Chlorine leak on Mumbai Port Trust's Sewri yard: A case study

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ABSTRACT

Chemical emergencies involving hazardous chemicals are not uncommon in India. More than 25 incidents have been identified in National Disaster Management Guidelines – Chemical (Industrial) Disaster Management, released in May 2007. In a recent occurrence on the morning of 14 July 2010, nearly at 3:00 a.m., chlorine leak was reported from a gas cylinder referred as turner, weighing about 650 kg, corroding with time at the Haji Bunder hazardous cargo warehouse in Mumbai Port Trust, Sewri, affecting over 120 people in the neighborhood, including students, laborers, port workers and fire fighters, of whom 70 were reported critical. It has been observed to be a blatant case of ignorance and negligence as well as contraventions to the safety and environmental safeguard requirements under existing statues as well as non-maintenance of failsafe conditions at the site requisite for chlorine storage. The analysis revealed significant gaps in the availability of neutralization mechanism and the chlorine stored in open increased the possibility of formation of ingress mixture due to busting of chlorine filled tankers. The Government of India has institutionalized emergency preparedness framework at national, state and district level as envisaged in Disaster Management Act, 2005, to prepare the nation to mitigate such incidences, if all the preventive safety provisions fail. Ministry of Environment and Forests (MoEF) is preparing National Action Plan-Chemical (Industrial) Disaster Management based on National Guidelines to implement all the mechanisms of capacity development across the country.

KEY WORDS: Chlorine, disaster management, neutralization, port

On the morning of 14 July 2010, chlorine leak incidence was reported at Haji Bunder hazardous cargo warehouse in the Mumbai Port Trust (MPT), Sewri, affecting over 120 people in the neighborhood, including students, laborers, port workers and fire fighters, of whom 70 were reported critical.[1,2] Sewri yard on one side is adjacent to LBS College of Advance Life Time Studies and Research, while a vast area of sea and vacant land lies on the other side. The leak was observed at nearly 3:00 a.m. Many students from LBS College hostel that is barely 100 m from the site of leak were affected. Those who were sleeping were the most affected and they started vomiting. Examination saved many students who were awake and studying.[3] Suddenly, they felt suffocated and they saw outside their rooms a blanket of smoke in the yard where chlorine cylinders were kept. By 4:00 a.m., the hostels were completely evacuated. Police vans and ambulances took the victims to the hospital where it took few hours for the clinical symptoms of the victims to subside. The Mumbai Police has registered gas leakage case against unidentified persons.

Chlorine, under ordinary conditions of temperature and pressure, is a greenish yellow gas with a characteristic pungent smell and suffocating odor. Gaseous chlorine is approximately 2.5 times heavier than air. Liquid chlorine is clear amber in color and 1.5 times heavier than water. Chlorine reacts readily with lime and caustic soda to form hypochlorites. Hence, lime and caustic soda solutions are generally used for handling chlorine leaks.

Chlorine gas is a primarily a respiratory irritant. It is extremely irritating to the mucous membrane, the eyes and respiratory tract. The threshold limit values (TLV) of chlorine is 1 ppm or 3 mg/m^3 of air. If the duration of exposure or the concentration of chlorine is excessive, it causes restlessness, throat irritation, sneezing and copious salivation. In extreme cases, lung tissues may be attacked, resulting in pulmonary edema. The revised Immediately Dangerous to Life or Health (IDLH) is 10 ppm and the fatal dose is 1000 ppm.

The prolonged symptoms intolerable to patient might lead to

possibilities of pulmonary embolism, denudation of alveolar and bronchial epithelium, pulmonary edema, chemical pneumonitis, alveolar disruption and, as a rare complication, pneumomediastinum. This rare complication needs to be understood for providing immediate care to the victims in the proper way. In case of acute exposure, it may lead to acute lung injury (ALI) and/or acute respiratory distress syndrome (ARDS) due to which 1% of the patients might die. Humidified oxygen and inhaled β-adrenergic agents are appropriate therapies for victims with respiratory symptoms while assessments are underway. Inhaled bicarbonate and systemic or inhaled glucocorticoids also have been reported anecdotally to be beneficial. However, it is still at an experimental level and requires further clinical evidence prior to its universal utility.

