The Trend of Chemical Disasters in India: Past Three Decades 1980-2010

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Abstract

The Study was an attempt to reveal the trend of chemical disasters in India for the past three decades (1980-2010). Retrospective and Preliminary Hazard Analysis (PHA), method was used to chart out the trend. The reported chemical disasters (RCD) from open access sources and websites were collated that enabled the study to know the trend in number of chemical disasters (CD) state, union territory and year-wise in India. RCD was chronologically identified ranked and termed as identified reported chemical disasters (IRCD). The types of CD was identified based on its origin, the hazardous chemicals (HAZCHEMS), natural and manmade origin was identified. It was clear that the trend of chemical disasters was varying for the time period; in year 1994 and 2003 the maximum number of CD was identified, Maharashtra state stood highest in CD and the RCD was 37. Crude oil, ammonia, chlorine, sulphur compounds are mostly reported HAZCHEMS. Oil spills, toxic gas leakage, explosion are the type of IRCD. Orissa super cyclone was only the natural calamity that triggered CD 99 percent of IRCD was manmade. Thus, this study reveals the status of CD that has occurred in India. The study will be beneficial to planners to plan better preparedness and mitigation strategies to mobilise resources, strengthen capacities for to cope up those chemical disasters not to occur again, lessons for to implement "Safety as Culture" in India's developmental policies and planning. Help government to draw more guidelines, policies and regulations for chemical safety during manufacture, storage, transport of HAZCHEMS, to bring new technologies to early warn these situations.

Keywords: *Trend, Retrospective Method, Chemical disaster, Reported Chemical Disasters (RCD), Hazardous Chemicals (HAZCHEMS), Safety.*

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Introduction

India at present is achieving new milestones to become developed nation. The economic breakthroughs are moving ahead for sustained industrial growth from agrarian base (Draft NCP, 2012). It has become crucial to attain progress in the chemical sector. The progress of chemical and industrial sector stands vital to mankind, by providing the basic needs that improve the quality of life (textile, paper, paint, soap, pharmaceutical, detergent and varnish, etc.). Chemical industries contribute 7 percent of GDP to India (Draft NCP, 2012).The growth of chemical sector has increased the use of chemicals that are hazardous or HAZCHEM (NDMG, 2009) used in manufacture, to store, to supply and to transport. Growth of MAH has enhanced the risk and posed threat to cause chemical accidents or chemical disasters (CDs). MAH facilities and industries constitute major threat to property, population and environment (Maruthappa, 2009). Instance of the accidents and the probability due to chemical disasters have now become a cause of concern (NDMGCD, 2007). To prevent accidents in future (*Wagenaar and* van der Schrier, 1997), it is essential to learn from previous accidents and incidents (Lindberg *et al*., 2010; Kletz, 2001).

Initiators of chemical disasters

There are innumerable causes that lead to major or minor chemical disasters (Maruthappa, 2009). Chemical accidents may originate in manufacturing and formulation installations including during commissioning and process operations; maintenance and (GSDMA-Gujarat State Disaster Management Authority) disposal, material handling and storage in manufacturing facilities, and isolated storages; warehouses and godowns including tank farms in ports & docks, fuel depots and transportation (road, rail, air, waterways and pipelines) (Tamil Nadu Fisheries University). Human errors trigger chemical accidents that lead to chemical disasters. Main human errors occur due to neglect of safety instructions, lack of information and lack of emergency warning procedures. Technical errors: the defects in design systems, fatigue, metal failure and corrosion etc. Organisational errors are caused by weak crisis planning, co-ordination and non-delivery of mock drills at regular time intervals. Terrorist attacks/sabotage, chemical disasters, and warfare activities further vandalise HAZCHEM facilities like transportation vehicles (NDMGCD, 2007).

Types of chemical accident/disaster

No two accidents are exactly the same; similarly each disaster is unique. Important types of chemical accidents or disaster are: explosion in a plant or in a storage facility, fire, toxic releases and chemical poisoning.

Impacts

The impacts of chemical disaster depend upon HAZCHEMS involved, quantity stored, used, released. Impacts depend upon the nature of chemical (Figure 1) and its dispersion to the abiotic and biotic factors.

