Journal of Loss Prevention in the Process Industries 41 (2016) 295–302

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

An evaluation of risk assessment framework for industrial accidents in India

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ARTICLE INFO

Article history:
Received 11 May 2015
Received in revised form
15 December 2015
Accepted 15 December 2015
Available online 22 December 2015

Keywords:
Hazardous industries
Policy
Regulations
Risk analysis
Risk evaluation
India

ABSTRACT

Due to rapid industrialization, with high population density and constraints of land, it is expected that level of risks arising from the hazardous industries will increase in India in the coming decades. However, 30 years after the Bhopal accident (1984), except a few discrete regulations, there is as yet no integrated system for assessing and managing risks arising out of these hazardous industries in India. The gravity of aspects related to the management of industrial risk still remains crucially important. In particular, there is no standard guideline on risk analysis methodology, acceptability or tolerability criteria, nor is there an accident database or a risk reduction strategy for the areas where risk levels are already high. On top of this, there are technical and legislative gaps in the institutional framework to implement any of the above mentioned issues. With the backdrop of the Bhopal gas tragedy, the objective of this paper is therefore to evaluate the effectiveness of a comprehensive risk assessment framework for the emerging economy of India, in order to control and/or to reduce the risk level that exists. In this context, regulations and policies pertaining to industrial risk assessment were reviewed.

1. Introduction

The rapid growth in the use of hazardous chemicals in industry has brought about a very significant increase in the number of people whose life could be endangered at any time by an accident involving these chemicals. The rapid pace of progress in modern technology allows less opportunity for learning by trial and error, making it increasingly necessary to set design and operating procedures. Today India is one of the fastest growing economies in the world, and a considerable part of this growth is because of the good performance of key industrial sectors including the chemical industry. It is the 3rd largest chemical producer in Asia (after China and Japan) and 8th largest in the world (CeFIC, 2011). Based on its rapid GDP growth, the country is also identified as one of the highly industrialized countries in the world. The 12th Five Year Plan (2012–2017) envisages that the chemical industry would grow with a projected annual growth rate varying between 11 and 15%. As on date there are 1666 Major Accident Hazardous (MAH) industries in India (NDMA, 2007). Many of these MAH units are often found in clusters to take advantage of common infrastructural facilities and the availability of skilled manpower. An inventory undertaken by the Central Pollution Control Board (CPCB) identified 170 industrial clusters or pockets housing more than five MAH units across the nation. Moreover, the number of such industry cluster is anticipated to go up significantly in the form of Petroleum, Chemicals and Petrochemicals Investment Regions (PCPIRs) (DoC&PC, 2007) and Special Economic Zones (SEZs).

However, there is a flip side of this growth. The pursuance of

Abbreviations: ALARA, As Low As Reasonably Achievable; ALARP, As Low As Reasonably Practicable; CPCB, Central Pollution Control Board; DGFASLI, Directorate General, Factory Advice Service and Labour Institutes; DoE, Department of Environment; EAC, Environmental Appraisal Committee; EIA, Environmental Impact Assessment; EPPRCA, Emergency Planning, Preparedness and Response to Chemical Accidents; ERDMP, Emergency Response and Disaster Management Plan; HSM, Hazardous Substances Management; MAH, Major Accident Hazardous; MoEF, Ministry of Environment and Forests; MSIHC, Manufacture, Storage, Import of Hazardous Chemicals Rules; NDMA, National Disaster Management Authority; NEFA, National Environmental Protection Authority; NEP, National Environmental Policy; OISD, Oil India Safety Directorate; PCPIR, Petroleum, Chemicals and Petrochemicals Investment Regions; PESO, Petroleum and Explosives Safety Organization; PNGRB, Petroleum and Natural Gas Regulatory Board; SEZ, Special Economic Zone; SPCB, State Pollution Control Board; ToR, Terms of Reference; UTPCC, Union Territory Pollution Control Committee.

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http://dx.doi.org/10.1016/j.jlp.2015.12.012
0950-4230/

such rapid industrialization has resulted in disorganized development characterized by the regional imbalances. This has often led to the growth of polarised industrial-urban centre without adequate infrastructure, appropriate housing facilities, and other basic amenities like health and sanitation etc. In the absence of such planning, many industrial clusters have not taken into account environmental and risk factor during their development phase. This in-turn led to large number of low-income group people migrated to this area for job opportunity do not have any alternative but to settle in adjacent areas to these highly hazardous industries, thus becoming more vulnerable to any industrial accident, of which the Bhopal disaster (1984) is an example (de Souza Porto and de Freitas, 1996). By any standard, it was the worst manmade disaster that the world has witnessed to this day. The immense loss as a result of the incident brought into home worldwide the importance of a holistic approach towards managing the risk for such events and thereby forced the legislators to amend the existing regulations. The incident highlighted significant deficiencies of the then existing legislative and regulatory system for industrial risk assessment and/or management of India (Mannan et al., 2005).