It was learnt that the chlorine cylinders have been abandoned by an importer nearly a decade ago in 1997 and MPT has been unsuccessful in selling off these cylinders.[4] According to MPT officials, the leak occurred from one of 141 cylinders stored at the storage place. For over 6 hours, rescue and relief teams struggled to control the situation and it took fire officials, Bombay's Municipal Corporation teams, and experts from Herdillia Chemicals, Rashtriyia Chemicals and Fertilizers, Century Rayon and Mutual Aid Response Group, to identify, seal, and clamp the leaking of other cylinders. Fire fighters created water curtains in the area diluting the gas cloud that was spreading because of the leakage. The air pressure thus created helped the clouds of chlorine to float toward the sea. The neutralization process of the remaining chlorine filled cylinders using caustic soda and water was carried out by the National Disaster Response Force (NDRF) and other emergency responders. Out of 105 cylinders that had been found, 100 were clean but five of them had residual chlorine that leaked out. On an average, 6 hours had been consumed in cleaning one cylinder. In all, 16 out of 100 cylinders were neutralized. It was noticed that MPT did not have a chlorine neutralization tank, which every establishment that stores and uses chlorine maintains, to control such conditions. It was also observed that no safety guidelines were observed or safety systems maintained at the facility.

Observations and Lessons Learnt

Prima facie, it is a blatant case of ignorance and negligence as well as contraventions to the safety and environmental safeguard requirements under existing statues as well as non-maintenance of failsafe conditions at the site. Following reasons can be attributed for the grave incidence of leakage. 1) According to Manufacture, Storage and Import of Hazardous Chemicals (MSIHC) rules, 1989,[5] under the Environment (Protection) Act 1986, the imported cylinders which were lying in the open should have been accepted for delivery as empties, only if the residual chlorine was fully evacuated either at the facility at the exporting country or here at Mumbai as created in the vicinity of port or with assistance taken from a chlorine manufacturing or user industry having facilities of evacuation and neutralization. Until this was done, cylinders with residual chlorine should not have been stacked in the open where there was a likelihood of temperature and pressure increase, triggering busting of a cylinder with respect to standards laid down for the said parameters. 2) The area of storage should have been provided with suction pipelines and suction hoods connected with neutralization tank, which should have been in continuous operations. 3) Cylinders should have been imported with certification from competent authority on the residual life as well as present state of soundness certified through Non Destructive Testing (NDT) like hydraulic testing, thickness survey and radiography of the welded joints and approved by Chief Controller of Explosives (CCE). An inventory check at Haji Bunder warehouse revealed that at least 77 consignments containing 1168 packages were lying unclaimed. These packages comprise hydrogen sulfide and nitrous oxide, apart from chlorine. It calls for immediate actions to prevent any such emergency.

Managing Chlorine Leaks

Chlorine gas is stored in cylinders in a compressed form (around 400 V of gas is compressed to 1 V) and, in case of any leakage, liquefied gas is released, which takes heat from the ambient conditions for evaporation. Therefore, as a safety precaution, yard of chlorine cylinders is covered to minimize the effect of ambient temperature, as well as the surrounding of the cylinder yard is continuously cooled by installing high-pressure water nozzles to create a water blanket. This would help in reducing the evaporation rate and generation of cryogenic stresses; in case arrangement for spreading foam on the leaked compressed gas is made, the evaporation is further reduced. As a safeguard, the leak in the gaseous form is collected with the help of suction systems which suck the leakage in the gas form and take it to the neutralization tank which is kept running 24 × 7, where provision for alternate power supply is also made. The various Dos and Don'ts for chlorine emergency management are given in Table 1.

For 141 cylinders that are stacked at the incident site, the safety requirement is to provide monitors at the periphery of the yard, as well as an arrangement for anemometer for ascertaining wind speed and direction, and a public address system to communicate with the neighborhood population. We observed that none of the above safeguards were considered to be provided when it was not ruled out that cylinders contained residual or more chlorine gas which leaked even after storage for more than a decade. The next point of concern was maintaining the cylinders in an unattended form in the open where chances of ingress of mixture cannot be ruled out, and as the leak has developed, it could have been the result of corrosion in the cylinder or giving way of the fusible plug or leakage developed in a wall as moist chlorine is very corrosive and can corrode the containing vessel.