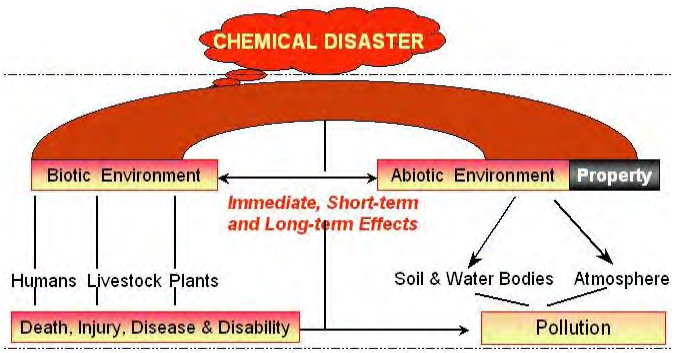

Figure 1: Impact of Chemicals. Adapted from: Gupta & Nair, 2012; Training Module Chemical (Industrial) Disaster Management, NIDM, GOI, Ministry of Home Affairs

Methodology

To analyse chemical disasters *Retrospective* method was used, that allows better understanding of historical records and enables to foresee hazardous situations (Silano, 2006). The study of past accidents, their course effects, and circumstances in which they occurred stands a basic key for identifying hazard situations. Retrospective method facilitates the definition that implies to implement preventive measures and emergency response measures for chemical disasters (Silano, 2006) not to happen again. Trend analysis is *sine qua non* for the development of vulnerability assessment methodologies for formulating policy scenarios and rationalising decision-making for proactive disaster preparedness. It is the practice of collecting information and attempting to spot a pattern, or trend. Although trend analysis is often used to predict future events, it could be used to estimate uncertain events in the past (Yoganath et al., 2009). The retrospective method was used to collect the information of past accidents and incidents pertaining to CD and trend analysis used to know the situation of CD during the period. Preliminary Hazard Analysis (PHA) method was used to structure the chemical and industrial accidents data in chronological order.

Analysis

A detailed review literature on CD was collected from open access sources and search engines (websites - government & nongovernmental portals) that reported

CD Incidents/Accidents) having occurred in India for the time period. Based on the available electronic documents (portable document files, document files and html, etc.), data was obtained mainly from studies conducted by Surianarayanan & Swaminathan; Maruthappa, 2009; Blue Waters 2010, 2009; National Disaster Management guideline for Chemical Disasters, 2007 documented by and ranking the chemical disasters in chronological order state wise and year wise.

The data on Reported Chemical Disaster (RCD) were classed and arranged in MS-Excel 2007. Thus, the RCD was identified and documented according to name of the state, date, month, year, location of accident, natural or manmade cause, type of accident (explosion, release, leakage), name of chemical material involved, physical state of material, material storage, quantity, reported deaths, injury, exposed, number of persons evacuated. Thus, the trend was analysed by using MS-Excel to obtain the result.

Results and Discussion

Learning from accidents helps integrate knowledge and experience and also identify the need of future research (Lindberg *et al.,* 2010). There are different methods to analyse accident (Wagenaar and van der Schrier 1997). The present study is based on bibliographical investigation of chemical disasters that occurred in India during 1980 to 2010, based on available literature.

The Reported chemical disasters were identified from various web sources and documented in MS-Excel data sheets as 'Identified Reported Chemical Disasters (IRCD)'. A total of 140 IRCD (major and minor) in 18 States, 1 Union Territory and 1 National Capital Territory (Delhi) during the period were identified (Table 1). The 18 states reported 118 incidents, 2 union territories reported 22 incidents.

Table 1: Chemical Disasters in India for Past Three Decades 1980-2010

Total Numbers Reported		**Total Identified Reported Chemical Disasters (IRCDs)**
States	18	118
National Capital Territory (Delhi) & Union Territory	1+1=2	22
Total		140

Similar historical studies were conducted by Purohit and Suthar (2012) for all types of disasters during past two decades (1990-2009). Maruthappa (2009) studied major chemical disasters in India. Surianarayanan and Swaminathan also studied 100 case histories of accidents in Indian chemical Industry (1988-2000) and developed

BLAZE database to document chemical industry accidents. Courtesy to Joseph, et. al. (2004); Janak, et. al. (2007); Jayachandran (2011); Bhawana and Fulekar (2011); Jyoti and Suthar (2012) are solicited. The articles delivered the status and perspective of chemical disasters management and their data served as the source of information for CD study.

Similarly, study by Dev and Bhattacharya (2012) documented case histories of chemical industrial accidents and disasters. Amongst the total 140 IRCDs documented in Ms-Excel database, only few important are listed below (Table 2); these are based on life lost.