The Bhopal-accident (India) in 1984 was not an exception. Since the 1970s, many major accidents in the chemical industry have occurred worldwide, including Mexico City (1984), Basel (1986), etc. Independent of region, the number of such events with significant 'off-site' effects seems to be increasing over time. Learning from experiences driven by these major accidents, many countries have put in place regulations that potentially hazardous industries need to comply with in order to demonstrate sound environmental and safety performance and minimize the chances of major accidents. The evolution of the Seveso Directive, the comprehensive regulatory regime of Europe for industrial risk management and control of major accident hazards, is a good example in this regard. In Europe, the concept of major accident prevention legislation has evolved in response to two major accidents that had happened in Flixborough (UK) in 1974 and Seveso (Italy) in 1976 (Kirchsteiger, 2002; Vierendeels et al., 2011). Consequently, the Council Directive 82/501/EEC (so-called Seveso Directive) was issued in 1982 (Wettig & Porter, 1999). The mere fact that the legislation was named after one of the major accidents indicates the importance of major accidents as an influential parameter for changing legislation. Since 1982, the Directive has been amended several times. The Bhopal-accident (India) in 1984 lead to a first Amendment and the Rhine pollution in Basel (Switzerland) in 1986 gave rise to a second Amendment. On 9 December 1996, Council Directive 96/82/EC (the so-called Seveso II Directive), was approved with a significant reorientation from a prescriptive to a goal-oriented regulatory approach (Wettig & Porter, 1999; Wettig et al., 1999). Introduction of Article 12 for land use planning implications around the hazardous installations was one of the important key additions of the Seveso Directive II. In 2003, the Directive was amended for fourth time. Amendment 2003/105/EC mentions three major accidents which have been taken into account during making the changes to the previous legislation: an environmental accident in Baia Mare (Romania) in 2000, a fireworks explosion in Enschede (The Netherlands) in 2000 and an ammonium nitrate explosion in Toulouse (France) in 2001. At present, a fifth amendment of the Seveso legislation is in full progress (Vierendeels, et al., 2011). Following the Seveso Directive, the EU Member States have formulated specific regulations. Some regulations focus setting up an adequate institutional framework at the administrative level to enable proper decision making on issues related to emergency preparedness, response and mitigation; while others try to ensure better risk management by these potentially hazardous industries. Selected clauses also lay emphasis on making risk information available to the stakeholders and the public so that they are better prepared to face technological emergencies, if the need arises.

Prevention of industrial accidents in India has a long history dating back to 1881 with the enactment of the first Factories Act. It is only after the Bhopal disaster, that policy and decision makers realized the true nature and severity of the problems inherently linked with the process of economic development. Against the backdrop of the Bhopal tragedy, the Environment (Protection) Act 1986 was introduced as an umbrella Act, to protect the environment by preventing major accidents. Since then, there has been a gradual evolution of a number of subsidiary regulations in the form of Rules under EP Act 1986 focussing on control and minimization of risk from hazardous installations. Following the provisions made by these regulations, an institutional and legal framework for management of hazardous substances, enforcement and monitoring of safety and emergency management came into place.

Despite the considerable progress that has been made in the post-Bhopal era, in formulating and implementing regulations and programmes to prevent the recurrence of such an incident; still there is lack of a holistic approach. Although there exists a comprehensive set of regulations and a number of competent authorities that are responsible for regulating risk, the implementation of risk prevention and mitigation measures yet has been weak as a result of insufficient coordination between authorities and inadequate monitoring due to a lack of institutional strength and capability. Resultantly, there is an increasing debate emerging between various stakeholders including policy and regulatory bodies, on the effective management of industrial risk. A significant number of weaknesses prevail in the existing regulatory and institutional setup as well as in the procedural framework itself. Some of these weaknesses of the existing risk governance framework have been identified in a review undertaken by a high powered committee set up under the NDMA, (NDMA, 2007).

The above mentioned issues thereby provide an opportunity to cast a broad look at the subject of governance of industrial risk in India. From this perspective, the existing regulatory, institutional and procedural framework for managing industrial risks were critically appraised in order to be able to identify the gaps and provide potential solutions which can bridge these gaps and make way for a safer society in India.

2. The context: policy, regulatory & institutional framework

The risk assessment practice in a country perspective is strongly driven by the regulatory and institutional setup. Thereby to comprehend the current state-of-the art of risk assessment practice of India, it is important to discuss the existing policy, regulatory and institutional framework first.

2.1. Policy framework

Traditionally, the policy framework of the Government of India has focused on policy formulation from the sectoral perspective. Typical examples are the economic policy statements, transportation policy, rural development policy etc., which are then supported by different national and state level plans and programs. The need for policies in the front of environmental protection and resource consumption was only felt around the early nineties. Accordingly, the 'National Conservation Strategy and Policy Statement on Environment and Development and Policy Statement for Abatement of Pollution' was formulated in 1992 (MoEF, 1992). This policy outlines some fundamental principles to balance economic growth with sustainable development goals in line with the mandate of the Rio Summit 1992; however the scope of the policy was considered to be too broad and not providing any specific

direction on how such goals were to be attained. And as a result the policy has minimum impact on improving environmental governance. Moreover, in spite of the Bhopal disaster having occurred, the policy did not mention or show any direction to be adopted for attaining effective management of industrial risks. Subsequently, when the need for a common ground policy was felt to cover all environmental issues, the 'National Environmental Policy (NEP)' of 2006 was formulated (MoEF, 2006). But, then again NEP does not provide enough emphasis on management of industrial risks either.

