Reports of hazardous materials spills and releases have become increasingly commonplace in recent years. In Mexico City (1984) incident, a series of explosions in the LPG terminal resulted in 500 fatalities and destruction of the whole facility and surrounding residential area (Pietersen, 1988). In what is considered the worst industrial disaster in Bhopal (1984), the toxic gas was released because of the introduction of water in the storage tank containing methyl isocyanate (MIC) and resulted in 4,000 fatalities (Joseph, 2005).

As a result of major incidents at refineries and chemical plants, many legislations and regulations have been created to eliminate or minimize the potential for such events. For instance, the Occupational Safety and Health Administration (OSHA) published "the PSM rule," entitled Process Safety Management of Highly Hazardous Chemicals, Explosive and Blasting Agents, which became part of OSHA's regulations as 29 CFR Part 1910.119 (OSHA, 2008). The Environmental Protection Agency (EPA) required the implementation of Risk Management Program regulations (40 CFR Part 68) in the industries in order to prevent major chemical incidents that could harm workers, the public, and the environment (CFR, 1996). The American Institute of Chemical Engineers formed a separate branch – the Center for Chemical Process Safety (CCPS) to disseminate process safety resources, information and guidelines for safer process design. Another entity created under the Clean Air Act Amendments of 1990 is the Chemical Safety and Hazard Investigation Board (CSB), an independent US federal agency charged with investigating industrial chemical incidents. All these type of entities have generated significant reduction of incidents; according to the US Occupational Safety and Health Administration, since 1992 onsite fatalities from process safety incidents have dropped by over 60% (CCPS). Since 1984, there has not been another incident having as strong impact or large consequences as Bhopal disaster (CCPS).

Experience of harm forces society to reevaluate risk and the way it is managed. Investigating and analyzing the origins and consequences of disaster can provide lessons on how to improve assessment and management of risk. Unfortunately, these lessons are often disseminated in different data sources which make this information inaccessible, while other lessons can only be applied to some particular cases because the information provided is too specific. Although incidents occur due to a diversity of causes and many entities are involved in incidents investigation, there are many similarities. Therefore in order to translate lessons learned into effective practice, attention should be given to similarities and common factors to determine corrective actions and recommendations that prevent the recurrence of similar incidents. The main objective of this paper is to present a set of common lessons learned from a representative group of incidents including: Texas City disaster (1947), Philips 66 incident (1989), Buncefield explosion (2005), Imperial Sugar fires and explosions (2008), amongst others. These incidents had substantial differences in their root causes; however careful comparison leads to the identification of general lessons applicable to any kind of industry. It is hoped that lessons from previous experience can provide an effective countermeasure against reasonably avoidable risks.

CASE ANALYSES

In this study, major incidents that occurred between the past decade and recent years, most notably, Texas City disaster (1947), Mexico City disaster (1984), Buncefield (2005), Imperial Sugar (2008), among others were analyzed in order to derive the lessons learned that can be used for organizational learning. The incidents described in this paper could occur in many types of plants, and should therefore be of interest to a wide variety of plant operators. Table 1 summarizes the list of historical incidents used in this study.

DISCUSSION

Following the analysis conducted on the historical incidents, there are ten lessons that can be summarized as follows:

PERFORM A CAREFUL REVIEW OF MATERIALS USED IN CONSTRUCTION; CREATE A RECORD CHANGE NOTIFICATION

Many incidents have occurred because the wrong materials of construction were used. A careful review of design specifications and material selection should be conducted because use of the wrong grade of material could have adverse results and lead to disastrous incidents. In 1943, a very large LNG tank with capacity of 100,000,000 ft^3 (twice the volume of storage spheres in existing plant) was added in East Ohio Gas Corp. (1944), Cleveland, OH (Van Tassel, 1996). Unfortunately, the tank was made of 3.5% nickel alloy due to material shortages during World War II and was not able to withstand the cold temperature required to contain the LNG. Low temperature and excessive vibration gave rise to crack propagation in the inner shell which created a leak in the tank. On October 20, 1944, the new tank failed and released all of its contents into adjacent streets and sewers. After a short time, the LNG vapor cloud ignited and engulfed nearby neighborhood on the east side of Cleveland, killing 131 people and obliterating one square mile of the surrounding area (Van Tassel, 1996).