Table 2: Important IRCDs based on life lost

1.	Mandir Asod plant explosion on 3rd May 1980: a fire explosion was reported, plant was storing explosives, around 50 people died in the Fire explosion.
2.	In Assam Dhulabar in 1983 in a plant fire broke out from cylinder of crude oil stored; 76 died, 60 injured.
3.	Toxic gas release (Methylisocynate) Bhopal 1984, on 2nd and 3rd December, Union Carbide plant in Bhopal; about 25-27 tons of the deadly methyl isocyanate gas spread. About 2500 persons died, half a million people were exposed to the gas.
4	Oleum gas tragedy Delhi on 4th to 6th December 1985 was reported at the Shriam Foods Ltd.; more than 150 deaths and 130 injuries, incident lasted for two days.
5.	SEDCO West Coast 1989: Indian Coast- 3 lost in a fire blow out.
6.	Gas Leakage: Transport accident at Patna on 16th April 1990; gas leaked from a transport vessel leaked 100 death and 100 injuries were reported.
7.	Release of metal fumes in Delhi 1994 metal fumes was released and 14 Death was reported 12 persons were exposed to the fumes and caused respiratory arrest.
8.	Fire At Delhi 1998 in Fire was caught to plastic and toxic cloud of fumes was released into the atmosphere. 6 reported death to the incident and the injured are inaccessible
9.	Digboi Assam in 7th March 2003, refinery had broke out with fire from a tank stored motor sprit (liquid), 11 death, 112 injured and exposed.
10.	Mumbai Maharashtra on 14th July 2010 at Mumbai port trust (650 kg cylinder) chlorine leaked 120 people injured and evacuated

Akhil Adapted from Dev & Bhattacharya, 2012 (Academic Thesis)

Trend of IRCD, state & union territory wise

The states that reported chemical disasters were Andhra Pradesh, Assam, Bihar, Goa, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Maharashtra state stood first

to report maximum number of major and minor IRCD (37 incidents reported) during past 30 years (Figure 2). The reason for maximum number of IRCD in Maharashtra was due to its high industrial growth. The state contains 38150 registered factories, 31100 working factories, 3200 chemical factories, 336 MAH units (Figure 3) as the statistics shown by Disaster Management Institute in Bhopal. The presence of major industrialised cities, Mumbai, Pune and Thanae bears chemical factories and MAH. The cities of Maharashtra are densely populated with people. So, the impacts and vulnerabilities to chemical disasters are high to the region. Delhi, the National capital city of India which stood second in IRCD (20 number of incidents reported in 30 years). The region contains 15 MAH units (Saxena, 1998) it might be the cause for increased number of incidents. Though Gujarat has 260 MAH units (Saxena, 1998) it stands third in IRCD (14 number of incidents), probably safe measures for handling HAZCHEMS was practiced in chemical facilities of Gujarat. Tamil Nadu stood fourth (11 number of incidents), Andhra Pradesh fifth (10 number of incidents) in IRCD. Rest of the states has shown considerably low in IRCD (1-7 in number of incidents) to 30 years time period. The states that did not report the chemical disasters are Arunachal Pradesh, Chhattisgarh, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Manipur, Meghalaya, Mizoram, Nagaland, Uttar Pradesh, Sikkim and Tripura. Among 7 the union territories in India, Delhi and Andaman Nicobar (2 number of incidents) has IRCD.