The NEP also followed similar trends like its precursors and lack specific focus or direction on several aspects. Many of the principles stated in the policy essentially reads like a listing of global best-intentions rather than being directed at specific issues which are compatible with existing impact level conditions in the country, characterized by degradation of environment and high risk levels that prevail in many industrial areas which are also listed as pollution hotspots (Chatterjee, 2009). In spite of the fact that specific emphasis was provided to the adoption of the 'precautionary principle', it's jurisdiction appears to be more from the point of environmental protection rather than the aspect of industrial risk. Further detailing the concept, the principle goes on to mention that "where there are credible threats of serious or irreversible damage to key environmental resources, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". But, then for a country like India witnessing developmental pressures resulting from fast pace of economic growth, implementing development plans based on the precautionary principle can be extremely challenging. First, in the realistic sense, without specific guidance, it is difficult to ascertain what presents a 'credible threat' especially when the concept of risk is intrinsically linked to the probability of occurrence and wherein design principles in industries generally take into account that an accident with high damage potential has lesser probability of occurrence. Second, application of such an approach in industrial towns which house large clusters of chemical industries would essentially make these industrial areas infeasible and would lead to prohibition for any further industrialization.

It needs to be mentioned that a Disaster Management Policy (DMP) has been formulated more recently in India (NDMA, 2009). But yet again, there is no added focus or strategy for managing the risks that may arise in MAH industrial clusters. Generally though, the DMP introduces policy thrust to reduce risk from various kinds of hazards or to create a mechanism that assists in minimizing damages, but only if a severe accident unfolds.

2.2. Regulatory framework

After being a party to the Stockholm Convention, the government of India formulated several environmental regulations starting with the Water Act of 1974. Additional impetus to broaden the portfolio of regulations to cover issues like industrial hazards and risks was prompted primarily by the Bhopal disaster of 1984. However, the regulatory framework on chemical safety can be traced back to chemical class-specific regulations like the Explosives Act, 1884; the Petroleum Act, 1934; the Factories Act, 1948, the Inflammable Substances Act, 1952; the Insecticide Act, 1968 and Static & Mobile Pressure Vessels Rules, 1981, etc. The focus of these pre-Bhopal regulations was mainly limited to on-site safety of the workers; whereas legal system to regulate off-site emergency, safe storage and transportation of hazardous materials hardly existed (NDMA, 2007).

Learning the lessons from the Bhopal accident made it imperative for the government to create an overarching legislative framework, the Environment (Protection) Act of 1986. It should be mentioned that prior to the Bhopal incident, the Factories Act of 1948 was the major Indian law that dealt with worker's welfare and health. After the promulgation of the EP Act, additional impetus was put forward to further broaden the regulatory framework (or portfolio of regulations) to encompass issues like industrial hazards and risks caused by chemicals and wastes, which were earlier not considered to be a priority. Drawing the powers conferred by the Environment (Protection) Act, a comprehensive set of regulations in the form of Rules focussing on the management of hazardous substances, was enacted. The key rules in this context are the Manufacture, Storage, Import of Hazardous Chemicals Rules (MSIHC) notified in 1989 (amended in 1994 and 2000); and the Emergency Planning, Preparedness and Response to Chemical Accidents (EPPRCA) Rules in 1996, amended 1994 and 2000.

Drawn up on the model of the COMAH regulations of the UK, the MSIHC Rules were notified in 1989 under the powers conferred by the Environment Protection Act to widen the scope and provide for a few additional requirements. The principles objectives of the rules are the prevention of major accidents arising from industrial activities, the limitation of the effects of such accidents both on man and on the environment and the harmonization of various control measures and agencies to prevent and limit major accidents. As per provisions of the Rules, industries storing or handling more than a certain threshold of hazardous chemicals (as mentioned in the Schedules of the Rules) are categorised as Major Accident Hazard (MAH) industries. The MAH industries have to fulfil a number of obligations in order to ensure that they are in control of hazards and risks that may originate from the facility and ensuring the public is informed about suitable safety measures to be adopted in case of an accident. Following are the key requirements:

- Take necessary precautions to prevent major accidents and limit their consequences to humans and the environment;
- Bring, major accidents involving the release of major emissions, fire or explosion linked with a hazardous chemical that has the potential cause substantial loss of life and property or adverse impact on the environment, to the notice of concerned authorities;
- Prepare safety reports on that industrial activity and submit them to competent authorities;
- Prepare an On-Site Emergency Plan;
- Inform the public about the accidents that might occur and the do's and don'ts in case of particular accidents;
- Provide assistance in the preparation of an Off-Site Emergency Plan in accordance with guidelines provided.