The primary requirement while participating in such rescue and response operations is to wear protective clothing including gas masks, fire and chemical proof suits, gloves and shoes; self-contained breathing apparatus (SCBA) is essential while working in hot zones. The six gas cylinders were degassed by

Table 1: Dos and don'ts for chlorine emergency management

Public safety
Immediate call emergency numbers of the region
Isolate spill or leak area immediately for at least 100 or 200 m in all directions; keep unauthorized people away
Stay upwind
Possibility of ingress mixture cannot be ignored and gases heavier than air will accumulate in confined areas
Ventilate closed spaces before entering
Keep out of the hot/warm areas
Emergency response
People should move in the upwind direction at right angle to the wind direction
Don't panic, walk, don't run and keep a handkerchief on the mouth, keep breathing as normal as possible
At least two persons should go to attend leakage
Wearing of SCBA is an essentiality prior to going toward leakage clamping
If there are fires, use water only and not dry chemical powder, carbon dioxide and halon
In case of fire involving tanks, fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Cool the containers with flooding quantities of water well until after fire is out. Don't direct water at the source of leak or safety devices, icing may occur. Immediately withdraw from the site in case of rising sound from venting safety devices or discoloration of tank
If all efforts to control the leak fail and the leakage continues, neutralize the chlorine by passing into a solution of caustic soda, soda ash or hydrated lime through a suitable pipeline with a perforated distributor. Caustic soda is recommended as it absorbs chlorine more readily. Never immense the leaking container in the tank containing alkaline solution or water
Universal protective equipment, emergency equipment, standard first aid and emergency health management procedures should be attempted

NDRF and two of them were dumped into the deep sea 40 km from the shore. One of these was found on sea shore of Worli, Mumbai, on 21 July, and this might have been due to high tide. NDRF and Bomb Disposal Squad along with other first responders rushed to the site. The cylinder was taken to check its weight to see whether it was still hazardous or not, as the cylinders that were dumped into sea after the gas leak contained 850–900 kg of chlorine. This observation revealed that mechanism of neutralization and disposal should be environment friendly and permanent in nature; otherwise, the problem will persist for longer periods.

Statutory Requirements

According to MSIHC rules, 1989 (as amended 1994, 2000),[5] various provisions on safety report, night site notification report, display of Material Safety Data Sheets (MSDS) at site in different languages, as well as on-site and off-site emergency plan should have been observed and the responsibilities assigned with legal backing to Chief Controller of Export and Import, Chief Inspector of Dock Safety, Chief Controller of Explosives as well as safety establishment of Port Trust should have been very well adhered to avoid such nature of grave incidence which shakes the confidence of public in the hazard control measures adopted by chemical storages as well as other establishments like warehouses, container depots, dock yards, etc.

National Disaster Management Authorities' Activities Toward Zero Tolerance

National Disaster Management Authority (NDMA) has prepared and released National Guidelines on Chemical (Industrial) Disaster Management in May 2007,[6] which calls for refining and strengthening national mechanisms on prevention, preparedness and mitigation from stages of planning to field operations and response. The guidelines have also set in timelines of action under short-, medium- and long-term modules to achieve zero tolerance in the chemical safety.

In its objective to achieve the results, NDMA, jointly with Ministry of Environment and Forests (MoEF), Petroleum and Natural Gas Regulatory Board (PNGRB), Federation of Indian Chambers of Commerce and Industries (FICCI) have conducted 10 regional conferences and two national mega conferences. Out of these, two conferences exclusively dealt with safety and security provisions in handling of chemical cargo in ports, warehouses and isolated storages. NDMA has also conducted 25 mock exercises inclusive of testing of on-/off-site emergency plans, wherein about around 50 Major Accident Hazard (MAH) units participated. Some of these exercises were conducted in the storages and chemical facilities in the ports. The outcome of such awareness campaigns was compiled in the form of referral books, i.e., Chemical Industrial Disaster Management (CIDM)-2009 and Chemical Mock Exercises: Good Practices and Lessons Learnt (2010).[7,8] CIDM-2010 compendium has also been compiled and will be released in the next sequel national conference proposed to be held in Delhi in August 2010.[9] The consortium also proposes to accelerate the program pertaining to awareness generation, education, and training across the country.

Ministry of Environment and Forests is preparing a National Action Plan on the basis of national guidelines prepared by NDMA to ensure fast implementation of provisions contained in the guidelines to help in achieving zero tolerance in chemical disasters in the country.

Community risk management

Community can be taken as a group that may share one or more things in common, such as living in the same environment, exposed to similar risk exposure, having been affected by hazard, having common problems, concern and hopes regarding risk and resources. Risk may arise when a hazard strikes a community. If skills, resources, and readiness are insufficient, if weaknesses are

too great, and if the scale of hazard is too big, then the risk is too high. A holistic approach to community risk management is required by building capacity and dealing with root causes in order to reduce the total risk. The traumatic impacts of chemical disasters (like Minimata and Bhopal gas tragedy) are well known as they caused huge losses to human lives, liquidation of the entrepreneurs (millions of rupees worth of property and investment in high-cost infrastructure were lost) and damage to environment. A high all round concern is developing worldwide on innocent lives lost or dicey functional posterity born out as a disaster consequence. The sufferings of the community during post-disaster phase are endless, which have moved the world against the defaulters.