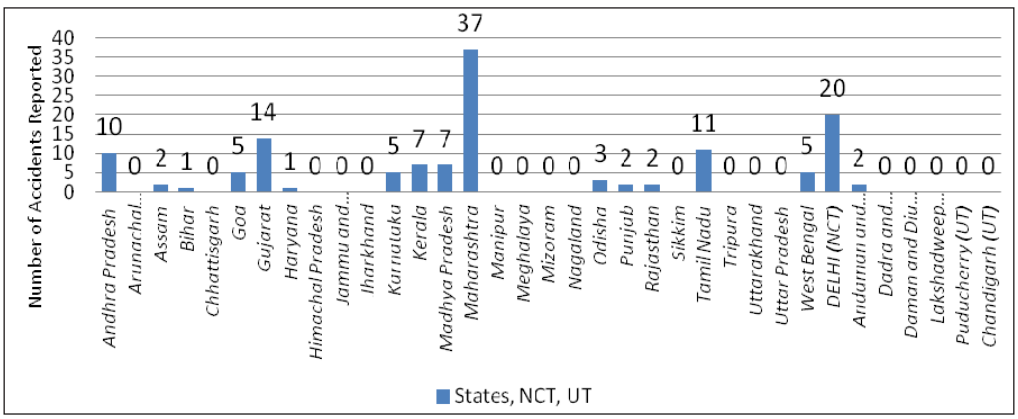

Figure 2: Identified Reported Chemical Disasters in India 1980-2010

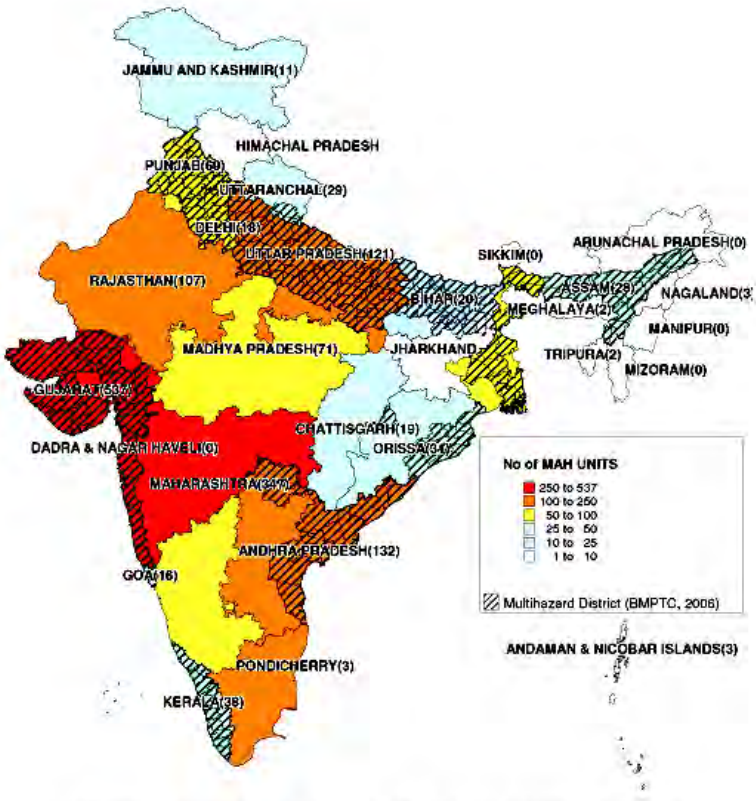

Figure 3: Major Accident Hazard Units in India (Gupta & Nair, 2012)

Trend of IRCD year wise (1980-2010)

The trend of chemical disasters for past 30 years (1980-2010) in India revealed considerable variations with passage of years (Figure 4). In the year 1980 the IRCD were considerably less, only 1 incident was reported in Mandir Asod plant, on 3rd May an explosion was the first incident reported from the study. The highest number of IRCD (10 incidents) was reported in the years 1994 and 2003 (Figure 4). Second highest IRCD (9 incidents) was in 1993 while the third highest IRCD (8 incidents) in 1989 and 1993. The fourth highest was in the year 1992, 1997 and 2004 with a total of 7 IRCD. In fifth, during 1985, 1991, 1995, 1996 and 2006 years 5 number of incidents were reported. The year no IRCD were 1981 and 2008 (the reason was unknown). The IRCD of remaining years were in the range, 1 to 4 incidents.

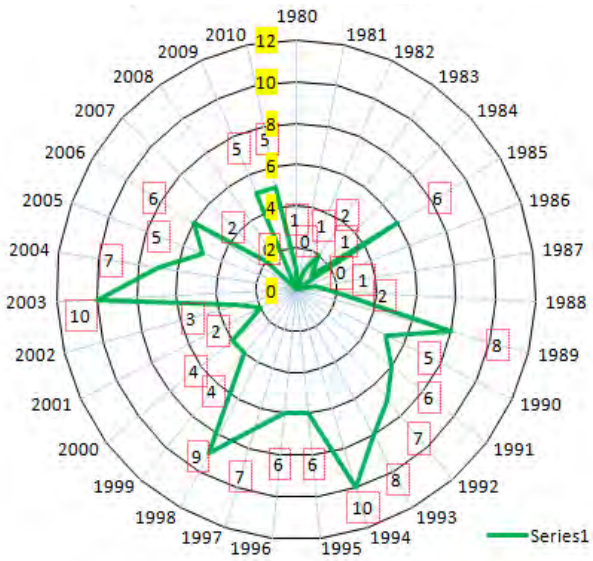

Figure 4: Year wise Trend of Identified Reported Chemical Disaster (IRCD) in India, 1980-2010

Decade wise trend of IRCD

The linear forecast trend line from past three decade revealed (Figure 5) an increasing trend for CDs and polynomial trend line revealed decreasing trend. The linear forecasting trend was not satisfactory because chemical disasters are unpredictable, there might not be any increasing trend unless the Hazard probabilities of HAZCHEM facilities are known.