Keeping in view the vastness and the highly populated nature of the country and multiplicity of authorities, another scheme for the control of hazardous and toxic chemicals with three levels of controls were prescribed for industries. Accordingly, the EPPRCA Rules was notified in 1996, as a complement of the MSIHC Rules envisaging a four-tier crisis management system of the country involving the Central Crisis Group, the State Crisis Group, the District Crisis Group and the Local Crisis Group to manage emergencies arising out of industrial operations. Effectively, the EPPRCA Rules thus provides statutory backup for setting up of Crisis Groups at various levels to ensure the management of risk arising out of Major Accident Hazard (MAH) installations across the country.

In advance of the MSIHC and EPPRCA rules, the Factories (Amendment) Act came into force with effect from 1st January 1987 which introduced special provisions on hazardous industrial activities in the backdrop of the Bhopal Gas tragedy and the Supreme Court's judgment in the Shriram gas leak case. The Act was amended to establish safeguards for the use of hazardous substances by facilities. The amending Act has conferred vast powers on the Factory Inspectors with the objective of implementing the

safety provisions of the Act. In conjunction with the Factories Act of 1948, most of other acts of the pre-Bhopal era were amended to strengthen the safety and disaster prevention related provisions. In addition, provisions of existing regulations like the Factories Act and Rules, the Petroleum Act and Rules, the Explosive Act and subsidiary Rules that were concerned with regulating safety performance of industrial operations and plants involving hazardous operations or handling of the hazardous chemicals and explosives were strengthened.

Other regulations like Petroleum Rules complemented by the OISD Standards and Guideline provide industry specific criteria with regard to operational procedures, maintenance of safety distances between storages and safeguards for processes and equipment's. The Petroleum and Natural Gas Regulatory Board (PNGRB) have also promulgated Codes of Practices for Emergency Response and Disaster Management Plan (ERDMP) for petroleum and natural gas industries. The Codes stipulates that all such industries would carry out a systematic risk assessment to identify potential failures, calculate a combination of potential consequence and probability, evaluate the risk based on maximum tolerable risk criteria, and adopt measures to keep the risk "as low as reasonably practicable (ALARP)".

2.3. Institutional framework

The existing institutional set-up of India for industrial risk assessment and/or management is a two-tier system. The responsibility for control and management of risk from hazardous industries is dispersed amongst multiple organizations, which come under the ambit of several line-ministries and authorities both at central and state level.

At the federal level, the Ministry of Environment and Forests (MoEF) is acting as the nodal ministry for instituting and implementing the regulatory framework. This is because in India the whole gamut of laws for hazardous chemicals is formulated under the Environmental (Protection) Act (EP) Act, 1986 (Gupta, 2006). Within the Ministry, the Hazardous Substances Management (HSM) Division is the nodal point for management of chemical emergencies and hazardous substances. The main objective of the HSM Division is to promote safe management and use of hazardous chemicals and wastes, thus to avoid damage to health and environment. The Division also acts as the nodal point for the implementation of the International Conventions like the Basel Convention, the Stockholm Convention and the Rotterdam Convention. Other federal agencies, the Central Pollution Control Board (CPCB) under MoEF; the Directorate General, Factory Advice Service and Labour Institutes (DGFASLI) and the Directorate of Industrial Safety and Health (DISH) under the Ministry of Labour and Employment (MoLE), the Petroleum and Explosives Safety Organization (PESO) under the Ministry of Commerce and Industry (MoC&I), the National Disaster Management Authority (NDMA) under the Ministry of Home Affairs (MHA), are also responsible for enacting and monitor compliance of the regulations.

Similarly, at the state level, such responsibilities and roles are primarily led by the State Pollution Control Boards (SPCBs) and the Union Territory Pollution Control Committees (UTPCCs) under the state Department of Environment (DoE), and by the Inspectorate of Factories to implement the Factories Act and Factories Amendment Act. In nutshell, the power for regulating and enforcing the laws and rules pertaining to industrial risk management, is dispersed between many organizations at central and state levels.

There are several lacunae's in the existing institutional framework:

- First, there is an absence of an independent regulatory body (other than the competent authority) to assess the overall effectiveness of the system.
- Second, there is no structured and clear hierarchy to comprehend the institutional mechanism as well as the role of individual organizations.
- Third, the multiplicity of institutions to deal with permitting, reporting and inspection for industrial risk aggravate the compliance problem. With the number of institutions at different levels, there is often a lack of both horizontal and vertical coordination between the agencies. In the vertical chain, there is more a tendency of central and state level agencies to get into a conflict.
- Fourth, there has been a lack of adequate institutional capacity at both the nodal (MoEF and CPCBs) and implementation level (SPCBs and others) to match the demand for compliance services as a result of a steady increase in the numbers of the regulated community and the complexity of environmental issues that are being encountered. Several reviews undertake by different agencies have strongly recommended strengthening of existing institutions and certain recommendations proposing setting up a new National Environmental Protection Authority (NEFA) along with the appropriate regional authorities. The absence of adequate powers with the MoEF or the CPCB to sanction the state level projects often makes it possible that the state agencies can dilute certain requirements, if it is seen as an impediment to the development of the state. This has often been the case, when permissions are given at the State level to several hazardous industries to be sited in close proximity in a prospective industrial area without considering cumulative impacts or risks to the population or the environment. At the horizontal level, the lack of a common database of information on the regulated community often result in duplicate efforts which result in industries to fill in multiple forms to meet the permitting requirements.