In this particular incident East Ohio Gas Corp. did not verify design specifications with the material being used. Due to the stored fuel's nature, the LNG tanks are designed with an inner and outer walls separated by insulation materials. The inner wall must be designed for LNG's cryogenic temperature (-260°F). The material used most extensively for LNG tank is 9% nickel steel as it remains ductile at cryogenic temperatures. In this incident, the material of construction: 3.5% nickel steel was too brittle at -260°F (Kruzic, 2004). Additionally, this incident could have been prevented if the management has done hazard identification of new tank material, unfortunately, East Ohio Gas Corp. did not document any equipment change.

MAINTENANCE AND INSPECTION SHOULD BE PERFORMED PERIODICALLY TO ENSURE EQUIPMENT RELIABILITY

Maintenance and inspection programs are designed to ensure that process equipment receives appropriate, regularly scheduled maintenance. The goal is ongoing mechanical integrity rather than breakdown maintenance. The following incidents show how poor inspection and maintenance may create a hazardous situation resulting in severe incidents.

On November 13, 2005, a severe incident occurred in Jilin Chemical Industrial Corp. in Jilin, China. The incident was triggered by the malfunction of a sensor which failed to detect a blockage at the nitration unit for aniline.

In Mexico City disaster (1984), the failure of the process safety valve (PSV) caused an overpressure inside the tank and pipeline and developed a leak in the LPG pipeline. The resulting vapor cloud of LPG occupied an area of $200 \times 150\ m^2$, with a thickness of 2 m; it ignited 5–10 minutes after the leak occurred (Pietersen, 1988).

In the Buncefield explosion (2005), both level gauge and ultimate high-level switch were not functioning properly when the tank was overfilled with unleaded petrol. The level gauge of Tank 912 recorded an unchanged reading (2/3 full) while filling of Tank 912 continued at a rate of around 550 m^3/hour. Several hours later, the tank began to overflow through the eight breather holes in the roof of the tank. Protection system should have closed the valves automatically; however the automatic shutdown did not operate. A vapor cloud from the escaping fuel gathered over the site and subsequently ignited.

In Port Hudson incident (1970), the release of liquid propane from pipeline was primarily due to corrosion. The resulting gas cloud flowed into a valley and about 20 min after the release started, the gas cloud exploded violently. The explosion started as an internal explosion in a pump house and triggered the unconfined cloud to detonate.

MANUFACTURERS SHOULD DEVELOP EFFECTIVE WORKER TRAINING PROGRAMS

Many incidents have occurred in the process industries because operators or supervisors or even managers did not understand the hazards of chemicals or technology. While training in hazard communication will help employees to be more knowledgeable about chemicals they work with, additional training should be conducted on operating procedures and safety work practices, emergency evacuation and response, safety procedures, and other areas pertinent to process safety and health. Some examples of training deficiencies are presented as follows.

In the Jilin chemical plant explosion, the operator noticed a blockage inside the reactor and attempted to clear it without success. As a result, the faulty operation triggered the explosion in the nitration unit (Fu, 2008). The other example is the Texas City disaster, which is considered the worst industrial incident in United States history. In this incident, the captain was not aware of the hazards of ammonium nitrate. Under normal storage conditions, ammonium nitrate poses a low risk; however, increases in temperature (between 160°C and 200°C) will result in explosion. On April 16, 1947, the incident started with the mid-morning fire, but it was more severe when the captain decided to pour water on the fertilizer in his attempt to save the cargo. The