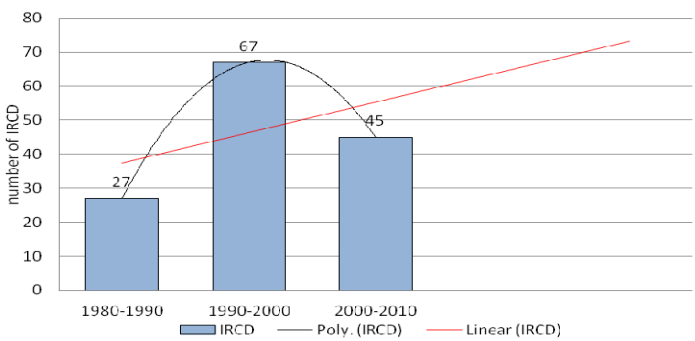

Figure 5: Decade wise Trend of IRCD in India, 1980-2010

The polynomial trend based upon the available IRCD was found to be true and India's status in CDs for the first decade was less (22 IRCD) when compared with second and third. In the second decade (1990-2000) it has tremendously increased to 67 IRCD and in third (2000 to 2010) decade CD was decreased to 45 IRCD when compared to the second decade (Figure 5). The period 1980 to 1990 India was on verge of industrialisation and development. Industrialisation was continued to metropolitan cities and few states only. There was less production and handling of HAZCHEMS and facilities or installations. During 1990s India's economic growth was mainly due to the industrial sector, more number of chemical factories and industries emerged. The reason to increase CDs tremendously during 1990-2000, the second decade was due to the lack of awareness among the manpower to use the sophisticated technologies in the facilities leading to human errors. The scenario of chemical disasters has changed from the Bhopal gas tragedy during 1984. For the effective safety measures, laws and regulations formulation, implementation with regard to chemical safety and management of chemical and industrial accidents Indian government put forth an umbrella act 'Environmental Protection Act in 1986 (EPA,1986)'. It provided a wholesome cover for all environmental issues rules, regulations and guidelines laid from for hazardous chemicals, hazardous waste, and emergency preparedness and planning (Gupta & Nair, 2012). The holistic act that covers all types of disasters was enacted by India government as Disaster Management Act, 2005' that might be the cause of decrease in number of incidents in the third decade. It can be presumed that a chemical safety culture came into being by embracing appropriate production, storage and transportation facilities with utmost care for safety as reflected in the decreasing number of IRCD (Figure 5).

Types of IRCD

Figure 6 shows the types of identified chemical disasters reported during 1980-2010. There are 10 types of chemical disasters that were identified. They are fire, explosion, fire and explosion, leakage, release, oil spills, transport accidents, toxic release by leakage, food poisoning and unknown types. Oil spills were mostly reported (68 number) during the period, which might have been due to unsafe transportation mechanisms and improper handling of the crude oil in the facilities or in the container vessels during shipping, loading/unloading the vessels. Oil spill causes great disruption and damage to the aquatic and marine life and ultimately causes economic loss. The spills of crude oil, diesel, petrol, etc. were reported. Toxic chemical release stands second, 17 number of toxic release or leakage were reported. Fire, another type of chemical disaster that stands third, a total of 15 incidents was reported due to fire. The number of explosions occurred were 11. Four number of incidents were found to be of unknown origin.

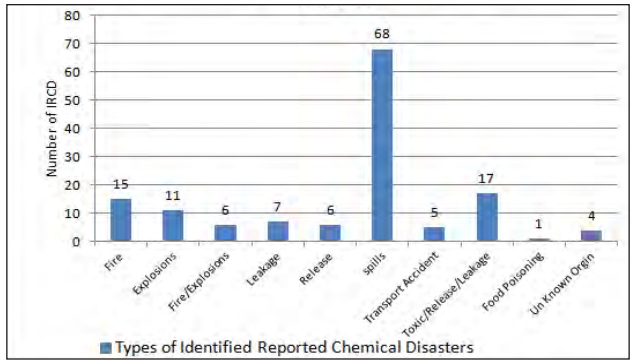

Figure 6: Types of IRCD in India 1980-2010

The reported increase in oil spills can be probably attributed to the open access. This was brought to limelight by the Indian Coast Guard through their newsletter. Other types of CDs could have been increased to the time period due to the study limit on availability of CD from open access, though the reliability to types of chemical disasters can vary.

Trend of HAZ-CHEMS and their physical state

A total of 140 IRCD with 38 types of hazardous chemicals (HAZ-CHEMs) were identified. The HAZ-CHEMs identified (Figure 7) and are Ammonia, Benzene, Chlorine, Crude Oil, Diesel oil, Ethane, Explosives (Fire work), Fuel oil, Furnace fuel oil (FFO), Gas, Gasoline, Hexacyclo-pentadiene, Hexane, LPG, Metal Fumes, Methylisocyanate, Motor Spirit, Naphtha, Nitrocellose, Oleum gas, Petroleum, Petrol, Propane, Plastic (Polythene), PVC Coating, Sodium Hydride, spillage of HAZ CHEM, Sulphios, sulphur, Sulphur Dioxide, Sulphuric Acid, Superior Kerosene oil, Tanker Wash, Toluene, Toxic Gas and Tri-chloro Ethylene.