3. Appraisal of risk assessment system of India

Risk assessment, in the broad sense, involves a structured procedure that evaluates qualitatively or quantitatively the level of risk that is imposed by a hazardous facility. It plays an important role in the risk governance framework by assisting decision makers to prioritize safety management within the facility and also take appropriate preventive and mitigation measures to safeguard the community living in the vicinity of such a facility from a potential accident. In this section, the procedural framework for industrial risk assessment as practice in India is analysed in order to identify weaknesses prevails in the existing practice and consequently uncertainty leads towards the decision.

3.1. Hazard identification

Conventionally, hazard identification is the first step in the risk assessment process. The identification of hazardous installations, the volume and nature of hazardous chemicals that they store, are the key elements of the hazard identification process. In India, industries dealing with hazardous chemicals equal to or in excess of the threshold quantities as specified in the Schedules 2 and 3 of the MSIHC Rules, 1989 are categorized as Major Accident Hazard (MAH) units. According to the regulatory requirement, the MAH units are obliged to report on their respective hazard potentials on a periodic basis. However, in most cases those reports are on paper and housed with different competent authorities. These results in a lack of accessible and valid information on a common platform which can further be used for emergency response and/or risk mitigation

planning. In addition, there is minimum guidance provided to the industry in order to enable them to acquire proper understanding and clarity on the regulatory criteria based on which an industry qualifies as hazardous or subsequently is rated based on their hazard potential. As a result of such inconsistencies, many industries are unable to file proper information or reports that may lead to correct identification of hazards in their premises.

To counter this, the MoEF had launched a cluster-wise hazard analysis programme, to identify the accident potential of those industrial clusters, their possible consequence and prevention strategies including rapid safety audits. But such an exercise is only implemented on a periodic basis of every 5 years for a cluster. Because sometimes this is done without the participation of state-level regulatory agencies it results in information not being shared or updated at all levels. More recently, the MoEF has taken another initiative for consolidation of such information in a GIS-based system, the Emergency Planning and Response (GEPR) System, for the major cluster of industries in selected industrialized states in the country. Nevertheless, the resulting system is still not available to most regulators.

3.2. Frequency estimation

Understanding that accident databases and information captured in them can provide vital learning's on preventing future accidents and lead to corrective action being taken at a facility of concern, some recent efforts have been initiated to establish accident databases. In order to ensure that such databases can be accessed by relevant actors' intent on submitting or retrieving data, in recent years there is trend towards developing internet based solutions.

At present there is no accident database available in India for frequency assessment (NDMA, 2007). The MoEF as a nodal agency is in the process of building a web-based accident information system with the objective of integrating accident reporting formats prescribed by several regulatory authorities such as the Central and State Pollution Control Boards, Inspectorate of Factories and the Controller of Explosives. It is designed as a centralized database in order to facilitate effective communication of accident information between the competent authorities and the parties concerned and to ensure access to accident reports from a single domain. However, though the project was commenced in 2009, the system is yet to be made operational. The DGFASLI and the NIDM has also initiated similar initiatives for recording accidents at MAH installations. However, in the absence of a proper institutional mechanism to supervise, coordinate and guide accident reporting by actors concerned, none of these initiatives can be considered to be successful at this time.

3.3. Scenario selection

Selection of reference scenarios for risk analysis constitutes an important component and on which the results can vary considerably. In India, the only guidance in this regard is provided in the method delineated by MoEF for undertaking cluster-level hazard analysis. The guidance mentions that analysis of consequence for storage of hazardous chemical is undertaken taking into account maximum loss scenario that considers catastrophic vessel failure. It also goes on to mention the weather conditions that are to be considered for generating the scenario. As there is no formal laid down risk assessment process, which takes into account the probability of an event to arrive at a measure of risk caused by a hazardous facility, no further guidance on scenario selection for risk analysis is provided in any regulations or regulatory guidance document.

3.4. Risk analysis

There is a variety of methods that have been developed to analyse risk originating from hazardous facilities, ranging from the strictly quantitative one which tries to assign a numerical value for risk to more subjective ones which try and evaluate risk through a semi-quantitative risk matrix. Various countries have formulated their preferred methods for risk assessment of the hazardous facilities, based on availability of data, credible risk models and accounting for management practices followed in industries.

However, in India, at this time there is not prescribed standard methodology for risk assessment of hazardous facilities based on which an evaluation of risk emanating from them can be rated and based on which risk reduction strategies for a region formulated. Though regulations like the Factories Act and the MSICHR Rules focus on undertaking risk evaluation and report them to regulatory authorities, the absence of guidance on a standardized method to be followed and any risk benchmark or criteria to be attained makes it impossible for regulators, planners or plant designers to work to a certain level of safety. In addition, facility level safety assessments which are commissioned by industries and undertaken by consultants are seldom shared with the regulatory agencies, if they bring forward any significant deficiencies in either technology or safety management practices of the facility. As a result, the agencies have to depend on the mandated ‘safety audit’ report which again is not carried out by an independent agency and thus is often biased towards the industry making an objective evaluation of risk impossible.