Table 1. List of process industry incidents used in this study

Location of incident	Year	Description of incident	Fatalities
East Ohio gas Co. (Mannan, 2005)	1944	The facility originally consisted of three spherical LNG storage tanks. When cylindrical tank was fully loaded, it failed and releasing all its content. The nearby spherical tank fell over due to the fire, and then it discharged its content which immediately vaporized and ignited. The liquid LNG rushed into the streets and public sewer systems. The generated confined flammable vapors were ignited resulting in explosion and fireballs from underground.	131 killed and 225 injured
Texas City disaster (Mannan, 2005, Spignesi, 2002, Stephens, 1997)	1947	The Incident started with the mid-morning fire and detonation of 7,700 tons of ammonium nitrate on board the ship, Grand camp in the port at Texas City. The explosion caused other many explosions of facilities and especially the explosion of another ship, High Flyer containing an additional 900 tons of ammonium nitrate and 1,800 tons of sulfur.	581 people killed and over 5,000 people injured
Port Hudson, Missouri (Burgess, 1973)	1970	This explosion resulted from a propane pipeline break, which led to the formation of a large dense vapor cloud. Upon ignition, the vapor cloud exploded with tremendous force. Both near- and far-field damage indicate that this explosion may be attributed to the detonation of propane in air with an energy release equivalent to that from about 50 tons of detonating TNT. The violence of the explosion is likely unprecedented.	No fatalities or serious injuries
Mexico City Disaster, Mexico (Pietersen, 1988)	1984	The Mexico City Disaster is a major fire and a series of catastrophic explosions. On that day, the plant was being filled from a refinery 400 km away. Two large spheres and cylindrical vessels were filled to 90% and 4 smaller spheres to 50% full. Process drop was noticed but causes were not identified. Pipe rupture caused the release of LPG when the gas cloud drifted to a flare stack. BLEVEs occurred and the LPG vessels violently exploded.	542 killed and 4200 injured
Pasadena, Texas (OSHA, 1990)	1989	Phillips' 66 chemical complex at Pasadena experienced a chemical release on the polyethylene plant. A flammable vapor cloud formed which subsequently ignited resulting in a massive vapor cloud explosion. Following this initial explosion there was a series of further explosions and fires.	23 killed and 314 injured

(*Continued*)

Table 1. Continued

Location of incident	Year	Description of incident	Fatalities
Kinston, North Carolina (CSB, 2004)	2003	The polyethylene dust settled on surfaces around the production area. As much as a ton of combustible powder could have accumulated in the area above the ceiling, and dust explosion occurred. The first explosion dispersed other dust accumulations into the air around the production area and ignited them, causing a devastating cascade of fires and explosions.	6 killed and 36 injured
Illiopolis, Illinois (CSB, 2007)	2004	An explosion and fire at the Formosa Plastics Corporation occurs when an operator drained a full, heated, and pressurized PVC reactor. The CSB believes that the operator cleaning a nearby reactor likely opened the bottom valve on an operating reactor, releasing its highly flammable contents.	5 deaths and 3 injured
Jilin Petrochemical Plant Explosion, China (Fu, 2008)	2005	The Jilin chemical plant explosions are a series of explosions over the period of an hour. The cause of the blasts was initially determined: T-102 tower jammed up but was not handled properly. The explosion had occurred as a result of a chemical blockage and improper treatment to the problem.	6 killed and dozens injured
Buncefield Explosion (Buncefield Major Incident Investigation Board, 2009)	2005	The tank 912 started to receive unleaded motor fuel from a pipeline. The terminal closed to tankers and a stock check of products reported "no abnormalities." Because of the level gauge for the tank remained an unchanged reading. Tank 912 was completely full and started to overflow. Meanwhile, vapor began to form and flow out in all directions. The first explosion occurred, and further explosions followed, eventually engulfing more than 20 large storage tanks.	No fatalities but 43 injured
Port Wentworth, Georgia (Holloway, 2008)	2008	A dust explosion. It is possibly caused by static electricity igniting fine sugar dust that had become too dry.	14 killed and over 40 injured

improper decision caused runaway reaction and detonated 7,700 tons of ammonium nitrate on board.

In Port Hudson explosion, the operator noticed the propane leak in pipeline. He tried to crash shutdown the system but failed without success. Instead of shutting down the system, he shut down a pump station which increased the pressure to 942 psig and consequently aggravated the gas release. In this incident, if the operator was trained well in crash shutdown of the system, the consequences might not have been so severe.