Among HAZ-CHEMs identified, crude oil was mostly reported, the reason for abundance of crude oil was due to the increased number of oil spills reported (Figure 6) by Indian Coast Guard; 40 number of incidents were reported due to crude oil spills. Fuel oil accounts for about 18 number of HAZCHEMs incidents CD. Chlorine and Ammonia stand the third HAZCHEM that reported 8 number of CDs for past 30 years.

Depending upon the chemical property and quantities, the vulnerability and consequences posed by HAZCHEMS vary. Ammonia and chlorine are environmental hazards as also respiratory irritants to humans and animals, with potential to pollute atmosphere and environment. The disasters posed by these types of HAZCHEMS the impacts are harsh.

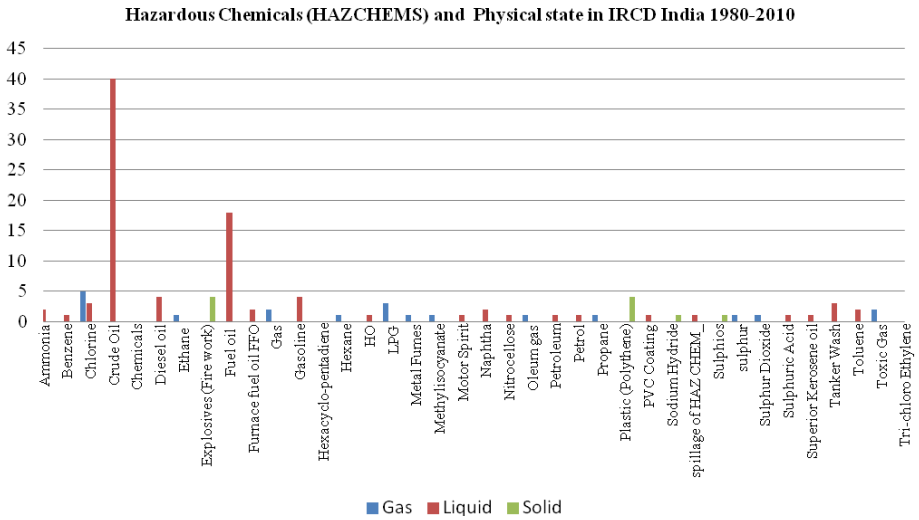

Figure 7: Hazardous Chemicals and Physical State (IRCD) in India 1980-2010

Trend of Natural and Manmade IRCD

The Orissa super cyclone was the only natural disaster that has lead to cause chemical disaster (Figure 8). In the year 1999 at Paradeep where Ammonia gas leaked from a cylinder in M/s Oswal Chemical and Fertilizers Limited, it was the only IRCD. No death on injury was reported.

The analysis revealed that majority of CD was caused by manmade source. From the past 30 years 99 percent of the IRCD were manmade. The human errors posed much of the CDs, the reasons for CD was not unveiled to the lack of information. Shear negligence and lack of awareness by the man power might be the reason. Gordon et al., 2005 have attributed the human factors responsible for accident in off shore oil and gas Industry in UK. Many studies carried out to find the cause of accidents have endorsed human errors as main factor.

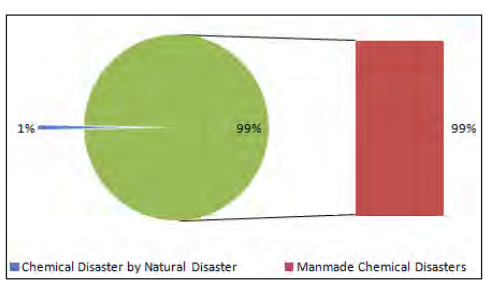

Figure 8: Natural and Manmade IRCD in India 1980-2010

Conclusion

The trend of chemical disaster in India for past three decades (30 year, 1980 to 2010) was pioneer study in India that shows the trends of IRCD like, state & union territory wise, year wise, decade wise, hazardous chemical and their physical state wise, cause of chemical disasters by natural or manmade wise. The different types of IRCD were analysed. The outcome of the study will be beneficial for the government and non-government bodies, corporate companies, chemical industries, hazmat industries, educational institutions etc. to know the current status of chemical and industrial disasters that have occurred in India. The prospective beneficiaries can plan better preparedness methods for mobilising resources, to strengthen capacities to cope chemical disasters not to occur again and to impart "Safety as Culture" in India.

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Reference

Akhil Dev, K., and Bhattacharya, R. (2012). Trend Analysis of Chemical Disasters in India for Past Three Decades and Societal Risk Assessment of Toxic Chlorine Gas Release: A Case Study for Incident Modeling with Aloha Software in Perspective of Environment Science and Disaster Management. M.Sc. in Env. Sci. & Disaster Management thesis at IPSD & ITSD from AERB, M. Gandhi Univ., Kottayam, Kerala.