The risk analysis process in India is functional in any of the following three forms:

First, all industries which fall under the categories regarded as having high potential to pollute the environment and exceeding certain minimal thresholds, qualify for an Environmental Impact Assessment (EIA) study based on which it has to acquire an Environmental Clearance. The EIA study involves a scoping process wherein the designated Environmental Appraisal Committee (EAC) reviews preliminary information on the project and prescribes a Terms of Reference (ToR) for the study. If the industry is hazardous in nature, it is expected that the EAC would include a risk assessment study as a part of the overall EIA study.

Second, operational industries which meet the criteria requirements and as a result are categorized as MAH industries and storing hazardous chemical beyond specified thresholds, have to undertake a facility level risk assessment. And according to the MSIHC Rules, are required to submit the results documented in a Safety Report (as per Rule 10) and an onsite emergency plan (as per Rule 13) to the Competent Authority. Regulatory provisions under Schedule 8 of the MSIHC Rules prescribe that the safety report should include: a preliminary hazard analysis based on the identification of the type of possible accidents along with an evaluation of systems elements, resulting hazards and relevant safety components; and a hazard assessment based on hazard identification, ascertaining the cause of major accidents, assessment of hazards based on their frequency and potential consequence, safety systems and accident history.

Third, the there is a provision to undertake an area level risk assessment as a part of the pocket wise hazard analysis program initiated by the MoEF during the 8th plan in order to enable district authorities to effectively manage off-site technological emergencies. After the preparation of the report, they are evaluation by core group of experts appointed by the MoEF, workshops are organized in the respective clusters and based on common understanding, recommendations for on-site and offsite emergency plans, improvement of safety management practice in industries are to be taken up and are to be followed by monitoring by the agencies

concerned.

However, there is no unified philosophy or principle which governs any of these risk assessment processes that may result in the characterization of risk based on certain acceptable criteria. Though, on one side the absence of such standardization provides considerable flexibility to the respective players to make decisions on the approach to be adopted for risk assessment, on the other the absence of guidance on a standardized method to be followed and any risk benchmark or criteria to be attained makes it impossible for regulators, planners or plant designers to work to a certain level of safety.

On the EIA front, though the intent of the regulation provides for scoping a risk assessment into the EIA study is present, the appraisal committee primarily constitute of members who focus on different environmental and socioeconomic impacts that can be caused by a proposed facility and often do not have the expertise or the scientific knowledge to propose a standardized risk assessment study. This lack of understanding is clearly evident in the guidance manuals that are made available by the MoEF for scoping EIA study. For example, the guidance manual that deals with EIA of isolated storage facilities for chemicals or petroleum refineries in which risk aspects should logically be provided additional emphasis in an EIA, instead provides only generic guidance on the formulation of safety, disaster and emergency management plans without specifying any clear approach for undertaking a systematic risk assessment of the proposed facility based on a standardized approach.

A review of hazard analysis reports for about 53 clusters of industries undertaken in 2001 by the MoEF brought out a number of striking gaps in these reports which are prepared by consultants based on information provided by the industry and the safety audits. The report indicated that consequence analysis calculations for many of the hazardous chemicals (including explosive, flammable and highly toxic chemicals such as pesticides) has not been undertaken, which may affect the overall output of the study, and there was often no consistency in terms of generation of scenarios for probable or worst case accidents leading to widely varying results for the same risk scenario pointing out towards a gap in the assessment practice being followed by different consultants. Significantly, even though the gaps were pointed out eight years back, the government has not initiated any study for formulating a standard guidance for area level risk assessment taking into account Indian circumstances.

3.5. Risk evaluation

The next step in the risk assessment process is the evaluation of assessed risks for an activity to determine whether the risks are acceptable to regulators and society at large. In the absence of any clearly laid down risk philosophy or standard criteria, there are measureable levels for risk which can be considered to be acceptable. Understanding that it may be difficult for a single risk level to be applicable to the entire country as diverse as India, however it is expected that a set of guiding criteria or a framework to lay out a logical basis or a range of risk measure against which the results of the risk assessment can be evaluated. Without this, the assessment of a hazardous industries performance towards attainment of safety goals becomes arbitrary and subjective. It is also difficult to compare or arrive at a summation of risk originating from multiple hazardous units, carry out an industry wise apportionment of risk or arrive at a measure of cumulative area level risk in an industrial area. In practice, therefore, most industries would undertake a consequence analysis study based on certain benchmarked hazard end-points for toxic gas concentrations, overpressure or radiation levels and present the footprints as an output of the risk assessment process. Neither are there any subjective engineering good practice principles like 'As Low As Reasonably Achievable' (ALARA) or 'As Low As Reasonably Practicable' (ALARP) been espoused in any policy, regulations or guidance based on which risk mitigation measures can be planned, implemented and monitored.