In another example, a dust explosion occurred in the Imperial Sugar Company was primarily due to lack of training program and awareness about combustible dust hazards. The company did not address the risks from combustible dust, despite having a history of dust explosion prior to this incident (Bresland, 2008). Imperial Sugar also did not have a written dust control program or a program for using safe dust removal methods (Bresland, 2008). As a result, combustible dusts accumulated up to around an inch on ventilation ducts, waiting for the right conditions of suspension and ignition. In the Imperial plant, much of the electrical equipment was not dust-proof (CSB, 2005). Only the powder mill motor control room was enclosed to prevent dust intrusion.

MAJOR HAZARD INSTALLATIONS (MHI) SHOULD BE INSTALLED TO MINIMIZE THE IMPACT OF AN EXPLOSION

There has been a rapid growth of oil, gas and petrochemical industries over the past decades. These industries utilize complex processes operating at high pressure and temperature, employing continuous use of hazardous substances. Major industrial incidents occurred in the past and are likely to occur again in the future if no initial attention and precautions are taken to manage and control these installations.

In the Mexico City disaster, the plant was engaged in the distribution of bottled LPG, and each facility had about 20 mounded storage bullets (Pietersen, 1988). During the incident, the presence of thousands of LPG bottles (from the loaded trucks) at the plant area increased the severity of explosion. In the Texas City disaster, high proximity of petrochemical facilities to each other created domino effects. The explosion on the ship caused many explosions of facilities and particularly, the explosion of another ship (High Flyer) containing an additional 900 tons of ammonium nitrate and 1,800 tons of sulfur. In the recent Buncefield explosion (Historical Record of Catastrophes), the short distance between gasoline tanks created domino effects and a bigger disaster.

PLANT LAYOUT AND SITING SHOULD BE DESIGNED FAR AWAY FROM THE RESIDENTIAL AREA

Large quantities of dangerous substances, especially explosive or toxic gases, are often processed or stored in hazardous installations. If the substance is accidentally released to the atmosphere, it will have an adverse impact to the nearby area. Therefore, the siting of a plant should not be placed near the populated area. There are many reported fatalities in the past due to plant siting. In 1944, the explosion in the East Ohio Gas Corp. took place near the inhabited area and killed 131 people and injured around 225. In 1947, a serious explosion at Texas City killed 581 people in a residential area of the city (Stephens, 1997). In the present time, the Mexico City disaster has greatly increased the awareness of plant layout and siting. At the time of the incident, the distance measured from the center of the incident to the nearest residential area was around 100 m. As a result, 542 people were killed and 4,200 were injured. Nearly 10,000 people lost their homes, 5 plant workers died, and 200,000 people had to be evacuated. Virtually all the fatal victims were located within a 300 m radius of the center of the plant (Pieterson, 1988).

To date, there are many regulations requiring that hazardous facilities be sited at a safe distance from adjacent industrial, communities and other public areas. The safe distances or exclusion zones are based on vapor dispersion data, and thermal radiation contours and other considerations as specified in regulations.

COMPLETE PLAN AND APPROPRIATE PROTECTION SYSTEM SHOULD BE IN PLACE IN CASE OF EMERGENCY

Emergency planning is an important part of company operation. Since emergencies will occur, preplanning is necessary to prevent possible disaster. An urgent need for rapid decisions, shortage of time, and lack of resources and trained personnel can lead to chaos during an emergency. Time and circumstances in an emergency mean that normal channels of authority and communication cannot be relied upon to function routinely. The stress of the situation can lead to poor judgment resulting in severe losses. Additionally, the emergency response is characterized by the urgent need for rapid decisions; therefore the protection system should be in place and in operable status. The lack of an emergency plan could lead to severe losses such as multiple casualties and possible financial collapse of the organization.

In the Jilin Petrochemical Plant incident the existing monitoring system did not operate properly during the abnormal situation and corrective actions were not taken because the company had no emergency preparedness program. The explosion in the Jilin chemical plant released highly toxic substances, killing at least five people and forcing the evacuation of more than 10,000 nearby residents (Fu, 2008). It also contaminated the Songhua River with benzene and nitrobenzene. The contamination plume subsequently moved downstream towards Harbin City and further downstream towards the Russian border. Pollution threatened the water supply and left three million peoples in Harbin with no water (Fu, 2008). As seen in this incident, the emergency response plan for large spills was not available. The existing monitoring system did not work properly to ensure that critical information was available to all pertinent response officials downstream of the river and prevented the officials from initiating appropriate response measures.