Basic approaches to risk management include managing the source of the threat and empowering the community. Substantial amount of catastrophic risk needs to be exported out from the local context. One of the prime aims of disaster management is to develop a national community that is informed, resilient and prepared to face disasters with minimal loss of life, while ensuring adequate care for the survivors. People's own strategies and capacities to cope with, recover from, survive, and adapt to the risks they face and bounce back is the most important resource for managing risk and disaster. During sudden disasters, where every second counts, well-prepared local teams can save more lives. Community resilience includes the ability to anticipate disasters and react quickly and effectively when the disaster strikes.

Disaster resilient communities can be built by enhancing community participation, appreciation of the problem, and being part of solution making process.[10] It is the ability of community to anticipate disasters and react quickly and effectively when they strike. The process of building resilience may include awareness generation, organizing health and sanitation fairs, involving them in mock drills to give directions to their actions, public–private partnership, and development of local capacities by education and training programs. To start with, it may be aimed at initiation of developing a culture of household sanitation, precautions to use electricity or noxious products at family level, safe handling of domestic chemicals, basic disaster related education including dramas, demonstrations, and poster competitions at school level, discussions, symposia, and introduction to curriculum at college level and preference in jobs to those who are aware of disaster mitigation. Next step could be preparation of job-specific disaster manuals at occupation level and inclusion of these as a major program in all developmental processes. Chemical specific resilience can also be developed in a similar way through need specialized training, specific Dos and Don'ts, and community awareness [Table 1]. It varies from generation to generation and has developed after the commissioning of industrial hubs in a particular vulnerable area. It needs active participation of industries, transparency in their actions and of district administration to build up confidence among the community. Pharmacists also have a big role to play in this national endeavor.[11,12]

The information management pertaining to safety issues using authenticated internet resources as well as freely accessible databases of critical information on data models and case studies can provide sufficient in-depth information to save many lives.

Chemical Disaster Management: Challenges Ahead

Current status and perspectives of chemical disaster management[8,13] deduce that such incidences are preventable. The use of poisonous gases, ranging from disabling chemicals such as tear gas and the severe mustard gas to lethal agents like phosgene and chlorine in World War I, was a major military innovation. Iraqi insurgents are now using suicide bombs laden with chlorine gas, a significant expansion in terrorism.[14] Chemical industry needs to be secured against acts of terrorism.[15]

We need to create a single window national level capability and competence to advise, train, and share development in hazardous chemicals by conducting education, training, mitigation, and R & D activities. The Chlorine Institute, Inc. at USA founded in 1924, is a non-profit technical trade association of chlorine manufacturers, distributors, users, and many related companies, whose business interest is safety in the manufacture, transport, and use of chlorine and related products.[16] The institute's concerns focus on enhancements to chlorine container design, safe transportation of chlorine, employee health and safety, the elimination of chlorine releases to the environment, control of chlorine emergencies, and product/process specifications. The prime objective is to handle the chlorine safely to prevent the occurrence of any emergency. Establishment of similar type of institute is an essentiality attributing toward the chlorine safety in India.

Focus of training and retraining should be on field-based activities using stimulants or live hazardous chemical/materials to create various scenarios that might occur in everyday lives and to test the emergency plans by practicing coordinated response.[7,17] Such inspirational learning environment wherein the trainees can study the theory and then go out and practice, will nurture efficient response mechanisms. Such training facilities shall make protocols and practical instruction as realistic as possible. Training field should be developed to enable exercises in hazardous CBRN substance emissions, fire-fighting, Hazmat response, search and rescue, medical management of CBRN casualties, etc. Training ground should be well equipped and environmentally quality certified. The idea is to provide an optimum learning experience in a safe environment. This method of training will also promote awareness of environmental and safety issues. Training ground shall be used to enact scene for joint exercises with police, ambulance teams, and other stakeholders and emergency functionaries, creating synergy effects for all players.

Emergency preparedness and capacity development in terms of adequately trained human resources and infrastructure are the basic issues in the pre-event planning. Capabilities for assessment of damage potential along with development of

strategies, tools, devices and resources inventory is essential to mitigate the damage induced and improve the medical response in a holistic and coordinated manner. Management of mass casualty incidences involving chlorine needs overall preparedness and risk reduction amongst all stakeholders/service providers/emergency functionaries, including contingency planning and capacity development for an efficient response.

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