4. Conclusions

Risks arising from such hazardous industries can be minimized through a more comprehensive or effective risk assessment framework. Therefore, an overarching framework in accordance with the existing legislation needs to be institutionalized to support any decision making process. At this time, there is no specific policy thrust to reduce risk or minimize damages, if a sever accident unfolds and the only option available to the government is to regulate various aspects related to it. 30 years since Bhopal following deficits are still there in the Risk Governance framework in India:

- Lack of harmonized or standard risk analysis methodology
- Lack of standardization to use for QRA (e.g. weather condition, threshold limit)
- No standard damage criteria (i.e. fixed endpoints or Probit endpoints)
- Non-uniformity in the structure of the on-site and off-site plan
- Lack in the procedure for conduct of safety audit and safety report preparation
- Lack of cumulative risk assessment practice for industrial clusters
- For safety audit many department for the same location are involved
- No place to report accidents that occur during commissioning and decommissioning of plants
- The testing of On-Site emergency plans every six months is a statutory requirement. A large number of units conduct mock drills shop-floor wise or cover only a few components, while the requirement is for the installation as a whole
- A yearly mock drill of district Off-Site emergency plans is essential and mandated. Very few full-scale drills of district Off-Site emergency plans are being conducted in the country, and even those are not conducted as per the norms.
- The information in MSDS is generally complex and exhaustive; therefore, supervisory staff and workers find it difficult to comprehend the information available with them.
- Case studies of major accidents including emergency response experience and yearly statistic of major chemical accidents are not compiled and published at the national level.
- There is lack of clear accessible information on potential chemical hazards and their management for ready use by local authorities. In addition, the officers responsible for issuing No Objection Certificates (NOCs) for establishing a storage facility often lack sufficient scientific knowledge and need to undergo appropriate training

From regulatory framework perspective, in spite of having a comprehensive set of regulations, one of the key weaknesses of the Indian regulatory system is its inability to keep pace with the rapid economic development and respond to the problems resulting from the process of intense industrialization and urbanization in the last two decades (World Bank, 2006). Operating mostly in the reactive mode, the regulatory system is often unable to pre-empt future or upcoming problems and the issue of management of environmental risk appears to be one of them. For example, though there have been two amendments to the MSIHC Rules of 1989 which is the principal regulation focussing on major accident prevention and control of hazardous industrial activities, both have effected only cursory changes to the original legislation. As a result,

yet, at present there is no linkage of hazard prevention with land use planning, an aspect which assumes significance considering the effect of the Bhopal disaster and subsequent accidents in the country that has led to considerable loss of life and property.

Effectiveness of the present regulatory framework can be gauged from the following specific gaps as identified in the regulations:

- Based on the Factories Act, 1948 (amended in 1987), the states have notified their own Factories Rules, need to be dovetailed with the subjects of accident prevention, preparedness and mitigation.
- Absence of national regulations on occupational safety and health and medical emergency management.
- Harmonization of classification and definitions in existing regulations including petroleum and petroleum products.
- Absence of regulations on storage and transportation of cryogenics.
- Lack of legislation on risk assessment requirements and classification, labelling and packaging for industrial chemicals.
- Need to identify technical competent authorities and standardisation of reporting mechanisms for the status of implementation of various chemical disaster-related activities.
- Non-availability of statutes for grant of compensation to chemical accident victims.
- Harmonization and incorporation of international laws in chemical management.

The regulatory mechanism plays an important role in risk governance. Worldwide, several regulatory styles have been practiced by nations in how risk regulations have evolved and are implemented. The contemporary style for regulating risk from hazardous installations was based on a prescriptive 'command and control' based approach which focused on licensing and monitoring based control of hazardous installations. However, appreciating the complexities involved in regulating risk originating from hazardous industries, and learning from the experiences of the Bhopal disaster in early 1980's, many countries initiated a review of their regulatory system for regulating risk. In comparison, the Indian regulatory system still continues to mainly be based on the paradigm of 'command and control' that is based on regulatory permitting with overt emphasis on inspections and monitoring to monitor regulatory conformance. Interestingly, even though there is general acceptance that compliance of industries to risk regulation is unsatisfactory, nothing significant has been done to bring about a shift in the regulatory approach, since the formulation of the EP Act in 1986. In addition to this rather ancient approach to govern regulatory compliance, the regulated community is also encountered with a multiplicity of regulations with scope for overlaps and confusion. Provisions of such regulations often require hazardous industries to acquire operations permits and/or file reports of internal assessments to several authorities. For example, the MSIHC regulations require reporting to be done both to the Factories Inspectorate and the State Pollution Control Boards, as both are designated competent authorities as per Schedule 5 of the regulation. The resulting complexity in regard often acts as an impediment for staying in compliance. In nutshell, the existing situation of having industrial safety under this Act in itself is a misfit in compare to the USA, UK or Europe. Important to mention here, though there is a lack of regulations in the general chemical sector in India, however it is be noted that the petroleum, upstream oil and gas are refineries are better regulated. In this regard, the OISD has produced several guidelines and safety requirements for the oil sector which are mandatory.

Besides, there is a prevailing confusion of technical (industrial) risk with environmental risk. It would also be worthwhile to note that the lack of any relevant research in India on process safety either from academia or industry (when compared with USA, UK and China) though India has large chemical and petroleum sector, which will also impact the process safety during the course of large scale industrialization.