Bhardwaj J.R., Chawla, R. & Sharma, R.K. (2007). Chemical disaster management: Current status and perspectives. *Journal of Scientific and Industrial Research,* 66(2), 110. http://nopr.niscair.res.in/handle/123456789/1140; http://nopr.niscair.res.in/bitstream/123456789 /1140/1/JSIR%2066%282%29%20%282007%29%20110-119.pdf

Blue Water (2010). Is the use of Oil spill absorbants the effective solution for environment friendly spill response? Marine Environment Security Biannual News letter, Volume-XII Issue1, Indian Costal Guard. pp 18-19.

http://www.indiancoastguard.nic.in/Indiancoastguard/NOSDCP/NOSDCP%20Publications_files/Blue%20Waters%20Jan%2010.pdf

BlueWater (2010). Threat of oil spill incident to sensitive shoreline application of OSD to prevent oil affecting the sensitive shorelines, Marine Environment Security, Biannual News letter, Vol. XII Issue 1, Indian Costal Guard. pp 1-20. http://www.indiancoastguard.nic.in/Indiancoastguard/NOSDCP/NOSDCP%20Publications_files/Blue%20waters%20Jul_%202009.epdf.http://www.indiancoastguard.nic.in/Indiancoastguard/NOSDCP/NOSDCP%20Publications_files/blue%20waters%20-%20Jan%2009.pdf

Disaster Management Institute, Major Accident Hazard- Maharashtra, website http://www.hrdp-idrm.in/ retrieved from http://www.hrdp-idrm.in/live/hrdpmp/hrdpmaster/idrm/content/e5783/e7545/e32703/e32704/ThaneMAH.doc

Draft National Chemical Policy (2012). Department of Chemicals & Petrochemicals, Ministry of Chemicals & Fertilizers, Retrieved from http://chemicals.nic.in/DNCP_2012.pdf

http://www.hrdp-idrm.in/e5783/e17327/e27015/e27708/ accessed on 11/04/2014, pp 19

Gupta, A. K. & Nair, S.S. Shard (2009). In Chemical Disaster Management: Proceeding, National Workshop (30 Sept.-01 Oct. 2008, New Delhi). Ministry of Environment & Forests (MoEF), GoI and National Institute of Disaster Management, New Delhi.

Gupta, A.K., & Nair, S.S. (2012). Training Module chemical (industrial) Disaster Management, Ed (1), National Institute of Disaster Management, Ministry of Home Affairs, Government of India, pp 21. Retrieved from http://nidm.gov.in/PDF/modules/chemical.pdf (accessed on 02/04/2014)

Gordon, R., Flin, R. & Mearns, K. (2005). Designing and evaluating a human factors investigation tool (HFIT) for accident analysis. *Safety Science*, 43(3), 147-171. doi:10.1016/j.ssci.2005.02.002.

Gujarat State Disaster Management Authority (2013). Chemical and Industrial Disaster: an Initiative of Government of Gujarat, India. Retrieved from http://www.gsdma.org/hazards/chemical-industrial-disaster.aspx, accessed on 07/04/2014, last updated 18/07/2013.

Janak, R.B., Raman, C. & Rakesh, K.S. (2007). Chemical Disaster Management: Current status and Perspectives. *Journal of Scientific and Industrial Research*, Vol 66, pp 110-119.

http://nopr.niscair.res.in/handle/123456789/1140, http://nopr.niscair.res.in/bitstream/123456789/1140/1/JSIR%2066%282%29%20%282007%29%20110-119.pdf

Jayachandran, K. 2011. Role of Emergency Preparedness in Industrial & Chemical Disaster Management, Disaster, Risk and Vulnerability Conference 2011, School of Environmental Sciences, Mahatma Gandhi University, India, pp 129-132.

http://www.docdroid.net/97ap/disaster-risk-vulnerability-drvc2011.pdf.html

Joseph G, Kaszniak M and Long L. (2004), "Lessons after Bhopal: CSB a Catalyst for Change, Prepared for Bhopal International Conference on Bhopal Gas Tragedy and its Effects on Process Safety, Science DirectVolume18Issues4–6,pp.537–548.

http://www.iitk.ac.in/che/jpg/papersb/full%20papers/J%20-%2096.doc http://www.sciencedirect.com/science/article/pii/S0950423005001397

Jyoti, P., & Suthar, C.R. (2012). Disasters Statistics in Indian Scenario in The Last Two Decades. *International Journal of Scientific and Research*, Volume 2, Issue 5, ISSN 2250-3153, pp.1-5.http://www.ijsrp.org/research_paper_may2012/ijsrp-may-2012-49.pdf

Lindberg, A.K., Hansson, S.O. & Rollenhagen, C. (2010). Learning from accidents–what more do we need to know?. *Safety Science, 48*(6), 714-721.