In the Mexico City disaster, many lives could be saved if the emergency plan had included clearer pathways to exit for emergency responders (Pietersen, 1988). In the Texas City disaster, an absence of arrangements for coordinated response hampered efforts to fight the fire on the Grandcamp was identified as a major source of difficulty in coordinating the emergency response (Stephens, 1997).

Developing the emergency response program has many advantages. Firstly, unrecognized hazardous conditions that would aggravate an emergency situation may be discovered and eliminated. The planning process may bring to light deficiencies, such as the lack of resources (equipment, trained personnel, supplies), or items that can be rectified before an emergency occurs. In addition an emergency plan promotes safety awareness and displays the organization's commitment to the safety of workers.

PROCESS HAZARD ANALYSIS MUST BE IMPLEMENTED PERIODICALLY

In process safety, a hazard is considered to be the potential for an incident with undesirable consequences (Baybutt, 2003). Processes can contain different types of hazards, for example, chemical hazard such as toxic material, reactive chemicals, mechanical hazard such as rotating equipment, physical hazard such as high pressure, electrical hazard such as high voltage power supply. A process hazard analysis (PHA) is an organized and systematic effort to identify and analyze the significance of potential hazards associated with the processing or handling of highly hazardous chemicals (OSHA, 1992). A hazard analysis is directed toward analyzing potential causes and consequences of fires, explosions, release of toxic or flammable chemicals, and major spills of hazardous chemicals, and it focuses on equipment, instrumentation, utilities, human actions (routine and non-routine), and external factors that might impact the process (OSHA, 1992). Such an analysis provides information to assist employers and employees in making decisions for improving safety and reducing the consequences of unplanned releases of hazardous chemicals. These considerations assist in determining the hazards and potential failure points or failure modes in a process. Several process hazard analysis procedures are available: (i) Fault tree analysis; (ii) Failure mode and effects analysis; (iii) Hazard and operability (HAZOP) studies; (iv) Safety system checklists; (v) SAFE charts; (vi) What-if studies; (vii) Checklist analysis; (viii) DiGraph analysis (Crowl, 1990). OSHA has not specified any single approved method, but has taken a flexible approach where owners must select the most appropriate method of analysis for their facility.

In chemical processes, it is important to understand the reactive properties of chemicals before working with them. Data of interest, from a safety point of view, include decomposition temperatures, reaction rate or activation energy, impact shock sensitivity, and flash point. The best source for this type of data, if available is the open literature. However, experimental testing is necessary if data is not available from public sources.

Among the incidents under assessment in this study, many occurred because a PHA had not been performed or had been performed inadequately. For example, in the Formosa incident, the 1999 PHA had not been revalidated nor had a new PHA been conducted prior to the April 23, 2004 incident. In the dust explosion at West Pharmaceutical Services, Inc., the company did not perform an adequate engineering assessment of the use of powdered zinc stearate and polyethylene as anti-tack agents in the rubber batch-off process. The company's management systems for reviewing MSDSs did not identify combustible dust hazards. The hazard communication program at the Kinston facility did not identify combustible dust hazards or make the workforce aware of such hazards. An ignition source inside the building was not identified as a hazard in the Port Hudson explosion. An internal explosion in a pump house triggered the unconfined vapor cloud to detonate.

PHA is listed under OSHA's Process Safety management (PSM) standard, 29 CFR 1910 (OSHA) and the EPA's Risk Management Program (RMP) rule, 40 CFR Part 68 (EPA). These regulations require that a PHA address toxic, fire and explosion hazards resulting from specific chemicals and their possible impacts on workers, the public and the environment. Incidents are avoidable if the process hazard analysis has been implemented appropriately and the potential of hazard is effectively identified. Thus, appropriate strategies and actions will be taken to prevent the incident from occurring.

ACTIONS MUST BE TAKEN TO PREVENT POTENTIAL HAZARDS ACCORDING TO LESSONS LEARNED FROM SIMILAR INCIDENTS IN THE PAST

What has already happened cannot be changed, but lessons should be learned from previous incident investigations to prevent future losses. To prevent similar tragedies from occurring, many legislative and industrial changes were invoked, such as the authority given by Congress to the U.S. Chemical Safety and Hazard Investigation Board (CSB). The ultimate goal of the CSB is to prevent incidents and save lives by improving process safety with the lessons and recommendations learned from the incident investigation.