An institutional framework for providing technical support services at various levels is the key requirement for sustaining proper development and implementation of the risk management. However, with an inadequate institutional framework, government agencies and regulatory bodies have been severely constrained in implementing most of the regulations under a "Command and Control" regime. Consequentially, many industries default on providing right and timely information on risks present within a MAH installation while on the other hand, the government is yet to set up and make operational functional Crisis Groups who can coordinate effective response in a contingency situation. The local emergency control centres are also handicapped with lack of proper information resources. Added to the problem, is the unavailability of competent technical personnel in controlling positions in the central and state regulatory agencies. As a result the decisions are made not based on the facts or any proper technical analysis. Moreover, the government officials are generally trained in traditional administrative roles are usually overwhelmed by the scale of a high consequence accident that would never occurred before.

Acknowledgement

We would like to acknowledge Prof B.J.M. Ale, Professor (Emeritus) of Safety Science and Disaster Abatement at TU Delft, The Netherlands for reviewing this article and provide with necessary feedback.

Abbreviations

ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
CPCB	Central Pollution Control Board
DGFASLI	Directorate General, Factory Advice Service and Labour Institutes
DoE	Department of Environment
EAC	Environmental Appraisal Committee
EIA	Environmental Impact Assessment
EPPRCA	Emergency Planning, Preparedness and Response to Chemical Accidents
ERDMP	Emergency Response and Disaster Management Plan
HSM	Hazardous Substances Management
MAH	Major Accident Hazardous
MoEF	Ministry of Environment and Forests
MSIHC	Manufacture, Storage, Import of Hazardous Chemicals Rules
NDMA	National Disaster Management Authority
NEFA	National Environmental Protection Authority
NEP	National Environmental Policy
OISD	Oil India Safety Directorate
PCPIR	Petroleum, Chemicals and Petrochemicals Investment Regions
PESO	Petroleum and Explosives Safety Organization
PNGRB	Petroleum and Natural Gas Regulatory Board
SEZ	Special Economic Zone
SPCB	State Pollution Control Board
ToR	Terms of Reference
UTPCC	Union Territory Pollution Control Committee

References

Chatterjee, T., 2009. Reorienting Environment Policy in India towards a local area-based development and management paradigm. J. Trans-discip. Environ. Stud. 8 (no. 1), 1–16.

Cefic Facts and Figures, 2011. The European Chemical Industry Council. The European Chemical Industry in a Worldwide Perspective. http://www.cefic.org/Documents/FactsAndFigures/(Offline)%202011/FF2011_Full%20Report_Chapter/Cefic_FF%20Rapport%202011.pdf.

Dept. of Chemicals and Petrochemicals (DoC&PC), Govt. of India, 2007. Petroleum, Chemicals and Petrochemical Investment Regions (PCPIR) Policy. http://chemicals.nic.in/PCPIRPolicy.pdf.

de Souza Porto, de Freitas, 1996. Major chemical accidents in industrializing countries: the socio-political amplification of risk. Risk Anal. 16, 19–26.

Gupta, J.P., 2006. Land use planning in India. J. Hazardous Mater. 130 (3), 300–306.

Kirchsteiger, C., 2002. Review of international industrial safety management frameworks. Institution of Chemical Engineers. Trans. IChemE 80 (Part B), 235–244.

Mannan, M.S., West, H.H., Krishna, K., Aldeeb, A.A., Keren, N., Saraf, S.R., Liu, Y.S., Gentile, M., 2005. The legacy of Bhopal: the impact over the last 20 years and future direction. J. Loss Prev. Process Ind. 18, 218–224.

Ministry of Environment & Forest (MoEF), Govt. of India, 1992. National Conservation Strategy and Policy Statement on Environment and Development. New Delhi, India. http://envfor.nic.in/sites/default/files/introduction-csps.pdf.

Ministry of Environment & Forest (MoEF), Govt. of India, 2006a. National Environmental Policy. New Delhi, India. http://envfor.nic.in/sites/default/files/introduction-nep2006e.pdf.

Ministry of Environment & Forest (MoEF), Govt. of India, 2006b. Environmental Impact Assessment (EIA) Notification. New Delhi, India. http://www.envfor.nic.in/legis/env_clr.htm.

National Disaster Management Authority (NDMA), Govt. of India, 2007. National Disaster Management Guidelines on Chemical (Industrial) Disaster. New Delhi, India. http://ndma.gov.in/ndma/guidelines/Chemical-Disaster.pdf.

National Disaster Management Authority (NDMA), Govt. of India, 2009. National Policy on Disaster Management. New Delhi, India. http://www.ndma.gov.in/images/guidelines/national-dm-policy2009.pdf.

Vierendeels, G., Reniers, G.L.L., Ale, B.J.M., 2011. Modeling the major accident prevention legislation change process within Europe. Saf. Sci. 49 (3), 513–521.

Wettig, J., Porter, S., Kirchsteiger, C., 1999. Major industrial accidents regulation in the European Union. J. Loss Prev. Process Ind. 12, 19–28.

Wettig, J., Porter, S., 1999. Policy issues on the control of major accident hazards and the new Seveso II Directive. J. Hazard. Mater. 65, 1–14.