Maruthappa, S. (2009), Case study on Major Chemical Disasters-One day Symposium on Prevention of Industrial/Chemical Disasters at Bangalore, Safety Engineers Association of India, President Institution Fire Engineers, (UK) Chennai Br, pp1-6

www.hrdp-idrm.in/live/…/CasestudyonMajorChemicalDisasters.doc

Mihailidou, E.K., Antoniadis, K.D., & Assael, M.J. (2012). The 319 Major Industrial Accidents Since 1917. International Review of Chemical Engineering-Rapid Communications, 4(6).

Ministry of Environment & Forests Notification. (1996). The Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules, 1996. Gazette of India, Part II Section 3 (i) Extraordinary S.NO. 241, dt. 2.8.1996, New Delhi, pp 1-106. http://envfor.nic.in/legis/hsm/gsr347.pdf,htrtp://www.moef.nic.in/legis/hsm/gsr347.htm, http://envfor.nic.in/divisions/hsmd/hsm96.html

National Disaster Management Guidelines, Management of Chemical (Terrorism) Disasters, June 2009. National Disaster Management Authority, Government of India. 10- 84. (Annexure-I) 98- *123*. http://nidm.gov.in/PDF/guidelines/chemical_terrorism_disasters.pdf

National Disaster Management Guidelines: Strengthening of Safety and Security of POL Tankers July 2010. National Disaster Management Authority, GoI. Recommendations 22-35. http://nidm.gov.in/PDF/guidelines/pol.pdf

National Chemical Management Profile of India prepared by Ministry of Environment & Forests and Central Pollution Control Board with assistance from United Nations Institute for Training and Research, Geneva under the auspices of Canada-India Environmental Institutional Strengthening Project, Canada. pp 1-227. Accessed on, March 20 2012 3:30 pm http://cpcb.nic.in/upload/NewItems/NewItem_112_nationalchemicalmgmtprofileforindia.pdf

National Disaster Management Guideline for Chemical Disaster, (2007). Section: I – Introduction. Disaster Management Institute (DMI), retrieved from http://www.hrdp-idrm.in/live/hrdpmp/hrdpmaster/idrm/content/e5785/e6157/e15651/NDMGCD.pdf, Accessed on July 2012 at 4: pm, pp1-99.

National Policy on Disaster Management,(*NPDM 2009*) 1. Preamble. http://ndmindia.nic.in/NPDM-101209.pdf

Pandey Bhawana and Fulekar, 2011, Review Paper Environmental Management- Strategies for Chemical Disaster, *Research Journal of Chemical Sciences*, Vol. 1 (1) pp 1-7.

http://www.isca.in/rjcse/Archives/vol1/16.pdf

Purohit, J. & Suthar, C.R. (2012), Disasters statistics in Indian scenario in the last two decade. *International Journal of Scientific and Research*, Volume 2, Issue 5. ISSN 2250-3153, pp 1-5. http://www.ijsrp.org/research_paper_may2012/ijsrp-may-2012-49.pdf

Saxena, S.K., (1998). INDOSHNEWS, Directorate General of Factory Advice Service & Labour Institute, Vol. 3 No. 2. pp 1-21. Retrieved http://dgfasli.nic.in/newsletter/apriljune98.pdf accessed 02/04/2014.

Silano, V. (2006). The Evaluation of Public Health Hazards associated with Chemical Accidents. 2nd edn, Pan American Health Organization Program for Emergency Preparedness and Disaster Relief, World Health Organization, pp 6-95. http://www.bvsde.paho.org/bvsacd/eco/evaluation.pdf

Surianarayanan, M. & Swaminathan, G. (Year un available). Indian Chemical Industry Accident Database – an Effort by Cell for Industrial Safety and Risk Analysis (CISRA). Chemical Engineering Department, Chennai, India, pp 1-15 Accessed http://www.rgipt.ac.in/title_doc/S%20-97.doc. http://www.iitk.ac.in/che/jpg/papersb/full%20papers/S%20-97.doc

Tamil Nadu Fisheries University, Unit II: Man Made Disaster. Retrieved from www.tnfu.org.in/university/wp/?page_id=3740 accessed on 10/04/2014

Yoganath A. & Junichi Y. (2009). Global Trends in Water-Related Disasters: an insight for policymakers, International Centre for Water Hazard and Risk Management, The United Nations World Water Assessment Program- Report-3, UNESCO, France. pp-4.

Wagenaar, W.A. & van der Schrier, J. (1997). The goal, and how to get there. *Safety Science*, 26(1), 25-33.