However, it is not enough to only perform the investigation, but it is imperative the recommendation and corrective action in the incident investigation be implemented into real on-site situations rather than just being documented on paper. Similar incidents have occurred again even though incident investigations were conducted in the past. Incident investigation can help us find the previously overlooked physical, environmental and process hazards, but only by taking action to apply the lessons learned. Future incidents can be prevented by improving the process design, procedures and employees training.

So one important lesson for a chemical company is the need to build its own incident investigation program to learn and improve safety performance continuously. Although some deficiencies exist in the identification and definition of process incident (incident investigation depth, incident record, corrective action, and knowledge sharing, etc.), the investigation process at least should propose appropriate remedial actions, and more importantly do the job at the right way. Finally, at least internally, the company should prepare a complete investigation report for future use.

APPROPRIATE PROTECTION SYSTEM SHOULD BE ALWAYS IN PLACE IN THE CASE OF AN EMERGENCY

The probability of incident occurring is always larger than zero. So emergency planning and response (EPR) should always be developed and implemented consistent with federal rules and good engineering practice, and applied to mitigate the impact of an incident on the public and the environment. All the safeguards and protection systems should be maintained on a regular basis to ensure their functionality when needed in an emergency situation. In the Philips explosion incident (1989), it was found that no permanent combustible gas detection and alarm system existed in the reactor units to provide early warning of leaks or releases. The fire protection system, particularly the fire-fighting water supply and its associated pumps, both regular and standby, was not maintained in an adequate state of readiness to provide adequate fire-fighting capability.

Therefore, a good emergency response practice should not only include the procedure of how to respond to an emergency situation, but also the capability of the emergency response facility. Overall improvement on EPR will help reduce loss and save lives during incidents.

APPROPRIATE OPERATION PROCEDURES MUST INCORPORATE ALL SAFETY PROCEDURES AND STANDARD INDUSTRY PRACTICES

When studying the incident cases, it was found that safety procedures and standard industry practice should be incorporated into the operating procedures to help eliminate injury to personnel, minimize incapacitating damage to facilities and maintain steady process. For example, we have to implement and enforce an effective hot work permit system when operating an activity that creates heat, flame, sparks, or smoke. In the Phillips 66 explosion, ignition sources (forklift truck, welding, and cutting-torch operations and vehicles) were introduced into such high-hazard areas without testing for the presence of flammable gases. Another lesson learned relevant to procedure is that implementation of standard maintenance operating procedures should be adequate. Phillips' existing safe operating procedures for opening lines in hydrocarbon service were not required for maintenance of the polyethylene plant settling legs. There was no provision for redundancy on DEMCO valves, no adequate lockout/tagout procedure, and improper design of DEMCO valve actuator mechanism. In the study of all the incidents, one must recognize that a good safety program is developed by implementing management systems to prevent the existence of safety problems in the first place by commonly using safety reviews, operating procedures, and maintenance procedures. These three elements must be integrated together to achieve a good safety practice.

CONCLUSIONS

In the present work, common lessons learned from multiple industrial incidents are presented. By identifying the root causes and contributing factors of industrial incidents, certain patterns emerged and were presented as a set of lessons learned. From this analysis, it could be concluded that an appropriate implementation of PSM apparently would have prevented most, if not all, of the incidents, nevertheless there is no doubt that something else is needed to improve incident prevention.

The following steps are recommended to translate lessons learned into improved practices for process improvement:

- Encourage industry to use lessons learned; for instance communicate lessons among authorities and experts though conferences, seminars, etc.
- Make lessons learned available to the people in the organization.
- Incorporate lessons into process assets by periodically reviewing the collected lessons learned and make process improvements to eliminate persistent problems
- Review the lessons learned from implementing the processes.

Finally, it is concluded that learning from incidents is a big challenge and implementing an effective lessons learned process is no easy task and means culture change in most organizations. This implies the necessity to create a detailed methodology in order to optimize the effectiveness of learning.

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